A Project Compendium

An assortment of works

Michael Kummer

Contents

1 Graduate Research

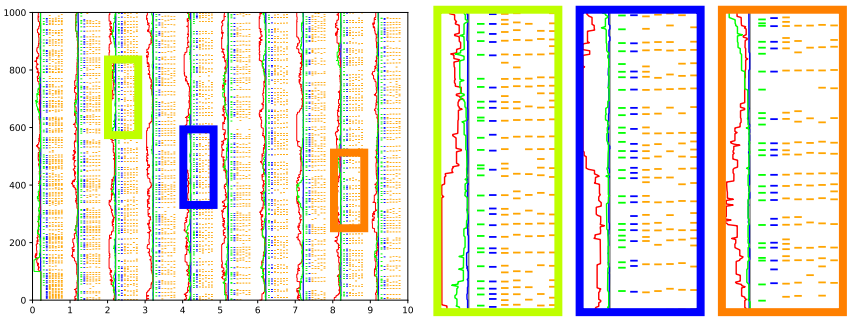
1.1 Neuron Theory and Simulations

1.1.1 Spike-Triggered Descent

I developed a technique in python to classify the function a network of neurons compute with respect to a signal. Here's the abstract, an equation, and a figure from our paper.

The characterization of neural responses to sensory stimuli is a central problem in neuroscience. Spike-triggered average (STA), an influential technique, has been used to extract optimal linear kernels in a variety of animal subjects. However, when the model assumptions are not met, it can lead to misleading and imprecise results. We introduce a technique, called spike-triggered descent (STD), which can be used alone or in conjunction with STA to increase precision and yield success in scenarios where STA fails. STD works by simulating a model neuron that learns to reproduce the observed spike train. Learning is achieved via parameter optimization that relies on a metric induced on the space of spike trains modeled as a novel inner product space. This technique can precisely learn higher order kernels using limited data. Kernels extracted from a *Locusta migratoria* tympanal nerve dataset demonstrate the strength of this approach.

$$\Delta t_l^O = \frac{\sum \frac{\partial \eta}{\partial t}\Big|_{t_l^O - t_k^O} \Delta t_k^O - \sum \frac{\partial \eta}{\partial \mu}\Big|_{t_l^O - t_k^O} \Delta\mu_k - \Delta K_0 - \sum_{n=1}^{N} \int \cdots \int_n (\sum B_i(\tau_{1\to n})\Delta\beta_{i,l}) \prod_{j=1}^{n} x(t_l^O - \tau_j) d\tau_j}{\sum_{n=1}^{N} \int \cdots \int_n K(\tau_{1\to n};\beta_{i,l}) \left[\sum_{m=1}^{n} \left[\prod_{j\neq m}^{n} x(t_l^O - \tau_j)\right] \frac{\partial x}{\partial t}\Big|_{t_l^O - \tau_m}\right] \prod_{j=1}^{n} d\tau_j + \sum \frac{\partial \eta}{\partial t}\Big|_{t_l^O - t_k^O}} \quad (1)$$

