Application Details

Research and Development Minigrants for 2017-2018: Application Review

Application Title: Passive Acoustic Primate Monitoring Project

Application ID: #000072

Review Deadline: Jan 27, 2017 11:59:00 PM

Primary Appointment Title: Assistant Professor Computer Science and Information Technology

Proposal Summary:

This international interdisciplinary research project joins computer scientists and animal behaviorists from CI and Liverpool John Moores University to investigate the benefits of using weather balloons to collect data from remotely deployed sensor networks. The sensors that make up this network will be used to conduct an acoustic biodiversity census in the Ugalla region of Tanzania, home to wide ranging populations of elephants, lions, and numerous primate species, including chimpanzees. Funding will be used to develop and deploy a proof of concept prototype system enabling initial experiments to be used in future external grant proposals.

Comments to the Administrator(s):

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Education

Ph.D. University of California, Santa Barbara, Electrical and Computer Engineering, March 2012
Dissertation: *UAV Data Mule Vehicle Routing Problems In Sparse Sensor Networks*
Adviser: João P. Hespanha

M.S. University of California, Santa Barbara, Electrical and Computer Engineering, June 2008
Major: Control Systems
Minor: Signal Processing

B.S. University of Kentucky, Electrical Engineering, *Summa Cum Laude*, Dec. 1999

B.S. Eastern Kentucky University, Engineering Physics, *Magna Cum Laude*, Dec. 1999

Teaching Experience

Assistant Professor, August 2015–Present
California State University, Channel Islands, Dept. of Computer Science and Information Technology

Courses Taught

F2016

COMP 150 Introduction to Object Oriented Programming
COMP 491 Capstone Preparation
COMP 597 Master Thesis
IT 491 Capstone Preparation

S2016

COMP 150 Introduction to Object Oriented Programming
COMP 462 Embedded Systems
COMP 494 Independent Research
COMP 590 Advanced Topics In Computer Science

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Other Work Experience

Visiting Assistant Researcher, July 2016 – Present
University of California, Santa Barbara, Center for Control, Dynamical-Systems, and Computation

Co-founder, January 2014 – July 2016
ShadowMaps Inc.

Post-doctoral Scholar, March 2012–April 2015
University of California, Santa Barbara, Center for Control, Dynamical-Systems, and Computation

Research Intern, Summer 2008
United States Army Research Laboratory

Senior Hardware Development Engineer, January 2000 – August 2006
Lexmark International Inc.

Honors and Awards

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Best Paper Award, ACM MobiCom S3 Workshop Wireless of the Students, by the Students, for the Students, September 2014

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Grand Prize, UCSB Technology Management Program, New Venture Competition, May 2014

Best Presentation in Session, American Control Conference, July 2011

School For Scientific Thought Teaching Fellowship, California Nanoscale Institute, May 2010

Doctoral Scholar Fellowship, UCSB Graduate Division, September 2006-September 2010

Selected Talks

Introduction to the AVES Lab, Channel Islands Chapter of Association of Unmanned Vehicle Systems International (AUVSI), Camarillo, California, September 13, 2016

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Optimal TDOA Sensor Placement For Uncertain Source Locations, 17th Southern California Nonlinear Control Workshop, Caltech, May 22, 2009

Professional Service

Technical Reviewer

IEEE Conference on Decision and Control ⋄ IFAC World Congress ⋄ IFAC Workshop on Distributed Estimation and Control in Networked Systems ⋄ International Conference on Control, Automation, Robotics and Vision ⋄ IEEE Transactions on Wireless Communications ⋄ American Control Conference ⋄ IEEE Transactions on Signal Processing ⋄ IEEE Transactions on Control Systems Technology ⋄ IEEE Sensors Journal ⋄ International Conference on Intelligent Robots and Systems ⋄ Robotics and Autonomous Systems ⋄ Journal of Optimization Theory and Applications ⋄ Unmanned Systems Journal ⋄ NSF Panelist

Session Chair

55th IEEE Conference on Decision and Control, "Kalman Filtering"

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Professional Affiliations

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Outreach

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Proceedings

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Passive Acoustic Primate Monitoring Project

Jason Isaacs

December 23, 2016

1

Proposal Narrative

Proposal Summary

This international interdisciplinary research project joins computer scientists and animal behaviorists from CI and Liverpool John Moores University to investigate the benefits of using weather balloons to collect data from remotely deployed sensor networks. The sensors that make up this network will be used to conduct an acoustic biodiversity census in the Ugalla region of Tanzania, home to wide ranging populations of elephants, lions, and numerous primate species, including chimpanzees. Funding will be used to develop and deploy a proof of concept prototype system enabling initial experiments to be used in future external grant proposals.

