Novel Use of Remote Sensing, Monitoring and Tracking for Animals in Wild Habitats

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Abstract

Parks and Wildlife requires a discrete system that can automatically and continuously monitor animal patterns and behaviors in remote environments in an efficient manner that does not disturb the animals. This paper proposed a stand-alone monitoring system that can inconspicuously monitor and track animals in their natural habitat and transmit data/footage to an off-site viewing module.

The genesis of the Argus Vision name is in ancient Greek Mythology. Argus Pantoptes was an all-seeing giant with 100 eyes who stood watch for the Goddess Hera. Upon his death and as a tribute to her trusted watchman, Hera took the eyes of Argus and placed them on the tail of her favorite bird, the peacock. The Argus Vision logo is the tail of the peacock with the eyes of Argus. Monitoring is accomplished using wireless outdoor cameras set up on-site. The cameras are connected to a central control unit, via a telemetry network, that takes the feed from all of them and broadcast, in real time, the footage to an Android application on a personal tablet. The end user will be able to control multiple cameras remotely and monitor the location without being on-site, hence eliminating the need for researchers to do the cumbersome job of going out into the habitat to retrieve footage and risk disrupting the animals. The Argus Vision is a unique system and the project aims to develop power supply, wireless communication, data storage, and controllability capabilities for the system.

Introduction

Biologists currently use camera traps to monitor and track wildlife in their habitats (Swann, Hass, & Wolf, 2004; Garcia-Sanchez, Garcia-Sanchez, Losilla, Kulakowski, Garcia-Haro, Rodriguez, López-Bao, & Palomares, 2010). These camera traps work well to collect images of shy animals but present two primary issues: disturbance and inefficiency. This problem can be overcome by use of remote vision technology that allows the user to monitor animals in their wild habitat, wirelessly and without disturbing or startling the animals (Paek, Hicks, Coe, Govindan, 2014). Similar to other recently published systems that use still camera footage to monitor bird nesting in the wilderness (Baratchi, Meratnia, Havinga, & Skidmore, 2013; Neumann, Martinuzzi, Estes, Pidgeon, Dettki, Ericsson, & Radeloff, 2015; Locke, Cline, Wetzel, Pittman, Brewer, & Harveson, 2005), the Argus Vision project aims at designing and

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implementing a live video monitoring system to track water fowl patterns and habits in a remote location.

The Argus Vision is a system that allows the customer to monitor a remote location without having to be on-site. It is designed to be used in rough, rugged, remote environments to monitor animal-landscape interaction, vegetation, reproduction cycles, expansion, and safety. The Argus Vision has a wide range of applications and would be an ideal system to use for facility security. The system could also be extended to use in habitats where poaching might occur, for border patrol, homeland security, and hunting.

The functional requirements for Argus Vision are wireless capability, long-range access point, Wi-Fi enabled; battery powered, operates for an extended time, low battery (state of charge) notification, solar panels to charge batteries; controllable cameras, pan, tilt, and zoom functionality, infrared night vision; interface with Android tablet, Android user application; interaction with server; recording and video storage; GPS locator; and enclosure needs to be durable and weatherproof.

Design Overview

The conceptual block diagram seen in Figure 1 depicts the high-level concept of the system.

