CPS: Medium: Collaborative Research: Remote Imaging of Community Ecology via Animal-borne **Wireless** Networks

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Students graduated and placement: William Scott, Ph.D. December 2016, Postdoctoral Researcher at University of Maryland, Katherine Fitch, defended Ph.D. September 2016, Postdoctoral Researcher at Technical University of Munich, Germany

INSTITUTE FOR SYSTEMS RESEARCH
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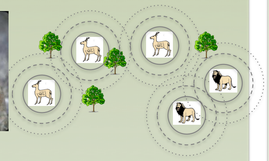
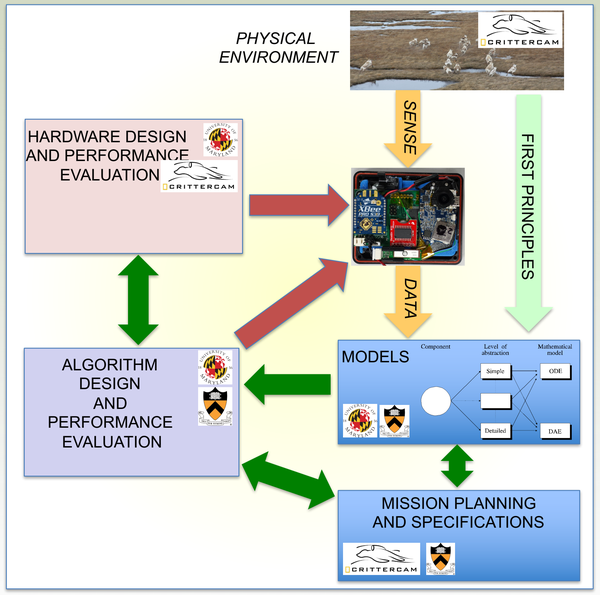
Research Goals

- Cooperative data collection and data-driven statistical modeling to extract animal group behaviors of sociobiological significance
- Team-decision strategy design to optimize system performance
- Development of a test-bed to validate and foster the development of new model-based principles for the design of power-constrained networked CPS





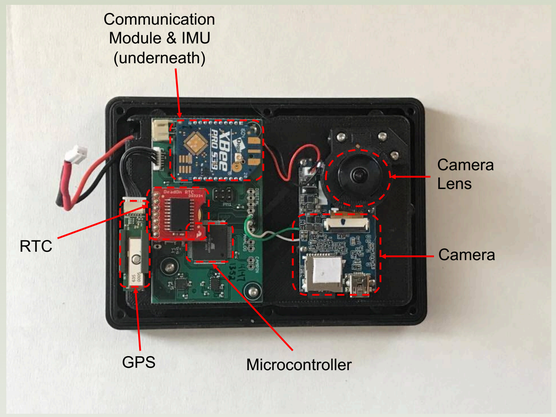


Project Anatomy

Remote Imaging System

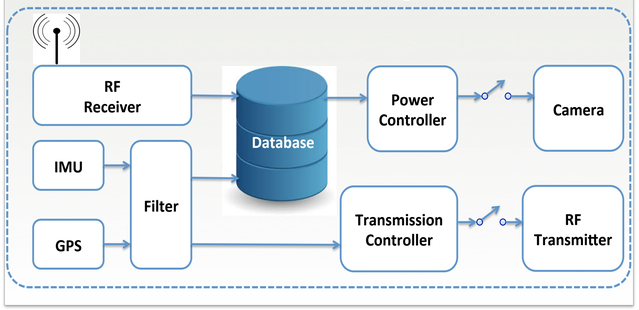
New System Design and Integration

- New circuit board design enables reduction in the size and weight of animal-borne tracking devices
- New system will allow the study of smaller but important animals such as coyotes, lynx, and foxes



New Firmware Design

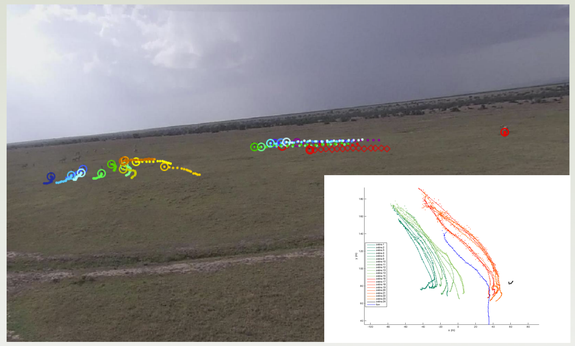
1. Online parameter estimation of animal motion models
2. Adaptive control of sensing and communication rates based on activity and battery levels
3. Event and time-based camera power control



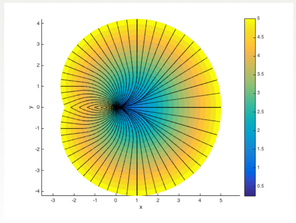
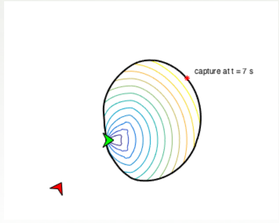
Models and Theories for Collective Motion