Project Goals and Outcomes

There are two main objectives to this study:

1) To conduct an acoustic biodiversity census across a landscape that varies from nearly absent human activity to urban;

2) To achieve this by pioneering an innovative system that integrates acoustic sensors and helium balloons that serve as relay stations for streaming real-time acoustic data.

Passive acoustic monitoring: progress and potential

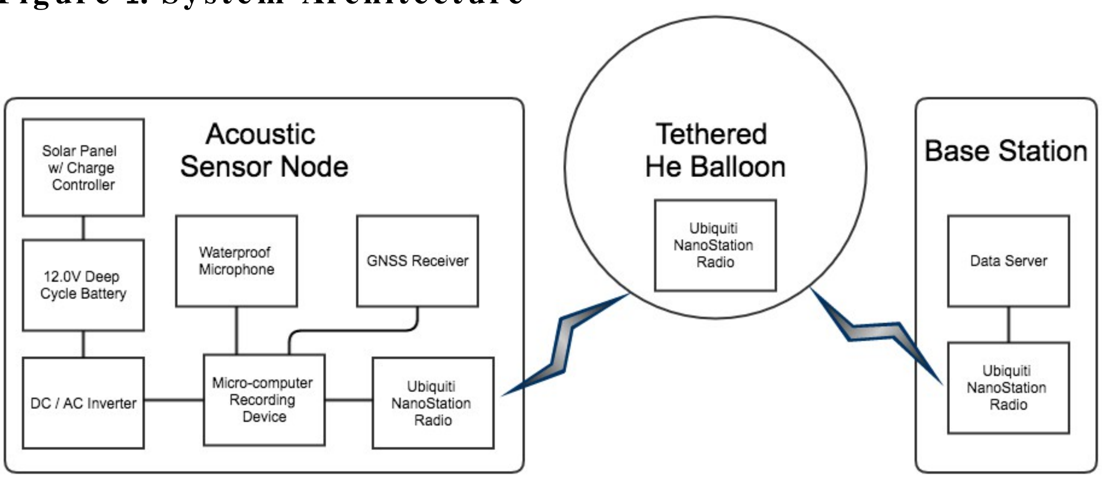
Historically, biodiversity monitoring involved deployment of teams comprised of various specialists (botanist, entomologist, mammologist, etc.) to collect inventories of often vanishing landscapes. Those surveys continue, but with limited time and financial budgets to conduct the work, research into new technologies is increasingly necessary to efficiently collect and/or analyze data on biodiversity. Recent developments include remote monitoring via camera traps, satellite imagery, unmanned aerial vehicles (UAVs), and autonomous acoustic recording stations that may store data (Brandes 2008; Thompson et al. 2009; Blumstein et al. 2011) or transmit data via radio (Piel 2014) or local wireless networks (Aide et al. 2013).

Passive acoustic monitoring (PAM) involves the deployment of autonomous recording devices. The method offers numerous advantages over traditional measures of data collection. First, acoustic recorders can be deployed in areas or habitats otherwise difficult to access, e.g. marine and freshwater environments, canopy tops, and even frigid regions such as glaciers. Further, deployment of acoustic arrays avoids the damage caused by teams of people tromping through the understory; instead, data from acoustic units often reveals hidden patterns in the acoustic structure of an entire ecosystem (Servick 2014) while remaining inconspicuous. Second, compared to active recording (whereby people use handheld microphones), PAM can record uninterrupted and continuously, revealing data on cryptic, discreet, or otherwise rarely encountered species. Third, the costs of deploying teams of people into remote areas far exceeds the costs of deployment of autonomous systems (see review in Blumstein et al. 2011). Finally, resulting data reveals diversity and patterns at the individual, population, species, and landscape level, expanding the application of the same dataset to conservationists working at all/any of these scales (Gasc et al. 2013).