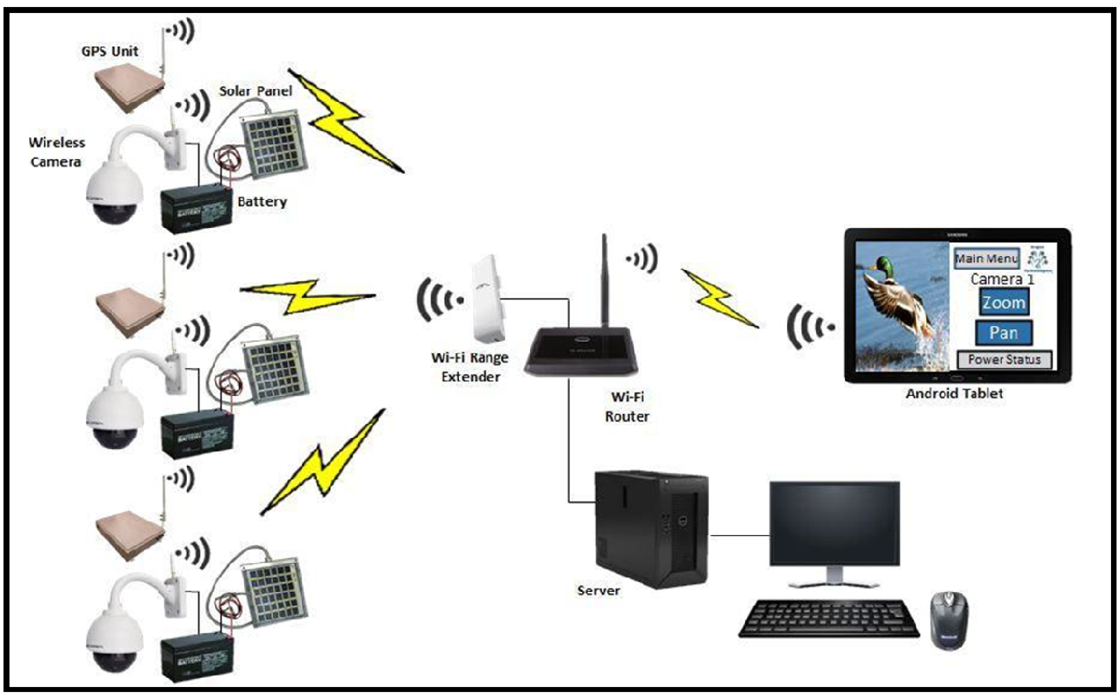

Figure 1. Conceptual block diagram.

The design integrates all the components depicted in Figure 1 into one system. Cameras are set up inconspicuously at the various remote locations. Circuits are designed to power the cameras and GPS units from a solar-charged battery. The batteries and GPS units are housed in weatherproof enclosures. A server is located on-site, and it is able to store the video and transmit it to an Android tablet. The end user will be able to control the multiple cameras remotely, including panning and zooming, via the Android tablet, essentially offering a real-time view of the location without being on-site.

Based on the conceptual block diagram and research conducted on how the different modules and devices need to connect, the functional block diagram in Figure 2 was developed. The heart of the Argus Vision system is the MSP430 microcontroller. The peripheral modules, such Wi-Fi and GPS, are selected based on their embedded communication protocol and the corresponding number of communication ports available on the microcontroller.