Data-driven Modeling of Pursuit and Evasion

- Field experiments to capture interactions between a zebra herd and a robo-lion
- Analysis of video data from the experiments to develop a new model for pursuit and evasion: the model takes physical constraints on speed, turning rate, and lateral acceleration of animals into consideration
- Examination of efficacy of the new model in a game theoretic setting



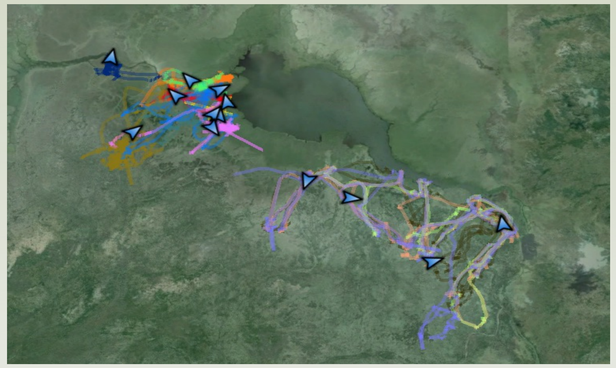
Analysis of video data from the experiments

A new model for study of pursuit and evasion

System Deployment and Data Collection:

- Deployment in the Gorongosa National Park (Mozambique) in August 2017
  1. Collaboration with Pringle's research group
  2. 29 devices were deployed on waterbucks and water buffaloes

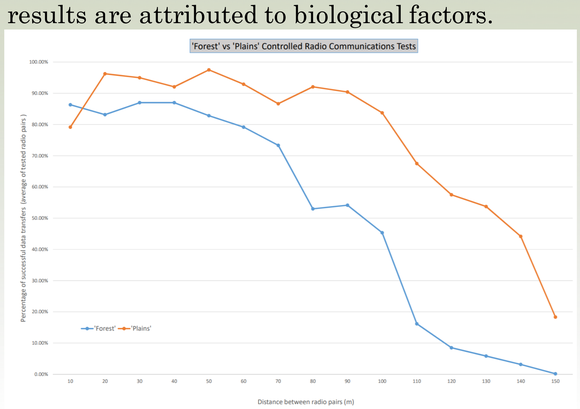


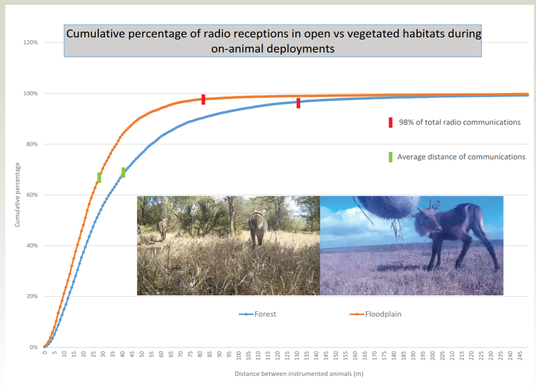
GPS Data Visualization

Animal Point-of-View Screenshot

Radio Network Performance Metrics:

- Results of empirical and experimental radio distributions show consistent communication range among multiple biomes. Differences in distribution averages between empirical and experimental results are attributed to biological factors.





Future Plans

- Analysis of the dataset obtained from the deployment and development of collective models for water buffaloes
- Analysis of dataset obtained from the deployment for development of habitat use model for waterbuck.
- Deployment of devices onto Buffalo in Sun Prairie Reserve, Montana in conjunction with The American Prairie Reserve

Sample Publications

- A. J. Savas, V. Srivastava, and N. E. Leonard, "On distributed linear filtering with noisy communication," Proceedings of the American Control Conference, Seattle, WA, 2017
- K. Fitch and N. E. Leonard, "Joint centrality distinguishes optimal leaders in noisy networks", IEEE Transactions on Control of Network Systems, 3(4): 366-378. 2016
- K. E. Fitch and N.E. Leonard, "Joint Centrality Distinguishes Optimal Leaders in Noisy Networks," IEEE Transactions on Control of Network Systems, to appear 2015
- V. Srivastava and N. E. Leonard, "On First Passage Time Problems in Collective Decision-making with Heterogeneous Agents," American Control Conference, 2015
- I. Poulakakis, G. F. Young, L. Scardovi, and N. E. Leonard, "Information Centrality and Ordering of Nodes for Accuracy in Noisy Decision-making Networks," IEEE Transactions on Automatic Control, to appear March 2016
- M. M. Vasconcelos and N. C. Martins, "A Survey on Remote Estimation Problems," Principles of Cyber-Physical Systems: An Interdisciplinary Approach edited by S. Roy and S. Das, Cambridge University Press, to appear
- S. Park and N. C. Martins, "Individually Optimal Solutions to a Remote State Estimation Problem with Communication Costs," IEEE Conference on Decision and Control, 2014
- S. Park and N. C. Martins, "Design of LTI Observers for State Omniscience," IEEE Transactions on Automatic Control, Vol. 62, No.2, 2017, Pages: 561-576
- S. Park, "Distributed Estimation and Stability of Evolutionary Game Dynamics with Applications to Study of Animal Motions," PhD Dissertation, U. of Maryland, 2015

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