

Simulating Representational Communication in Vervet Monkeys using Agent-Based Simulation

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1. Proposal Summary

Communication within any species is very crucial for its survival. One of the primitive forms of communication featuring mere alarm calls is claimed to aid in the survival of vervet monkeys (*Cercopithecus aethiops*). There have been attempts to document vervets' behavior in the wild (Seyfarth, Cheney, & Marler, 1980) to prove the significance of alarm calls in their survival. And this project aims to consolidate this claim using agent-based simulation.

2. Background & Project Description

This is the continuation of last year's (2021) Google Summer of Code project for Red Hen Labs under primary mentorship from Prof. Francis Steen & Maria Hedblom.



Google Summer of Code 2021 @ Red Hen Labs

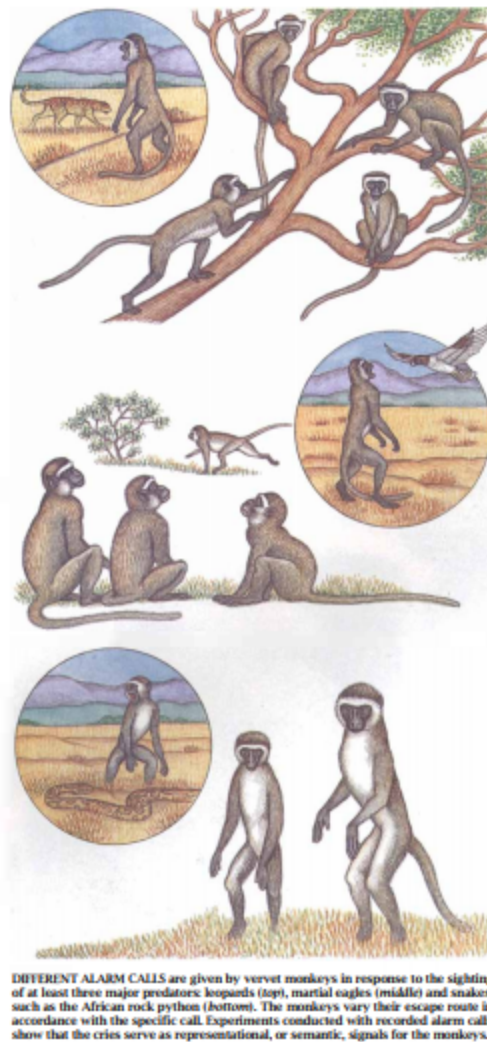


Image 1: Scheme of Vervet Alarm Calls

The project is an attempt to simulate an ecological setup consisting of vervet monkeys and their predators. The ideas for this are inspired by the work [*Vervet monkey alarm calls: Semantic communication in a free-ranging primate*](#) by Seyfarth, Cheney, & Marler, 1980. One of the main goals of the simulation is to efficiently model representational communication through an agent-based model and show how the differential meaning of vervet's alarm calls is helping in their survival. Although the simulation is tweakable to accommodate any kind of predator-prey agent-based modeling, for this project we have focused on semantic communication between vervet monkeys and their predators.

Vervets use distinct alarm calls for three types of predators: leopards, snakes, and hawks. While there is no location in the vervets' habitat where they can seek adequate shelter from all three predator types, they seek out bushes to conceal themselves from hawks, trees to escape from leopards, and stoney ground to stay safe from snakes. Please look at Image 1 for a pictorial representation of alarm calls.