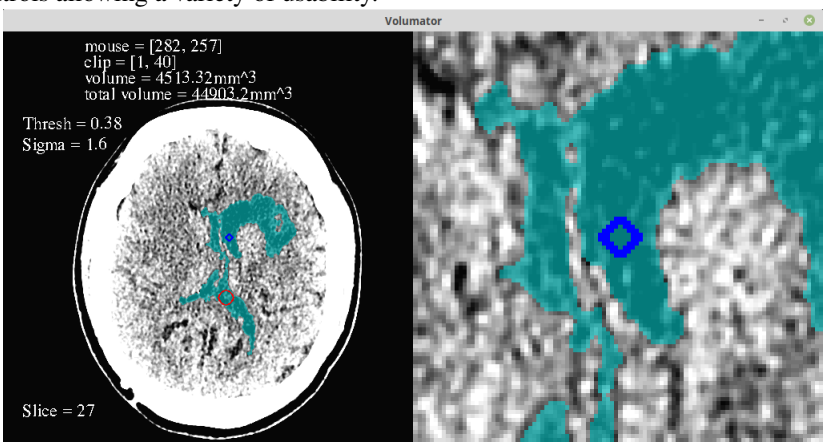


a **b**

1.2 Medical Imaging

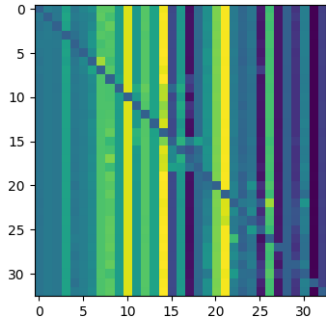
I created an interactive volume calculation tool for neurosurgeons to diagnose hydrocephalus and create a medical atlas. I implemented this in python with pygame, numpy, scipy, and skimage. There are a variety of features and multiple configurable methods of classification. The following image shows an example of the application automatically measuring the volume of a ventricle region with one click (red circle). The cursor

(blue circle) is show along with a zoomed in area around it. There are 25 separate controls allowing a variety of usability.



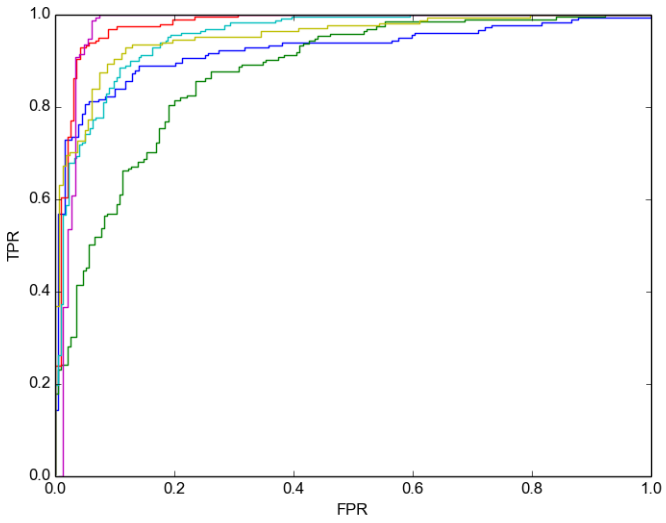
1.3 Computational Genetics

Worked with a computational genetics lab to increase the training accuracy on the assembly of rAAV codon mutations. Assisted in improving the classification accuracy from $\sim 75\%$ to $\sim 99.5\%$. Using a mixture of python and bash scripting I created many graphs like the following to explore the mutation space.



1.4 Landmine Detection

I worked on classifying underground objects with recorded from ground penetrating radar. The aim of this project was to explore the effectiveness of using Deep Belief Networks to detect landmines. We used a mixture of python, theano, pytorch, keras, scikit learn, and octave. The following ROC curve shows the true and false positive rates for various objects.



2 Undergraduate Research

2.1 Optics Lab

Machined optics equipment and set up equipment for analysis with a multi omnidirectional spectrometer (MONSTR) to conduct fourier transform infrared spectroscopy (FTIR).

2.2 Nanotech Lab

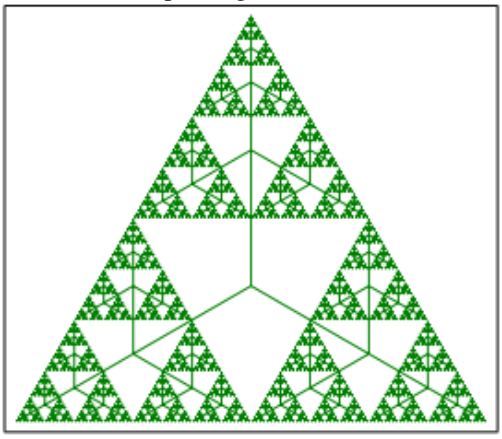
Conducted carbon vapor deposition experiments to synthesize graphene nanoribbons and boron doped carbon nanotubes. Characterized these materials with an assortment of SEM, TEM, PPMS, XRD, EDX, and Raman.

