ELECTRIC POWER RESEARCH INSTITUTE

Bird Activity Monitor

Conceptual Design

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PRODUCT DESCRIPTION

Avian interactions, such as collisions and electrocutions with overhead power lines, communication towers, wind turbines, and other utility structures are subjects of increasing concern among utilities, regulatory agencies, and environmental organizations. However, our ability to quantify the temporal and spatial extent of the problem or the efficacy of mitigating measures is severely hampered by a lack of standard monitoring methods and tools. EPRI initiated a research project in 2000 that led to development of a Bird Strike Indicator (BSI) sensor to monitor avian collisions. To fully understand and study avian interactions, a Bird Activity Monitor (BAM), a video-based monitoring tool, is needed.

Results & Findings

This technical update describes the conceptual design for the BAM system. The conceptual design outlines the main components of BAM and identifies requirements and challenges for component development.

Challenges & Objective(s)

The two overarching goals of the EPRI research project are as follows:

1. To develop automated monitors to gather information that is difficult or impossible to obtain through direct human observation.
2. To evaluate the efficacy of mitigating devices such as line markers and flight diverters.

This project is the conceptual design phase of the research project, and the objective is to provide details of the main components and their requirements for the BAM system that will help guide the research and development of the system in the next phases.

Applications, Values & Use

Once successfully developed, the BAM system can incorporate the BSI sensor as a trigger to initiate recording. BAM systems could potentially be used for monitoring other types of assets such as substations.

EPRI Perspective

Avian interaction with power lines is a growing concern. EPRI has taken the lead in recognizing the need and developing new technologies to study the extent of these avian problems. Development of cost-effective automated tools will make it easier to undertake monitoring of transmission lines in remote areas.

Approach

The team's goal for this phase of the project is to develop a conceptual design for the BAM system. The conceptual design identifies requirements and challenges that will likely be faced in development of a prototype BAM system.

Keywords

BSI
BAM
Bird collision
Avian interaction

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1
BIRD ACTIVITY MONITOR (BAM)

Background

Avian interactions (i.e. collisions and electrocutions) with overhead power lines, communication towers, wind turbines, and other utility structures are subjects of increasing concern among utilities, regulatory agencies, and environmental organizations. Recent studies in North America indicate previous estimates of avian (and bat) mortality from collision or electrocution is far too low. Current estimates around the country indicate birds cause 25% of all outages. The heightened awareness of the problem has led to efforts (sometimes misguided) to mitigate and reduce avian fatalities and to increase power reliability. Our ability, however, to quantify the temporal and spatial extent of the problem or the efficacy of mitigating measures is severely hampered by a lack of standard monitoring methods and tools.

To bridge this technology gap, EPRI initiated research projects in 2000 to develop and deploy automated avian monitors that can be cost-effectively used in remote locations to capture vital information necessary to develop programs to minimize impacts of utility structures on bird populations.

The two overarching goals of EPRI research project are, as follows:

- To develop automated monitors to gather information that is difficult or impossible to obtain through direct human observation; and
- To evaluate the efficacy of mitigating devices such as line markers and flight diverters.

As part of the research project, two different types of monitors were identified for development. The first was a Bird Strike Indicator (BSI), an impulse-based vibration sensing and recording tool to study bird collisions with aerial cables. The second monitor needed was a Bird Activity Monitor (BAM), an intelligent image-based sensing and recording tool to assist with detailed study of wildlife interactions with various types of structures. Other situations that could be monitored with the BAM include flight activity near proposed or existing wind turbine sites or communication towers, wildlife activity in/near substations, perching or nesting activity on towers, and the efficacy of mitigating measures.

As a result of the research project initiated in 2000, a Bird Strike Indicator (BSI) sensor system was successfully developed. The BSI sensor system was commercialized in 2008.

EPRI initiated this current project to develop a Bird Activity Monitor (BAM) to complete the tools needed to study avian collisions.

BAM Project Approach

The envisioned BAMs will capture, store, and transmit video images of the interaction of birds with power lines, communication towers, and wind towers when their flight paths approach facilities, which have BAMs installed. This video information can then be used as a basis for objective investigation. The video information can be used in concert with ancillary measurements made by devices, such as BSIs. BAMs can also efficiently monitor retrofitted lines to determine if mitigating measures are working as designed.