3. Current Status of Simulation Developed

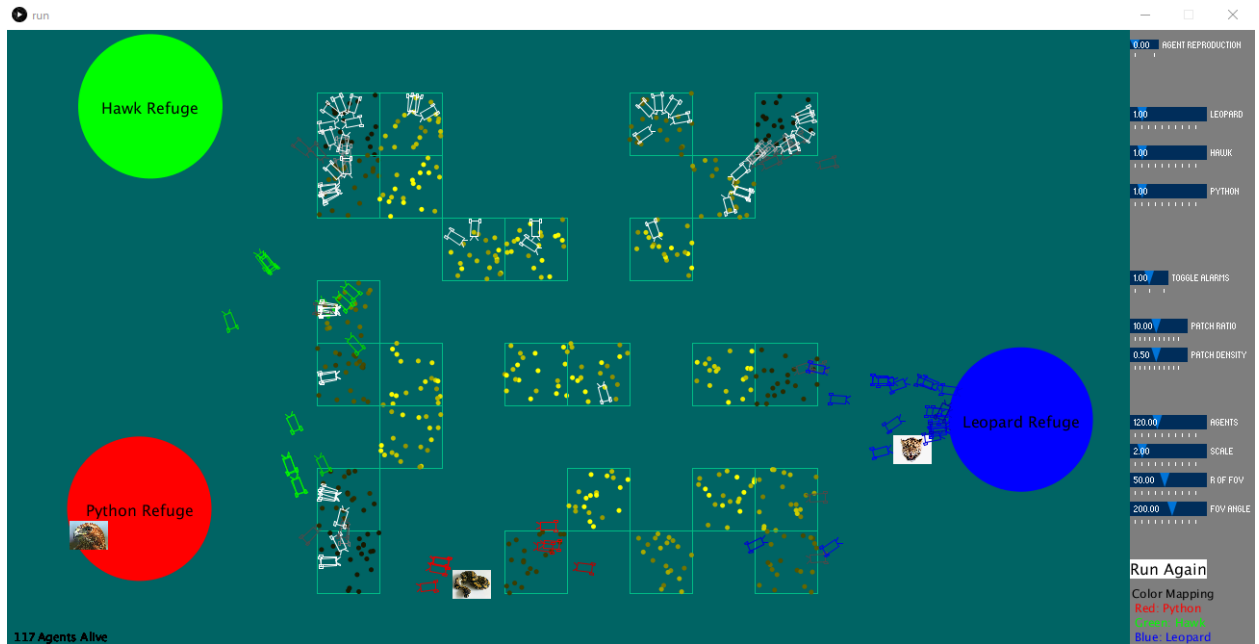


Image 2: The Simulation Interface with UI Control on the Right

I have developed a GUI consisting of the simulation rendering area as well as a side-by-side UI control as shown in Image 2. The floating image tiles represent various predators moving randomly. The agents/vervets/preys are represented by a colored outline corresponding to the type of predator fear and foraging. The yellow dots in each block represents food resources where the vervets move to forage.

Apart from rendering simulation output, the project also takes care of writing output CSV files containing simulation data that can be analyzed to come up with plausible inferences.

4. Goal & Objectives for Further Development

At the end of GSoC'21, even though we got some really encouraging preliminary results to support our hypothesis that alarm calls do help in vervet's survival, there remain many impending tweaks in the simulation itself to make it more realistic.

After we are done with the required tweaks and are satisfied with the simulation process and flow, the next big thing would be to systematically run the simulation with different parameter states and save corresponding data to be eventually analyzed to draw appropriate inferences. The goal here would be to do a differential analysis of simulation states and compare them with the actual data that are documented in the literature.

If time permits (or if my mentors and organization wish to extend this project to a 22-week project), I would aim to make this whole simulation more generalized to accommodate some more predator-prey ecosystems and analyze their resultant data too.

5. Minimum Deliverables

I am planning to have the following milestones to be necessarily met during this project duration, although I am very much open to any alternative plans which my mentor or organization feels would be more beneficial. If such a case arises, it is to be planned during the community bonding period and the first week of the project period.

- Further tweaks to be done in the simulation: mentioned at the end of my GSoC'21 final project [report](#) and after further discussion with mentors given the present state of the simulation.
- Data Collection with different parameter states: for example running the simulation with and without alarm call feature or varying ratio of prey & predators or varying food resource availability etc.
- Analyzing corresponding acquired data to draw conclusions in the above-mentioned parameter states.

6. Tentative Timeline

6.1. Community Bonding Period & Week 1

- Prepare a plan of action for the entire GSoC period.
- Discuss the current state of simulation with mentors and brainstorm over possible tweaks.
- Start a blog page.