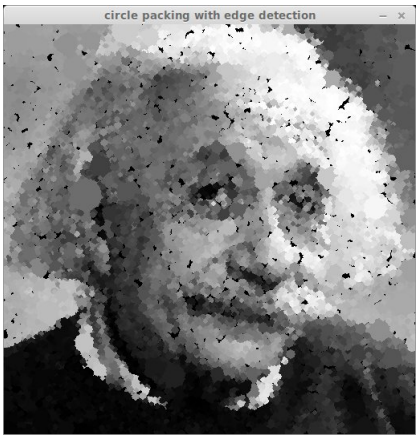
2.3 Computational Biophysics Lab

I worked on a project to simulate collagen elasticity from the ground up using pdb files with unix commands and Gromacs in order to match experimental results.

3 Teaching Assistant Experience

Created assignments, lead discussion groups, graded (exams, quizzes, projects), and held office hours for the following: Analysis of Algorithms, 2x Penetration Testing, Distributed Operating Systems, 2x Programming Fundamentals 2, Applications of Discrete Structures, Introduction to Digital Arts and Sciences, 2x Senior Project, Software Engineering. Here are some example assignments that I've created for students: fractals, breakout (game), rocket lab. And here are some animations: circle packing, circle rendering. And, here's a neat tree approach to creating the Sierpinski Gasket and result from the circle packing demo.





4 Volunteering Experience

Besides the Perfect Environs project:

1. I created problems for SwampCTF.
2. I modernized a blacksmithing website.
3. I helped build stands for GWIZ Science Museum.
4. I created an exhibit for TEDx Sarasota.

4.1 Perfect Environs

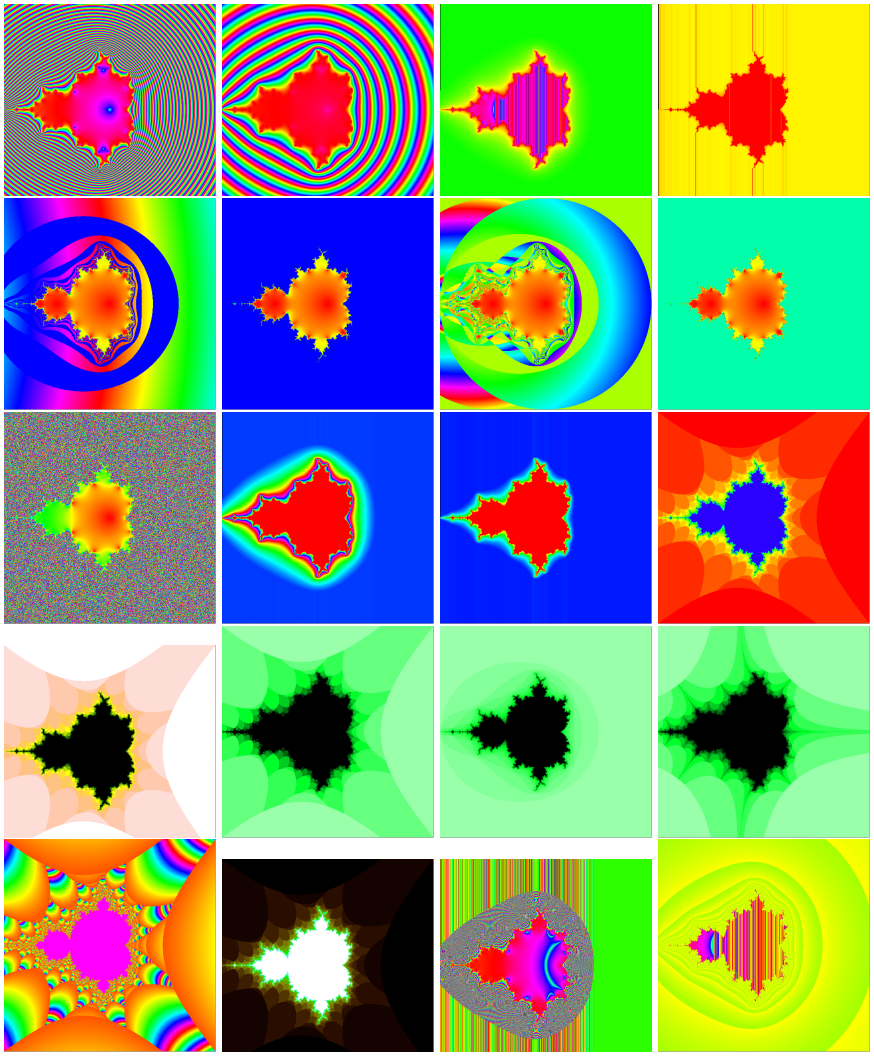
Created a GIS native plant mapping tool for Florida native plant experts using Google Maps/FT, JS, KML, LAMP.