Capturing these sounds, however, offers its own limitations. Traditionally, PAM systems store data internally, requiring close monitoring of storage capacity and regular visits to replace memory cards, for example. Likewise, power supplies often restrict sampling periods and require frequent maintenance checks. Innovative approaches to overcome these challenges include employment of radio (Kalan et al. 2016) or local wireless networks (Aide et al. 2013) to transmit streaming acoustic data, providing the data in real time. Unfortunately, even these systems are hampered by topographical features that prevent transmission, namely hills, mountains, or even thick forests. As a result, we may be biasing our recording units to only those areas that allow for transmission, not accessing potentially rich acoustic reservoirs that are beyond the reach of our sensors.

We will overcome this problem by integrating helium balloons to act as relay stations for streaming acoustic data from low-power, highly sensitive sensors, fixed with RF transmitters (see Figure 1). While this will not be the debut of helium (He) balloons in zoological research (Clayton and Vaughn 1986), the majority of applications of balloons involve weather monitoring (Sankar and Norman 2009), and none to date has ever explored their use in monitoring biodiversity.

Figure 1: System Architecture



Significance of Research

Professional Development Benefits for Faculty

Earlier this year Dr. Alexander Piel of Liverpool John Moores University approached me about potentially collaborating on this project. Dr. Piel has spent over a decade using acoustic recording devices to study chimpanzees in Tanzania as part of the Ugalla Primate Project (http://ugallaprimateproject.com/projects/bioacoustics). Dr. Piel has published numerous articles from his work on the Ugalla Primate Project pertaining to acoustic monitoring (Kalan et al. 2016; Kershenbaum et al. 2014; Piel 2014) as well as the roll of wildlife researchers in deterring poaching in western Tanzania (Piel et al. 2015).

This collaboration is exciting to me as a researcher in that it provides the opportunity for me to deepen my disciplinary expertise and apply my Ph. D. research on using unmanned aerial vehicles (UAVs) to gather information from acoustic sensor networks to new areas. My dissertation was primarily focused on the battlefield monitoring application where the objective was to rapidly geo-locate the source of explosions (Klein et al. 2010; Klein et al. 2013; Isaacs et al. 2012). There are new challenges associated with this application that were not present in my Ph. D. research including the need for extraction of large data files of high-fidelity acoustic recordings and the need for careful power management to allow for extended long term deployment. These challenges provide the incentive to explore exciting new research areas such as using Deep Learning to classify acoustic data before transmitting.

Broader applications

Biodiversity surveys enable conservationists and researchers to assess the current state of an ecosystem by providing data on species diversity, abundance, and distribution - critical information when we consider the rate of human deforestation and destruction (Hosonuma et al. 2012). However, the time and financial costs of surveys are often prohibitive. Consequently, we propose here to develop and test a rapid and innovative means of comprehensively acoustically surveying biodiversity, providing real-time data, especially from remote areas previously out of reach of monitors. Resulting data will inform on how human disturbance degrades acoustic diversity.

Once demonstrated, subsequent stages will involve developing wireless sensor networks (WSNs) that are comprised of multiple arrays of acoustic sensor nodes deployed across an entire ecosystem (sensu Colonna et al. 2016). With the analytical techniques developed here, these systems would then be placed to monitor biodiversity, especially of indicator or targeted species.

Research Plan and Methodology

Acoustic sensors

The current study will serve as a preliminary demonstration, e.g. proof of concept. We will initially deploy four acoustic sensors in each area, the Issa valley and Nguye forest, <10km from Uvinza. The four microphones will be located at the corners of a triangular pyramid, with playback sounds broadcast from inside and outside the array to allow testing of localization accuracy (Mennill et al. 2006). Each sensor unit will consist of a solar panel power source, a waterproof microphone, a GNSS receiver, and a networked radio. The microphone sensors will be Knowles H-Series waterproof omnidirectional microphones which are designed for fixed position outdoor usage and have a sensitivity of -50 dB. The GNSS receivers will be Ublox NEO series which provide precise timing information required for accurate acoustic localization. Acoustic data will be transmitted to a base station though a relay Ubiquiti NanoStation radio on the tethered He balloon.