The BAM design will build on related technology that was developed for real-time monitoring of power line conductor ground clearance. The ground clearance monitor utilizes video technology coupled with sophisticated image processing software to accurately monitor and track the motion of conductors for thermal rating purposes. By leveraging the BAM R&D effort with the ground clearance monitoring technology, this project can proceed at a fast pace with lower cost and greater likelihood of success.

Develop Conceptual Design for BAM

The goal of the current phase of research is to develop a conceptual design for a BAM system, identify the major components and their requirements. The conceptual design will also identify the challenges that will be faced in the development of BAM. The conceptual design will help guide the future development of a prototype BAM system.

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BAM CONCEPTUAL DESIGN

There are a wide variety of security and surveillance system currently available on the market. Most of these systems primarily are used to monitor a small area with a fixed field of view. Some of these systems can automatically generate alarms if intruders are detected and can operate during both day and night. The main difference between these systems and the envisioned Bird Activity Monitor (BAM) is that we are trying to monitor a large area for interaction with sometimes fast flying small birds. The monitoring has to take place in both daylight and night hours and needs to be automated to minimize the amount of video/image recorded.

The Bird Activity Monitor (BAM) is envisioned as a video/image based system that can be used to monitor the interaction of birds with power lines, communication towers, wind towers, and other utility facilities. The BAM system will typically consist of video camera sensors, a video/image processing and recording unit, remote communication module and power supply options. It is likely that multiple video cameras might be needed to effectively monitor a typical transmission or distribution span to limit the field of view being monitored by one camera. Multiple video cameras could be integrated into a single processing module. Firmware will also need to be developed for processing the video to automate detection of bird interaction in order to minimize the amount of video recording.

The conceptual design of a BAM provides an outline of the system and its development. It includes information on the major components of the system, their required features, and the level of effort and challenges that will be faced in the development. The conceptual design is to be used as a guide during the development of a prototype BAM system.

Main Components of a BAM

There are several major components required to build a BAM and are shown in Figure 2-1 and listed below. The basic function of each module is briefly described along with some suggestions for the type of hardware, which would be appropriate and the major challenges that might be faced in their development.