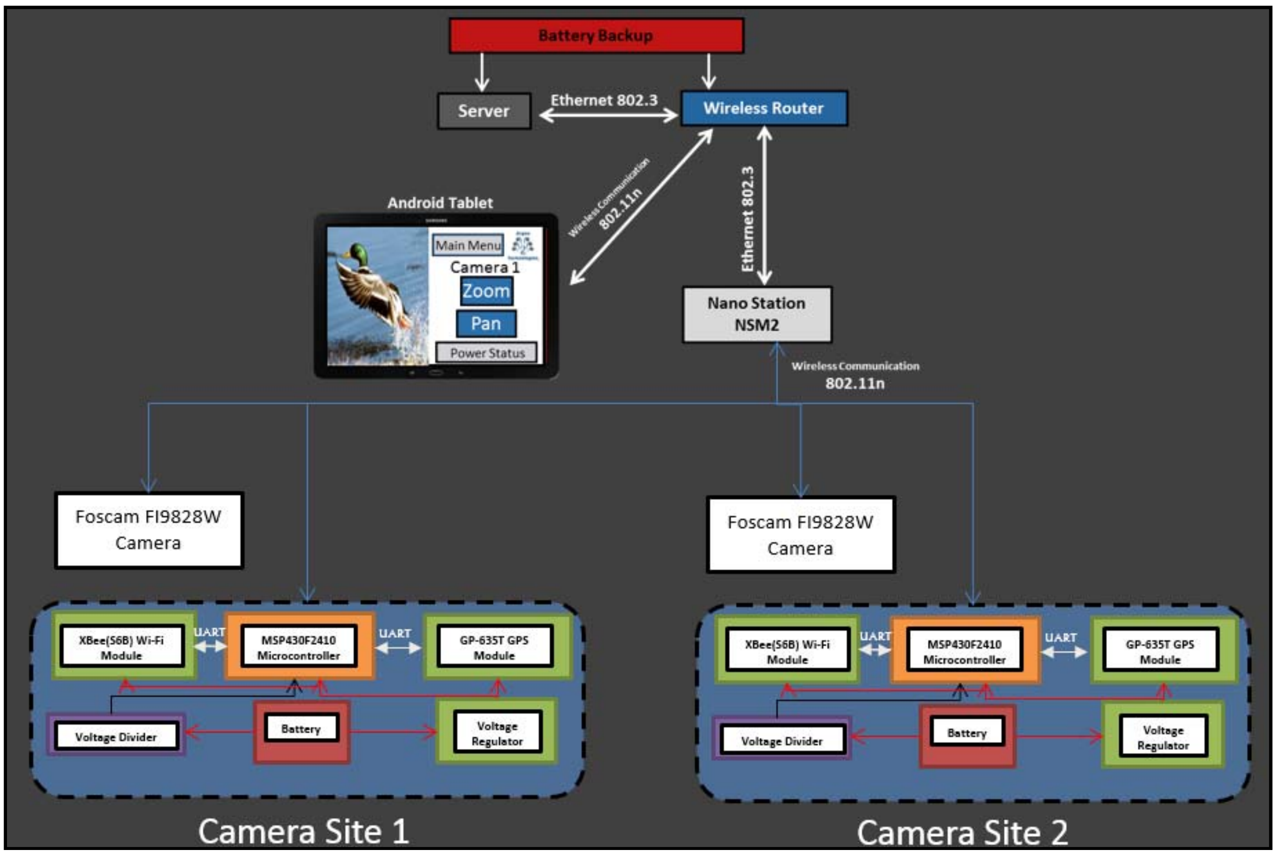

Figure 2. Functional block diagram.

The performance specifications for Argus Vision are seen in Table 1.

Table 1. Performance specifications

Function	Specification	Details
Wireless Capability	Long range access point	>1km wireless communication
	Wi-Fi enabled	2.4 GHz IEEE Standard 802.11n
Battery	Operates for and extended	Battery life of ≥24 hours

	time period	
	Low battery (state of charge) notification	Notification sent when battery is <10V
	Solar panels to charge batteries	Rechargeable to 12V DC via solar panels
Controllable Cameras	Pan, tilt, and zoom functionality	o 355° pan o 90° tilt o 3x optical zoom
	Infrared night vision	≤20 meters
Interfaces with Android tablet	Android user application	o Real-time video footage from multiple cameras o Display GPS location of cameras o View battery state of charge o Control camera functions
Interacts with server	Records and stores video	o Server will store video for up to 30 days o Server will have at least 1TB of storage available to accommodate data storage o Allows user application to access stored video
GPS Locator	Wi-Fi enabled	o Unassisted acquisition o Accuracy within 10 meters
Enclosure	Weatherproof	o Withstand rain and heavy water flow
	Mountable	o Capable of being mounted to a pole or tree without defect to functionality o Small size

Hardware Design

The Argus Vision PCB schematic is designed in Eagle CAD, and it consists of four subsections: power, microcontroller, Wi-Fi, and GPS.

1. *Power*: The power section inputs a 12V battery voltage source that then goes directly into the 3.3V regulator to supply a steady voltage to the rest of the circuits. The power section also contains the voltage divider to determine the battery voltage level for display to the user.
2. *Microcontroller*: Circuitry in the microcontroller section includes decoupling capacitors and a JTAG connector.
3. *Wi-Fi*: The XBee S6B module is the Wi-Fi module for the Argus Vision. It can use RPSMA-connected antennas, which are readily available. The module is connected over UART to the MSP430 microcontroller to send the data for transmission to the Wi-Fi module. The device is also connected to two DIO ports on the MSP430 to turn the module on and off.
4. *GPS*: The GP-635T GPS module is connected to the PCB via a 6-pin female JST connector. UART is used to communicate with the MSP430 to send the GPS data from the module to the microcontroller. The device also connects to a DIO port on the MSP430 to power the module on and off.