6.2. Week 2-5:

- Write code to implement the proposed tweaks.
- Update weekly progress on the blog page.
- Discuss all parameter states to be tweaked for which the data is to be collected.
- Write code to save corresponding data.

6.3. Week 6-9:

- Run the simulation with different parameter states to save corresponding data.
- Analyze the data to draw appropriate inferences from the simulation.

6.4. Week 10-12:

- Continue the work if not finished yet.
- Write detailed documentation for this software simulation.
- Write a manuscript for the project to publish results.
- Go ahead with generalizing the simulation for other predator-prey ecosystems as well if the above goals are met already.

7. References

- Dwight and Francis Steen (2008): “Reducing Uncertainty in Costly Information Gathering: An Agent-Based Model of Vervet Monkey Warning Cries”, a simulation created in the UCLA Human Complex Systems Program
- Seyfarth, R.M.; D.L Cheney; Peter Marler (1980). "Vervet Monkey Alarm Calls: Semantic communication in a Free-Ranging Primate". *Animal Behaviour*. 28 (4): 1070–1094. doi:[10.1016/S0003-3472\(80\)80097-2](https://doi.org/10.1016/S0003-3472(80)80097-2)
- The GSoC’21 Project Archive for Red Hen Labs:
<https://summerofcode.withgoogle.com/archive/2021/projects/6188011817009152>
- Final Project Report of GSoC’21 for Red Hen Labs:
<https://ankiitgupta7.medium.com/final-project-report-gsoc21-at-red-hen-labs-d88a6d4f66ad>
- Weekly Progress Report of GSoC’21 for Red Hen Labs:
<https://ankiitgupta7.medium.com/blog-gsoc21-at-red-hen-labs-16f9b8ae59d1>

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EDUCATION

Graduate Institute of Mind, Brain, and Consciousness, Taipei Medical University, Taiwan

Master of Science in Cognitive Neuroscience

Sept'21 - Present

Research Assistant at *Brain & Cognition Lab* - PI: Philip Tseng

Indian Institute of Technology (IIT) Kharagpur

July'16 - May'21

Graduated with Bachelor and Master of Technology (Dual Degree)

GPA: 7.52/10

Batch of 2021, Mining Engineering

WORK EXPERIENCES / INTERNSHIPS

Google Summer of Code, Red Hen Labs

[Report]

Student Developer — Primary Mentor: *Prof. Francis Steen, Prof. Maria Hedblom* May'21 - Aug'21

- Created an **agent-based model** simulating predator-prey interactions within an ecological setup
- **Modeled** representational communication in preys using differential cues helping in their survival
- Designed & developed GUI consisting of **simulation** rendering area as well as a side-by-side UI control
- Programmed & validated these models **analysing simulation data** showing improved prey survival
- Made a **standalone simulation software** of the simulation executable on Windows / macOS / Linux
- Click [here](#) for Project Github Page, [here](#) for Software download link, & [here](#) to see project proposal

Harvard University, Evolutionary Psychology Lab, Cambridge, MA, USA

[Report]

Research Intern — PI: *Prof. Max Krasnow*

May'20 - Aug'20

- Worked on an **agent-based modelling project** probing why human reciprocity is selected by evolution
- Made algorithmic improvements, removed redundancies **reducing simulation run time** significantly
- Introduced more GUI features to make a user friendly & interactive **agent-based simulation software**

Indian Institute of Science [IISc], Movement Control Lab, Bengaluru, India

[Report]

Research Intern — PI: *Prof. Aditya Murthy*

Dec'19 - Jan'20

- Integrated National Instruments Data Acquisition System with a **MATLAB** based **software toolbox**
- Programmed an experiment monitoring human motor control & perceptions using above assemblage

Graduate Institute of Mind, Brain & Consciousness, Taipei, Taiwan

[Report]

Research Intern — PI: *Prof. Philip Tseng, Brain & Cognition Lab*

May'19 - July'19

- Programmed a perception-based **web-experiment**, integrated it with **Amazon Mechanical Turk**
- Hosted it on a **website** recording and **saving subject data**, also analyzed resulting experiment data
- Reviewed literature for the above mentioned experiment, also assisting my PI in other projects