1. Found the data on an archive site.
2. Converted it to the appropriate format to upload to Maps/FT
3. Linked the plant associations and climate regions to custom native plant pages populated with a MySQL database.
4. Created these pages in a landscaping focused format, connecting them to wikipedia and plant image/nursery sites (FANN/FNPS).
5. Created drawing tools for adding microhabitats of arbitrary multigon complexity.
6. Added mediawiki and forum with FluxBB.

I worked on this with a native plant expert who has recently passed away. Here's a photo of him with the application we built together. We unveiled the website that hosted an interactive version of this map at a conference in Plant City in 2013. It was the keynote speech. I still remembered how the audience continued audibly gasping as he introduced the new features that I had developed.

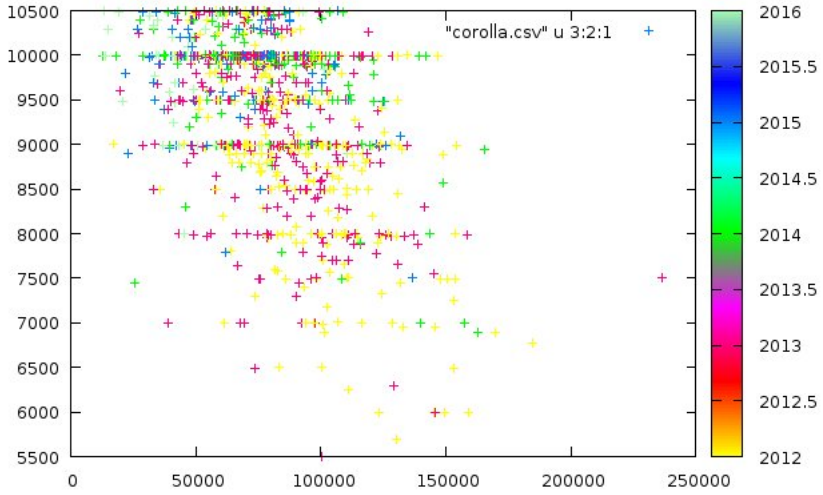
5 Projects

5.1 Mandelbrot



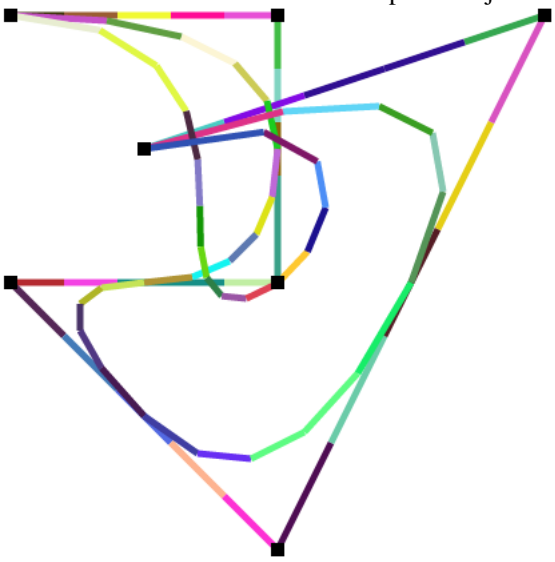
5.2 Car Shopping

I created a webscraper when I was looking to buy a new car so that I could get a better feel on what a reasonable price was. I made this plot of corrolla prices vs mileage with javascript and gnuplot. The color denotes the year.