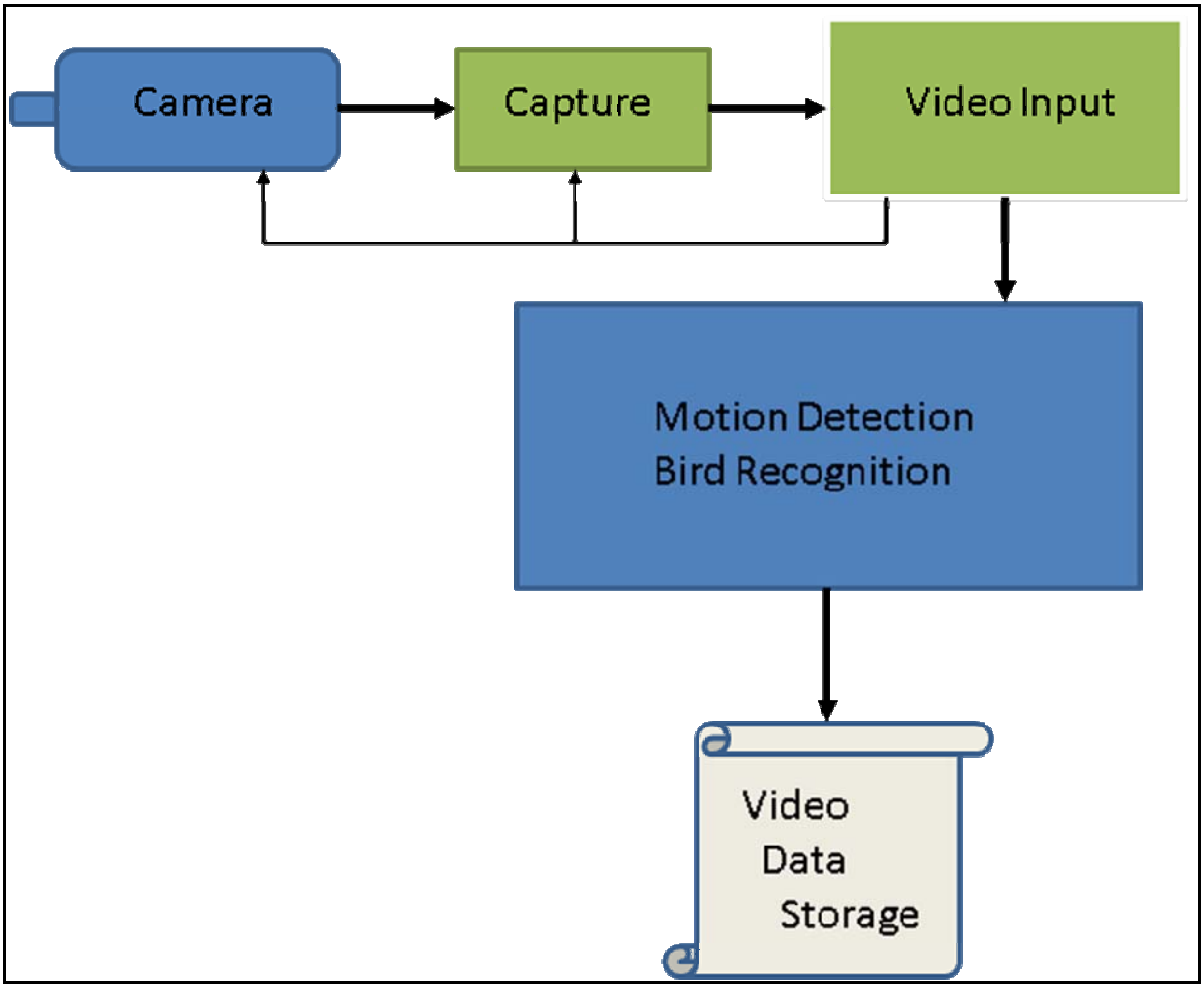

Figure 2-1
Main components of a BAM system.

Camera

The camera is the main input sensor of the BAM. The key camera features required for this application are, as follows:

- Dynamic exposure control for maintaining proper light level in daytime and nighttime;
- Sensitivity to visible and infrared illumination;
- High image resolution in excess of 550 lines to aid in bird recognition;
- Fast image response time for capturing fast flying birds; and
- Rugged weather sealed housing.

There are many examples of ruggedized cameras on the market which would fit within the requirements of the BAM. Typical Charge-couple Device (CCD) security cameras are among the most prevalent. There are also digital video cameras which eliminate the need for a video capture module. Some of these video cameras have very high frame rates which would give higher quality data to avian researchers; however, they are much more expensive and might not be as suitable for night use. Issues that still need to be addressed include image range and optical resolution, as a function of variable distance.

To effectively cover the range of up to a 1000 ft, multiple variable focus cameras with lenses focused at fixed ranges may be needed. These could be controlled by a single Digital Signal Processor (DSP). Figure 2-2 illustrates use of four different cameras with different fixed fields of view as well as different resolutions to monitor a typical span. Work must be done to validate that objects within each focal cone are in focus over the entire range and will also have sufficient resolution. If objects in the focal cone are not in focus or do not have sufficient resolution, more cameras will be needed. This increases the number of cameras and the complexity of the system along with overall cost.