Pre-processing

Data upload to the balloon will likely be our largest challenge, and thus we will pre-process audio data on sensor nodes, which will limit the amount of transmissions and thus save energy as well as extend the life of sensors. We will use Deep Learning to target specific animal vocalizations (e.g. playback pure tones, chimpanzee pant hoots, tropical boubous, etc.) as case studies. Deep Learning approaches are computationally and thus energetically efficient to employ, as has been shown with other taxa (birds: Koops et al. 2015; anurans: Colonna et al. 2016), and hopefully will overcome low accuracy rates reported from recent methods using support vector machines among others (Heinicke et al. 2015).

Balloon

We will install a single totex balloon (Kaymont Indus., payload up to 1.5kg), first at Issa and then shift the balloon and sensors to Nguye. To generate sufficient lift, we will fill the balloon with pure Helium (He) at each site. The weather balloon will be secured with at least four tethered (Kevlar) guy lines, which will also provide stability. If the balloon were to rupture or deflate for any reason, we will secure the payload against damage and impact by encasing the electronics in a small Pelican case, which will also protect against environmental elements, e.g. rain, humidity, extreme temperature fluctuations.

Biodiversity indices

Acoustic biodiversity is classified as either α-diversity, which measures the diversity within a given area, or β-diversity, which instead assesses variation in species turnover between two or more areas (Diserud and Odegaard 2007). Regardless of which measure is used, comparable data require sampling over multiple locations or seasons/years, and historically have involved the slow acquisition of biodiversity inventories. More recently, however, rapid acoustic biodiversity methods have been successfully employed across entire animal communities (Pavoine and Hamerlynck 2008; Sinsch et al. 2011; Depraetere et al. 2012). This approach assumes that acoustic diversity scales with species diversity within a community, and that species diversity translates into increased acoustic heterogeneity (Pavoine and Hamerlynck 2008). Across taxa, callers create acoustic niches to effectively transmit their sounds (Schneider et al. 2008; Sinsch et al. 2012; Villanueva-rivera 2014), and so we should find taxa-specific temporal or frequency patterns in calling if communities are in-tact. We will follow Sueur and colleagues (2008) and also calculate Acoustic Dissimilarity indices for each site, as well as the traditional Shannon-Wiener and Simpson Indices of diversity. These parallel metrics will facilitate comparisons with traditional means of biodiversity assessments (Magurran 2004; Gilhooly et al. 2015).

Dissemination Plan

While this project has clearly defined deliverables in terms of software and hardware, the larger goal is to foster the involvement of undergraduate students in hands on learning activities outside the classroom. This project will afford students an opportunity to participate in undergraduate research where they will learn about the process of conducting research as well as gain practical skills related to writing software to solve real world problems. It is my expectation that this work will lead to the submission of at least one article for journal publication. It is my intent to co-author this article with the undergraduate research assistant.

Project Timeline

A PhD student at LJMU has been hired to participate in the project, and we have already begun design and building of acoustic sensors. System design will continue throughout Spring 2017 with initial testing to be conducted both in California and the UK in Summer 2017. Two field trips are planned for this work: Summer (dry) and Winter (wet) 2017 to assess any seasonal effects. This funding is intended to offset some of the expenses for these trips. Data analysis will begin immediately after each season, as well as any technical adjustments for subsequent deployments. We aim to complete the project by Summer 2018.

Project Assessment

If the sensor network is demonstrated to be operational and sustainable, then the project will have been a success. Prior to deployment there will be several milestones to make sure that the project is progressing according to schedule. These checkpoint experiments make for ideal undergraduate research activities in that students learn the process of designing, conducting, documenting, and evaluating experiments. Two key metrics of success will be the ability to correctly classify various species from acoustic data and the ability of the sensor node to operate for extended periods without human intervention (e.g., change battery or replace storage device).