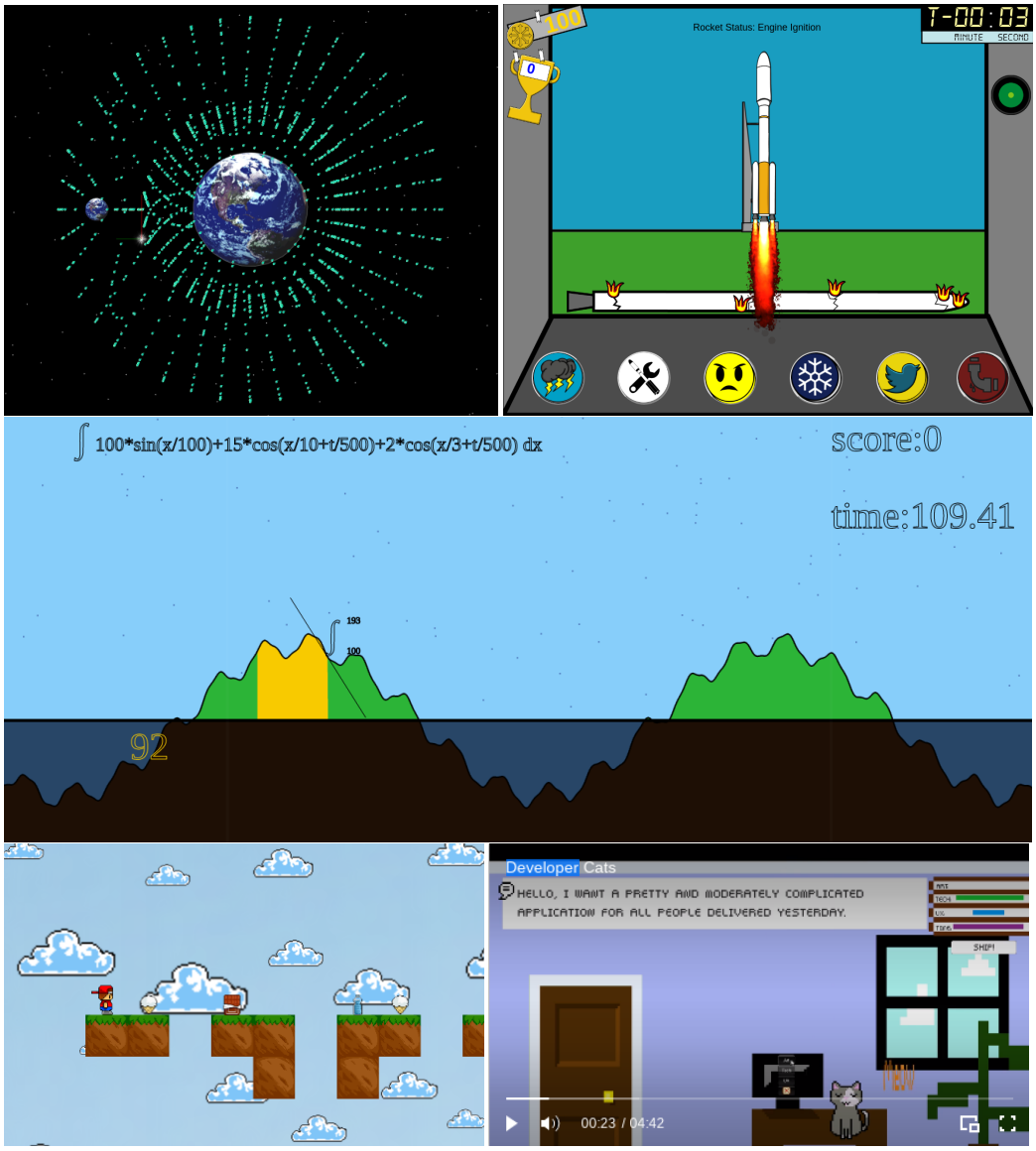


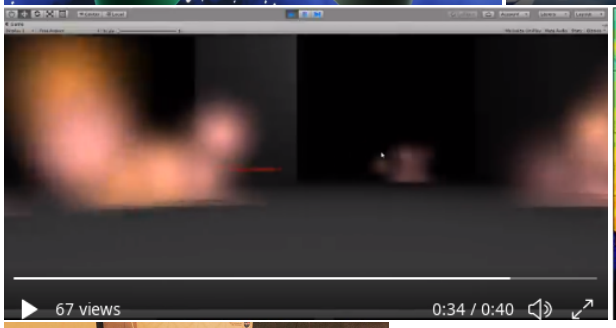
5.3 B-Splines

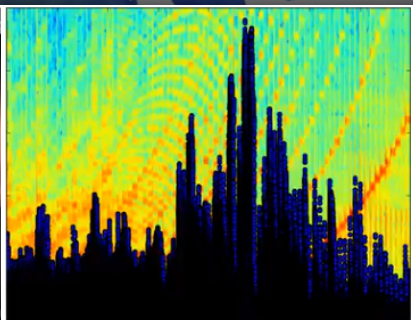
Implemented a tessellated version of b-splines in javascript.

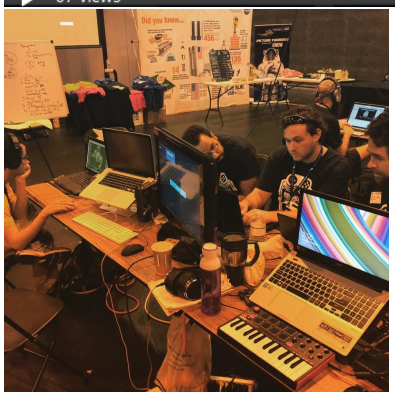


5.4 Game Jams

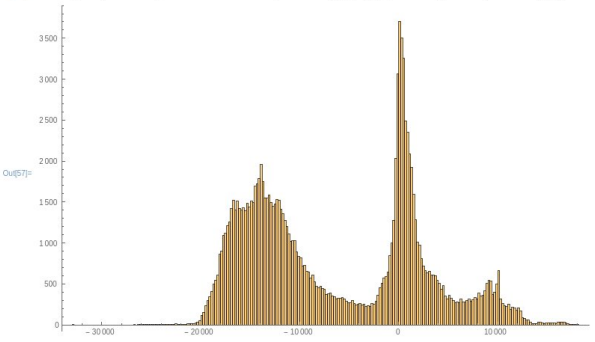

Rocket Status: Engine Ignition
T-00:03
MINUTE
SECOND
100
0
∫ 100*sin(x/100)+15*cos(x/10+t/500)+2*cos(x/3+t/500) dx