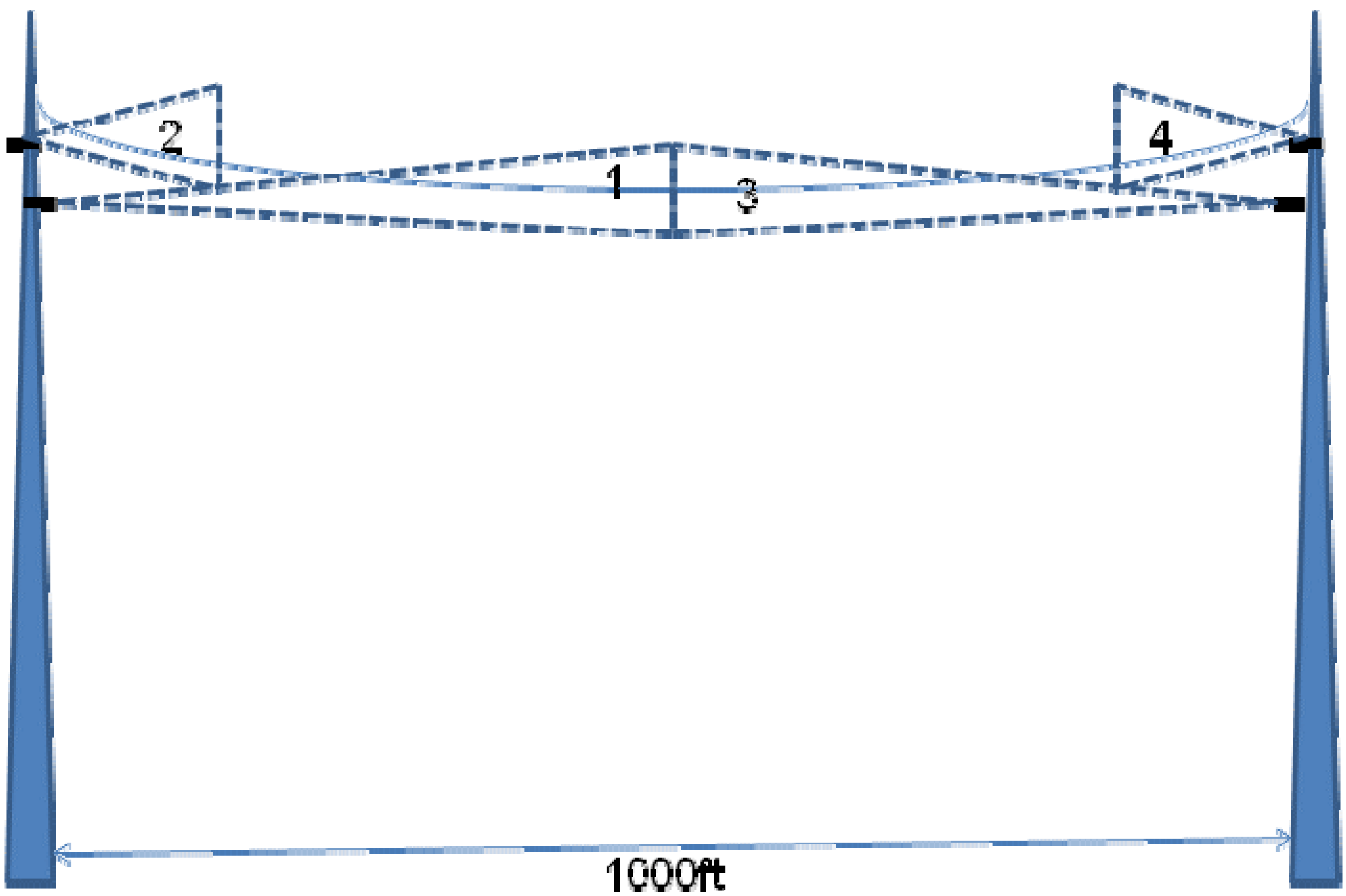

Figure 2-2
Multiple camera setup to monitor a typical span.

In many video security systems, the range is on the order of 10s of meters, not 300m like a typical span to be monitored using BAM. The camera might be the most challenging aspect of BAM. More work is also needed to verify that the optical resolution will allow small birds to be detected in the image. The AV5105DN (Figure 2-3) described below might be one of the possibility. The camera offers Day/Night capability with very high pixel array and 9 frames per second video rate. The AV5150DN has built-in motion detection and even offers pan, tilt and zoom capability.

Model Numbers:

AV5105 - Color
AV5105-AI - Color Auto-Iris
AV5105DN - Day/Night

Imaging

- 5 megapixel CMOS image sensor
- 2592(H) x 1944(V) pixel array
- 1/2" optical format
- 2.2 µm pixel pitch
- Bayer mosaic RGB filter
- Minimum illumination of:
  - Color: 0.3 Lux @ F1.4
  - Day/Night: 0 Lux, IR sensitive
- Dynamic range 60 dB
- Maximum SNR 45 dB

Full Field of View (FOV) Resolutions

• 2592(H)x1944(V)	5 megapixel
• 1296(H)x968(V)	1/4 resolution

Cropped Field of View Resolution

• 2048x1536	3MP
• 1920x1200	WUXGA
• 1920x1080	ADTV-1080p
• 1600x1200	2MP
• 1280x1024	1.3MP
• 1280x720	HDTV - 720p
• 1024x768	XGA
• 800x600	SVGA
• 704x570	PAL
• 704x480	NTSC
• 640x480	VGA
• 352x288	CIF
• 320x240	SIF