Naxap Technology Private Limited, New Delhi, India

[Report]

Software Intern — Guide: *Vineet Kumar*

May'18 - July'18

- Improved an **API mining peer-to-peer networks** for Piracy Data using **Node.js** libraries
- Used **Data Scraping**, **Data Caching**, and **OOP** in making crucial changes to the API

Last Updated on April 18, 2022

ACADEMIC ACHIEVEMENTS / SCHOLARSHIPS

Ministry of Education (MOE) **Taiwan Scholarship** – awarded for the entire duration of the Master's degree • Government of India **MHRD Master's scholarship** (2020-2021) • **2019 TEEP@AsiaPlus Scholarship** for summer internship in Taiwan • Bronze medalist in '**Open IIT Data Analytics Competition**', 2017 • **Merit Cum Mean Scholarship** under National Scheme of Govt. of India

PROJECTS

Simulating Autonomous Intelligent Systems with Braitenberg Vehicles [Report]
Masters' Thesis Project — Guide: Prof. Debashish Chakravarty, Bradly Alicea July'20 - May'21

- Used **Braitenberg Vehicle Model** in making an **agent-based simulation** to create a **system of intelligent autonomous vehicles** exhibiting **collective (swarm) intelligence** and embodied cognition
- Built a **virtual model** of a vehicle (agent), with the body, sensors, effectors, & internal neural wiring
- Designed & developed a **GUI** consisting of simulation rendering area as well as a side-by-side UI control

Electroencephalography & its Data Processing using EEGLAB [Report]
Bachelor Thesis Project — Guide: Prof. Rajlakshmi Guha July'19 - April'20

- Worked on a **MATLAB toolbox** to analyse EEG data samples of Relational Reasoning Tasks
- Reviewed literature and **proposed experiments** related to human cognitive information processing

PUBLICATIONS / CONFERENCES

Dvoretzskii, S., Gong, Z., **Gupta, A.**, Parent, J., and Alicea, B. (2020). 'Braitenberg Vehicles as Developmental Neurosimulation'. *arXiv, Neurons and Cognition* ([2003.07689](#)).

Alicea, B., Dvoretzskii, S., Felder S., Gong, Z., **Gupta, A.**, and Parent, J. (2020, July, 13-18). 'Developmental Embodied Agents as Meta-brain Models'. [Presentation/Talk] *The 2020 Conference on Artificial Life*. Montréal, Canada. [[link](#)]

Alicea, B., Dvoretzskii, S., Gong, Z., Parent, J., and **Gupta, A.** (2020, March, 20). 'Developmental Braitenberg Vehicles'. [Presentation/Talk] *OHBM Equinox Twitter Conference 2020*. [[link](#)]

COURSEWORK INFORMATION

Programming & Data Structure • Probability & Statistics • Image Processing • General Psychology
Cognitive Information Processing • Quantitative Decision Making • AI: Foundations & Applications
ML: Foundations & Applications • Neuronal Coding of Sensory Information • Psychology of Learning
Basic Electronics • Economics • Science & Humanism • Introduction to Algorithms & Analysis [NPTEL]

TECHNICAL STRENGTHS

Programming Languages & Tools: Java • Python • C • C++ • JavaScript • Ruby • MATLAB
Ruby on Rails • Java AWT • Processing.py • Turtle • Numpy • Scikit-learn • Pandas • p5.js • EEGLAB
MonkeyLogic • Amazon Mechanical Turk • Tableau • Git • Node.js • ReactJS • LaTeX • HTML
Other Skills: Agent-Based Simulation & Modelling • Computational Modelling • GUI Development
• Machine Learning • Data Structures & Algorithms • Web Scraping • Web Development

EXTRA-CURRICULAR ACTIVITIES

- Writer at [Millennial Poets Publications](#), published two poems named *Chaotic Reality* & *I Wish*
- Writer at a publication named [An Idea](#), published an article titled *The Pandemic*
- Former Student Volunteer at NSS, India • Former Reporter at The Scholars' Avenue, IIT Kharagpur