Proposal Budget

The total requested budget for this project is $9,000 and is described in Table 1 which contains three line items. The first line item will be to provide funding for one or more student assistants during the Summer 2017. The amount budgeted will fund up to 10 hours per week. I anticipate hiring one or two students to work approximately 10 (or 5) hours per week each on the project. During the Summer 2017 I will be working on the project to finalize the sensor design and working with students to test the sensors prior to deployment to Tanzania. During this time, I plan to provide hands-on mentorship to the student assistants working in the lab. The second line item is for reassigned time of 3 units at a cost of $2,000 per unit. The reassigned time will allow me to focus on developing and testing the Deep Learning acoustic species classification algorithm and preparing results for publication. The third line item is for partial assistance with travel costs to the Ugalla Primate Research Station in the Issa Valley of Tanzania. All visiting researchers to the Ugalla Primate Research Station are required to pay for necessary Tanzanian governmental research agencies TAWIRI and COSTECH research permits. The cost of these permits are approximately $1016 and $296 respectively (subject to currency exchange rates). It is important that I attend the first set of field experiments as I will be the most familiar with the sensor nodes and communication network.

It should be noted that this project is ongoing and has already been supported through several small grants from CI and from Liverpool John Moores University (LJMU). Through grants from LJMU, Dr. Piel is currently funding a Ph. D. student who is working on the project, Dr. Piel will visit CI in January 2017 to kick off the project and perform preliminary experiments, and Dr. Piel has secured partial travel costs for Dr. Isaacs to join the team at the Ugalla Primate Research Station during the Summer 2017 for the first set of field experiments described herein. Most of the necessary hardware to build the prototype system has been funded with a combination of a LJMU grant and a CI CIS minigrant ($500). As mentioned in the Proposal Summary, we plan to use the results of this preliminary experiment to develop external grant proposals to fund long term deployment of such a system.

Table 1: Project Budget

DESCRIPTION	COST	TOTAL COST
STUDENT ASSISTANT	$14 (per hour) x 10 (hours per week) x 11 (weeks) + 10% payroll tax	$1,694
REASSIGNED TIME	$2000 (per unit) x 3 (units)	$6,000
TRAVEL ASSISTANCE	TAWIRI and COSTECH Research Fees	$1,306
	Total	$9,000

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Research and Development Minigrants for 2017-2018: Review Form

Routing Step: Initial Committee Review

Application Title: Passive Acoustic Primate Monitoring Project

Application ID: #000072

Review Deadline: Jan 27, 2017 11:59:00 PM

***Project Goals and Outcomes:**

The proposal sets clear goals and outcomes for the project, and it explains the steps that will be taken to realize project goals.

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Rating Scale 1 (1 weakest to 11 strongest):

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***Research Plan and Methodology:**

The proposal conveys a complete and well thought-out plan for the project that describes the activities of all individuals involved in the project. If support is requested for student research assistance, the proposal must also include a description of their role in the project and how the faculty

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Rating Scale 2 (1 weakest to 11 strongest):

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***Professional Development Benefits for the Faculty:**

The proposed makes clear how the project will advance each individual applicant’s or research, scholarship, creative activity, or innovation in teaching. The proposal discusses whether the applicant(s) intend to pursue external funding and identifies those external funding opportunities.

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Rating Scale 3 (1 weakest to 11 strongest):

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***Project Benefits:**

To what extent does the proposed qualify for special consideration (e.g., applicant is *probationary, applicant has not had minigrant funding in the past, applicant has been especially successful in the use of past minigrant funding, project scope is particularly ambitious but realizable).*

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Rating Scale 4 (1 weakest to 11 strongest):

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***Dissemination Plans:**

The level and type of dissemination is appropriate for the project, its goals, and its outcomes.

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Rating Scale 5 (1 weakest to 11 strongest):

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***Project Timeline:**

The project goals and objectives are attainable within the timeline of the proposal.

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Rating Scale 6 (1 weakest to 11 strongest):

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***Project Assessment:**

The proposal describes how the product(s) of the project will be assessed and evaluated to determine the degree of success achieved.

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Rating Scale 7 (1 weakest to 11 strongest):

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***Project Budget:**

The proposed budget is reasonable in the context of the project description, and the project costs are necessary to achieve project goals and outcomes.

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Rating Scale 8 (1 weakest to 11 strongest):

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***Other considerations:**

To what extent does the proposed qualify for special consideration (e.g., applicant is probationary, applicant has not had minigrant funding in the past, applicant has been especially successful in the use of past minigrant funding, project scope is particularly ambitious but realizable).

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Rating Scale 9 (1 weakest to 11 strongest):

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