Data Transmission

- Data rate
  - up to 55Mbps
  - bit rate control from 100Kbps to 10Mbps
  - bit rate control available for full view, multi view, and archive
- Video frame rate up to:
  - 9fps @ 2592x1944
  - 12fps @ 2560x1600
  - 15fps @ 2048x1536
  - 24fps @ 1600x1200
  - 30fps @ 1280x1024
- Compression type
  - H.264 (MPEG4, Part 10)
  - Motion JPEG
  - 21 levels of quality
- TFTP, HTTP, RTSP image transmission protocols
- 100Base-T Ethernet Network Interface

Programmability

- Auto Exposure (AE) and Gain Control (AGC) >120dB
- On-camera real-time motion detection with 64 detection zones
- Auto backlight compensation
- Auto multi-matrix white balance
- 50/60Hz selectable flicker control
- Electronic pan, tilt, zoom (PTZ)
- Electronic image flip - 180 degree rotation
- Resolution windowing down to 32x32 pixels window
- Programmable shutter speed to help control motion blur
- MoonLight™ mode - extended exposure and proprietary noise cancellation
- Programmable resolution, brightness, saturation, gamma, sharpness, tint
- Picture-in-Picture: simultaneous delivery of full field of view and zoomed images
- Bandwidth & storage savings by running at 1/4 resolution

Electrical

- Opto-coupled alarm or trigger input, opto-coupled alarm and flash sync output
- Power over Ethernet (PoE): PoE 802.3af
- Power consumption 5 Watts maximum
- Optional DC AI connection (AV5105 - AI)

Regulatory Approvals

- FCC, CE and RoHS compliant

Environmental

- Operating temperature 0˚C (32 °F) to +50˚C (122 °F
- Storage temperature -20˚C (-4 °F) to +60˚C (140 °F)
- Humidity 0% to 90% (non-condensing)

Mechanical

- 3"W (76 mm) x 2.5"H (63.5 mm) x 2.25"D (57mm) (w/o lens)
- 8.6 oz (243 grams) (w/o lens)
- C/CS lens mount

Housing Accessories:

Dome 4-I - Indoor 4" Vandal Dome
Dome 5-I - Indoor 5" Recessed Dome

Lenses:

LENS 6.0 6mm MP Lens	M1614-MP 16mm MP Lens	H0514-MP 5mm MP Lens
M0814-MP 8mm MP Lens	M2514-MP 25mm MP Lens	LENS4-10 4-10mm MP Varifocal Lens
M1214-MP 12mm MP Lens	15M5018-MP 50mm MP Lens	LENS4-13 4.5-13mm MP Varifocal IR Lens

* Other megapixel lenses are also available

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Figure 2-3
AV5105DN Day Night Camera specification.

Video Capture Module

The Video Capture Module digitizes video signal and should complement the camera in bandwidth and image resolution. It will run continuously to provide data for subsequent processing. If a digital video camera is used, this module will not be necessary.

Basically, these are medium bandwidth analog-to-digital (A/D) converters, usually 10 or 12 bit resolution, and are available in many form-factors. The final selection of this module would depend on the selection of the camera and the video input module, which is described below.

Video Input Module

The video input module is responsible for the initial intake of the digital video data. It must check the input for light level and apply any correction required to the capture module and/or camera directly. It will maintain a buffer of sufficient length to provide pre-trigger data in the case of a bird approach.

This function would most likely be performed by a Field Programmable Gate Array (FPGA) or microcontroller. FPGAs are particularly well suited for this task as they could quickly average the data in an image to determine if the input is blooming or too dark. Both can access Dynamic Random Access Memory (DRAM) for buffering the video stream.

Motion Detection/Bird Recognition Module

This module will examine the stream of image data looking for a significant change in the visual field indicating bird activity. When a large enough change is found, then an identification algorithm is applied to determine if an object of interest (such as a bird) has entered the camera's view.