score:0
time:109.41
193
100
92
Developer Cats
HELLO, I WANT A PRETTY AND MODERATELY COMPLICATED APPLICATION FOR ALL PEOPLE DELIVERED YESTERDAY.
SHIP!
00:23 / 04:42



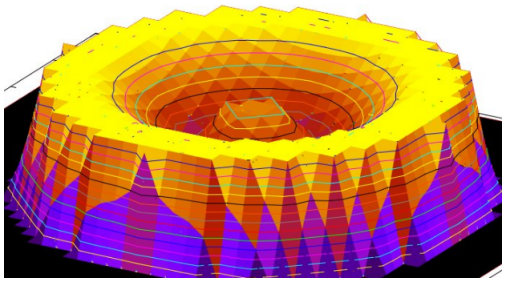


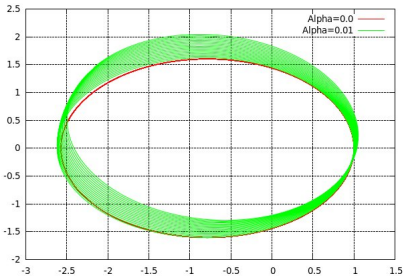


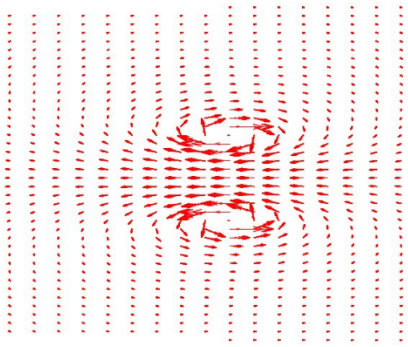
```
In[57]:= Histogram[Flatten[GeoElevationData[GeoDisk[{0, 0}, Quantity[10000, "Miles"]]]], 2000]
```