Software Design

Android Software Design

When the Argus Vision Android app is opened, the home or main screen will appear. All subsequent screens and functions are inherent to the main activity. From within the main screen, the user should first click the "Setup Menu" button to set up all the cameras in the Argus Vision system. Once the user inputs the number of cameras in the system and clicks the "Connect" and "Save" buttons, the system will be automatically set up. Clicking the "Save" button will direct the user back to the home screen for a choice to view the live feed or archived footage of any camera in their system. Users also have the option to view a map of all the cameras in their system and to then either view live or archived footage of any camera, based on its location. If the user chooses the "View Live Feed" button, the Foscam Android app will open, and the user will then be able to view the live footage as well as control the camera. If the user selects the "View Archived Footage" button, the ES File Explorer Android app will open, and the user will have to log into the server to view the archived footage, organized by date, of any camera.

Figure 4 shows the hierarchy chart for the application.

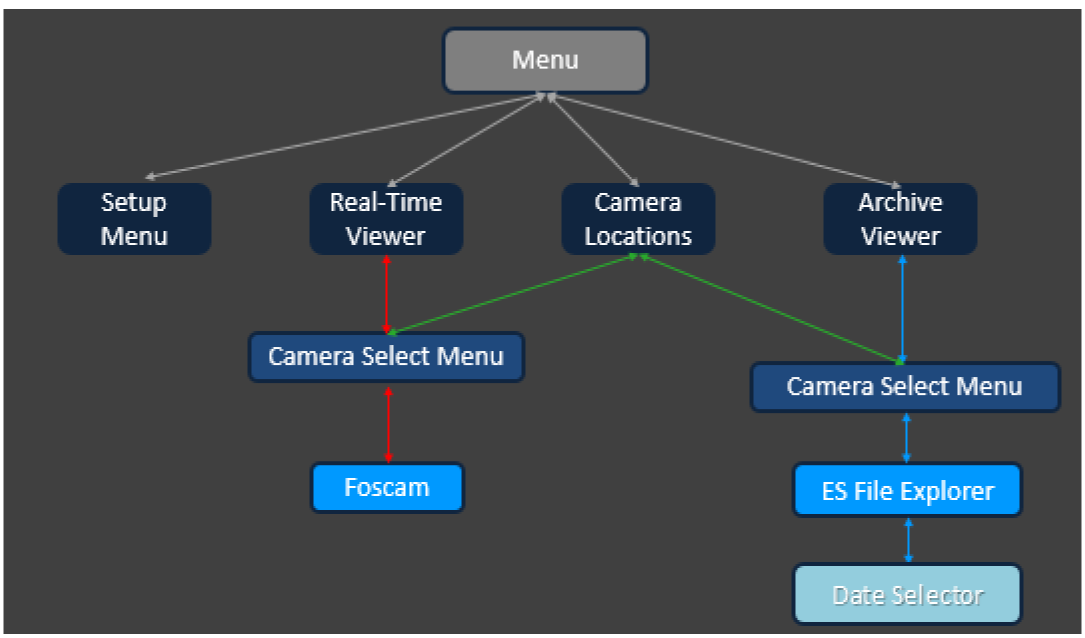

Figure 3. Android app hierarchy chart

Embedded Code Design

The Argus Vision's embedded software uses a timer to determine when all other tasks should occur. The battery percentage level is transmitted to the tablet every four hours, and the GPS coordinates transmitted every 24 hours. To implement this, the timer is used to count a second. When the timer count reaches 60 seconds, two other counts are incremented by one, creating two separate minute counters, one for GPS timing and the other for battery percentage timing. Development began using a development board specified for the MSP430. The first task was to successfully read and parse GPS data from the GPS module on the development board. Once this was complete, the next task was to successfully implement the on-board ADC on the development board to read the correct voltage value from a voltage divider connected to an external battery. The existing code modules were tested on the actual boards, and they were successful. The next task was to implement the Wi-Fi module. UART is used for the Wi-Fi module communication. The next task was to implement the timer in the microcontroller, and, once that was complete, some minor tweaking was necessary to make all the pieces of code work together.