The process of recognizing an object, such as a bird, is the most challenging part of the BAM design since there are many types and sizes of birds. A positively identified object will then be subjected to a tracking process and the current stream of data along with sufficient pre-trigger will be passed along to the storage module until the tracking algorithm loses the object (one assumes by its leaving the field of view).

Though the primary focus in creating a BAM is to use the video for detection and recognition, it may be valuable to consider some additional sensor technologies to assist in these functions. Infrared sensors are good candidates for motion detection for instance, and could reduce some of the processing requirements (and thus power) of the video system. Bird avoidance radar systems such as those developed by Detect, Inc. have a proven track record; however, they are quite expensive.

The bird recognition module will be the most complicated in terms of hardware development. It will likely consist of one or more FPGAs and a Digital Signal Processor (DSP) or a full scale Personal Computer (PC) with a FPGA add-in card. At least this is a possibility for the initial design or a prototype system, as it provides a more flexible development environment for algorithm testing and tuning. The software component of this module is an equal challenge. There are commercial packages, which may be suitable for this application, however, there might not be an easy fit and some customization will definitely be required. High level development languages, such as Labview® and Matlab® may be applicable, especially for the initial design as there are ways to embed the compiled high level code into an embedded system. There is also an open source software package, which would allow for a high degree of customization on minimal hardware without having to start from scratch.

Some of the difficulties faced by the recognition algorithms are the large variations in size of the subject birds, the possibility of the birds going in and out of focus as they travel through the visual field and the variations in illumination during the course of the day and into the night.

Video Data Storage Module

The storage module simply holds the segments of video, which are thought to contain bird activity until they can be off-loaded by an operator in the field or via a convenient telecommunications link.

The storage medium used will depend on the environment and the amount of expected data. Sample hardware includes mechanical hard drives, solid state hard drives, secure digital, compact flash, and disk-on-chip®. All of these would be managed by a microcontroller or by the PC host platform, if that route is taken.

Communication

A variety of communication options will be incorporated in the prototype BAM design to allow for remote control, monitoring and download of recorded video/image data. Some of the communication options that will be considered include cellular technology, wireless radios, wired telephone and satellite internet access. Cellular internet access and wireless connection to a nearby LAN might be the two most successful as they will be provide faster communication link to the BAM system that will be needed for faster download of the video/image data.

Power Supply

In the prototype BAM development stage all effort will be made to keep the ultimate design in mind and take decisions to minimize power consumption. The prototype system, however, will likely be AC powered as this will be a stage primarily designed for system feasibility testing and demonstration. The final system design will focus on minimizing power consumption so that the BAM system could easily be powered using solar panels.

Design Challenges

The major challenges, which the BAM design must overcome fall into the following categories:

- Determine an optimum visual field;
- Operate properly at night as well as during the day;
- Find an algorithm(s), which can properly distinguish birds from noise; and
- Fit the final required hardware and software into a suitable lower-cost platform.

The first challenge is to select a camera/lens combination which can cover a typical 1000 ft power line span, either from one of the towers or from a position on the ground. It may require two BAMs to cover the entire span. The field of view must have sufficient resolution over the depth of field to distinguish a bird of the minimum desired size.

Since bird activity does not stop at night fall, the BAM must be able to operate in the dark. If an infrared light source is to be used at night, then it must have enough output to illuminate the full area of interest.

The problem of bird identification has been tackled by many researchers, such as Nadimpalli et al., (2006). There has been some success using techniques such as template matching, neural networks, and contour tracking. Most of these techniques, however, only work well on a limited set of bird species within a limited size range. The BAM must work across species which have a number of variables including color, flight profile, and size. In the early stages, bird identification will not be automated and the focus will only be on monitoring activity in the vicinity of power lines. Hopefully, if we can automatically monitor and record activity, the recorded video stream should provide visual clues that will help identify species if enough details could be captured.

Once the initial prototype design of the BAM has been tested and proven, the challenge will be to make it reproducible at a reasonable cost in a small form factor with low power requirements. Ideally, it would be powered by a solar-electric panel. This will depend somewhat on the results which come out of the initial testing, but the form of the final configuration needs to be considered, as decisions are made.

References

Nadimpalli, Uma D., Randy R. Price, Steven G. Hall, and Pallavi Bomma. 2006. *A Comparison of Image Processing Techniques for Bird Recognition*, Biotechnology Progress, 22, 9-13

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