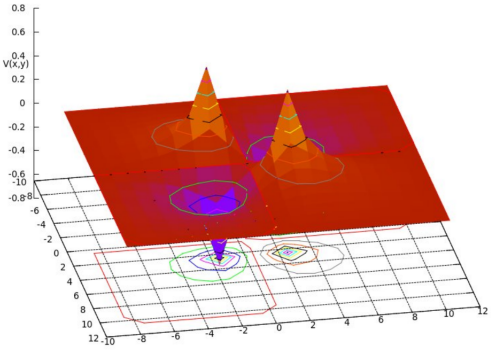


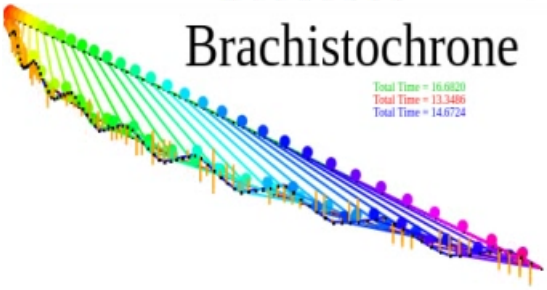
5.5 Computational Physics

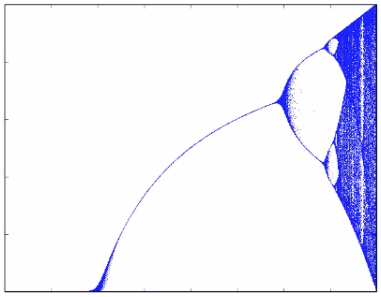


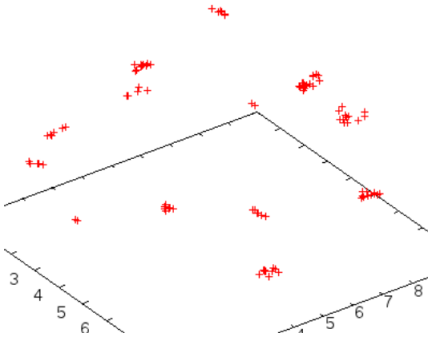


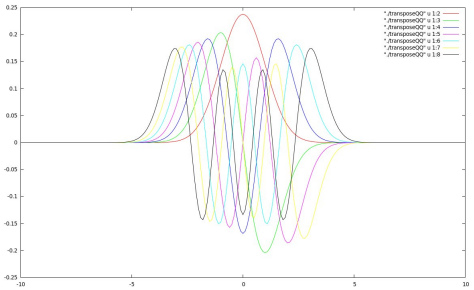




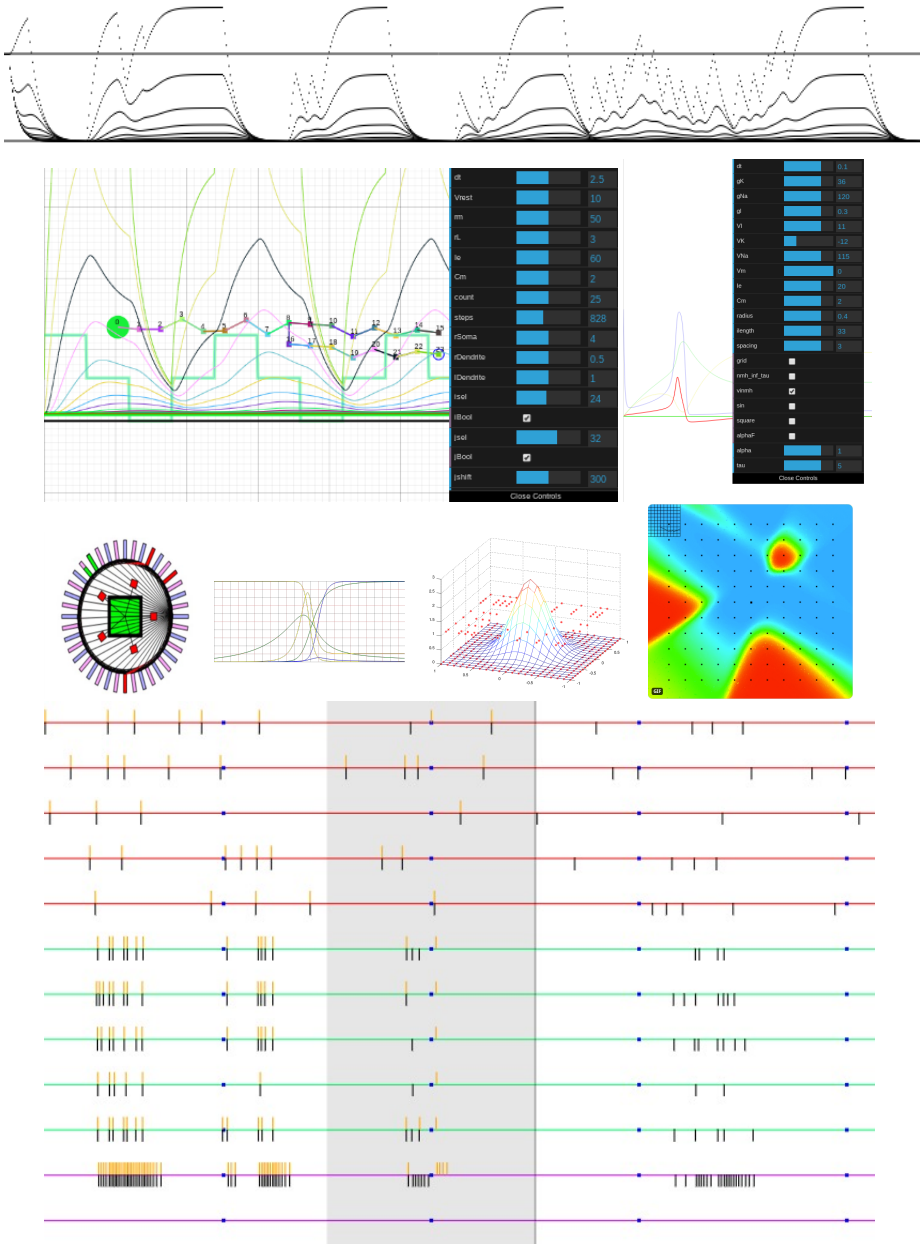