Testing

To ensure that Argus Vision works as expected and meets all functional requirements, the test matrix in Table 2 was developed.

Table 2. Test matrix.

	Battery Powered	**GPS Locator**	**Real-time view**	**Video Archiving**	**Android App**	**Camera Control**	**Enclosure**	**Wireless Communication**
Wi-Fi Connection at >300ft								X
Battery Life	X							
GPS coordinates		X			X			X
Real-Time Monitoring			X		X			X
Camera controllability via android app			X		X	X		X
View Archived data on app				X	X			X
Weatherproof enclosure							X	
Battery status displays in android app	X				X			X
Field test	X	X	X	X	X	X	X	X

1. *Wi-Fi Connection*: This test verifies that the cameras can connect to the wireless access point at distances greater than 300 ft. and receive at a signal of at least 70dBm. With the system being remote, it is verified that the connection is working correctly in a far-field communication setup. This test also estimates the

distance at which the cameras and access point can be separated and maintain reliable communications. The result indicated a strong, usable wireless connection at 301ft.

2. *Battery Life*: To confirm the battery operates at least 72 hours, the PCB and camera are powered and transmitting video and GPS data with a full battery charge and allowed to run until the battery fails. This test is timed to verify the battery capacity is sufficient to handle the full operational load. The result indicated that the battery lasted over 72 hours without powering off the camera.
3. *GPS Coordinates*: This test confirms that the GPS coordinates from the microcontroller correspond to the location that the GPS module was within 10 m when the data was read. This is done by comparing the actual camera location to the coordinates displayed in the Argus Vision App using Google Earth. The test indicated that correct GPS coordinates are broadcast to the tablet and are being populated on the map in the Argus Vision Android application.
4. *Real-Time Monitoring*: To ensure that the camera properly transmits real-time video, it is set up at a location with Person 1. Person 2 the views the video feed from another location while communicating with Person 1, to ensure that the video does not have a noticeable delay. Results indicated that Person 2 could immediately identify all the movements of Person 1.
5. *Camera Control via Android App*: This test ensures that the camera can be controlled from the app. If the user is able to pan, tilt, and zoom the camera, this verifies that the app functions correctly, the user has control over the cameras, and wireless communications are working. The test showed that the camera settings are controllable from within the Argus Vision Android application.
6. *View Archived Data on Android App*: This test verifies that the server is set up properly and has the ability to store video footage from the cameras for at least 30 days as well as verify the ability to transmit that stored data to the Argus Vision Android App via Wi-Fi. The test was successful; the user could access and view stored video from 30 days prior via the Argus Vision Android app.
7. *Weatherproof Enclosure*: In this test, the operation of the Argus Vision system was verified in various weather conditions. The enclosure is designed to be weatherproof and to protect the system's hardware from hazardous outdoor weather conditions. Neither the PCB or battery were damaged by simulated inclement weather.
8. *Battery Status Display in App*: Argus Vision needs to display battery life within the Argus Vision to prevent the PCB and camera from dropping below operating voltage levels. If the 12V DC battery drops below 10V DC, a notification appears in the Argus Vision Android app. This test was successful.
9. *Field Test*: As a final test, the Argus Vision system was installed on a ranch property, which is a real-world environment as close as possible to actual operation. The PCB, cameras, and tablet were powered on and the Android app launched. The user interface functioning and the data display on the app are verified. All parts of the Argus Vision system function as specified in the performance requirements.

Conclusion

The Argus Vision System is a unique video surveillance system that is designed for use in remote locations. It has been proven to be useful in providing facility security; the designers plan to expand it for use as game cameras for hunting as well as research purposes. The system addresses all the needs and requirements to allow for system scaling to almost any use. The small form factor allows the system to be discrete and non-invasive to the environment and animals living in the area.

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Biographies

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