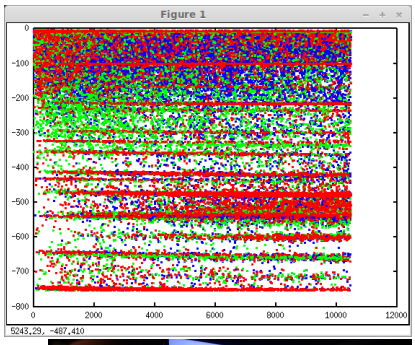


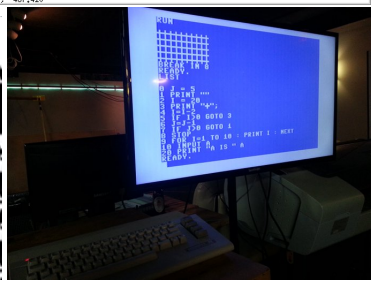


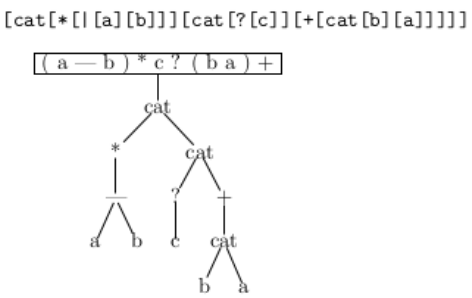
5.6 Neuron Simulations



5.7 Random







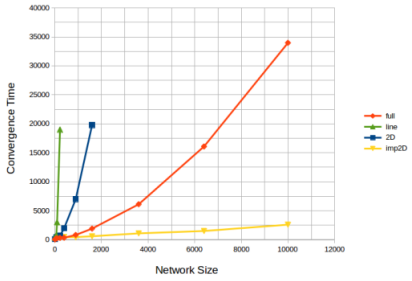


Figure 8: PushSum Sum, discrepancy = 0.0001