Order and Chaos

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Contents

Introduction

The course is based on large Human Experiences that can form the basis for **Model-based** Thinking.

Each of the following Section Titles is an *Abstract Noun* that represents one such **Human Experience**. The understanding of each Human Experience is intended to lead to a Model, in the manner of Charlie Munger and Scott E. Page. The Human Experience + Model will be, in each case, motivated by contemplating a well known Story, or a Drama, and a Painting. The Models may resemble a Thought Experiment, or a Diagram, or a simple Procedure or Math Formula, or a piece of Computer Code. The Models are intended to provide directions for artistic and design endeavours.

The Models will be understood, internalized, fitted in with what we already know, and generalized to new applications. This will done with the help of activities based on games, videos, art-related activities, open source software tools, field experiments, field visits, additional readings, writings and discussions.

Complexity

Other Terms: `Emergence / Coherence / Aggregation / Unison / Self Organization`

- Mitchell Resnick: Beyond the Centralized Mindset
- Steven Johnson: "Emergence": Chapter..TBD

- Motivate "individual, simple rules" that lead to "emergence of patterns" as a central idea

- Motivate Philip Anderson's idea "More is Different" PDF

- Simple and not so simple Phenomena

    - Mexican Wave and Clapping Patterns

    - Arpita Baypeyi's Idea: "Repetitive Patterns in Dance - Kathak"

    - Kannada Proverb "Gumpinalli Govinda"

    - Douglas Hofstadter, "Ant Fugue" in his 1979 book

    - Use the "Rain" video (though that does have Central Control...). Can be set up to be an emergent exercise:

        * by setting up the three actions (snapping fingers; slapping the knees; Jumping)

        * Rules would be to decide whether or not go to the next action in the sequence, spending 15-20 seconds in each

        * Imitate your nearest neighbour

Feedback

- Understand Basics of Systems, Simulations and Feedback Loops

    - Negative feedback and Barkhausen Criterion
    - Positive Feedback and Runaway

        * Loops in networks cause positive feedback. Example of brain neuron **loops** from Steven Johnson's book **Emergence** (page 133)

- Nicky Case's website Loopy : a tool for thinking in systems
- Modelling with STELLA Systems Modelling
- A Tale of two Dirks:

    - Dirk Brockman: Research in Complex Systems
    - Dirk Helbing: Pedestrians and Simple Rules

- Complexity Explorables
- NetLogo and ABM Model exploration
- Skye Bender-deMoll's tutorial on Temporal Phenomena in Networks using Statnet

    - Somewhat long tutorial so need time to execute this idea.
    - Need to club this along with the idea of *"Positive Feedback being a result of preferential attachment and causing Hubs and Spokes in networks"*

Repetition

- Growth / Repetition as a "natural" operation
- Extract from Dawkins **The Selfish Gene**. Replicators / Reverberators / Resonators
- Extract from D'Arcy Wentworth Thompson **On Growth and Form**
- NetLogo Examples
- Introduction to L - Systems
- Interpretation of Kolam as L - Systems
- @3blue1brown: With recorded COVID-19 cases (outside China) so eerily matching an exponential, a primer on exponential/logistic growth.

Chaos Theory

- Steven Strogatz's book, **Nonlinear Dynamics and Chaos** - Iterated Function Systems IFS
- Chaos from **Deterministic** Iterations
- Frame - Golubitsky: Symmetry on Average
- Feigenbaum and Cobweb Diagrams
- Smale and the Art of mixing Atta; Chickpete Experience of NavaDhaanya
- Devaney, First Order Differential Equations and Phase Plane Plots, Poles and Zeroes
- Phase Locked Loops
- Activity:
    - Time Series Analysis and the Stock Market??
    - Weather Data Analysis??

Fractals

- Complex Algebra, 2D plane
- Geometric interpretation of Canonical Operations - Translation, Reflections, Glide Reflections, Rotations
- Benoit Mandelbrot's TED Talk on Roughness
- Activity:
    - Fractals : Julia and Mandelbrot using XaOs or equivalent
    - Fractal text analysis of James Joyce's Ulysses
    - Fractal Antennas by Phil Felber

References

- SantaFe Institute Complexity Explorer
- Yale Fractals Course
- Gary William Flake - **The Computational Beauty of Nature**

Symmetry

- Elizabeth Barrett Browning "Sonnets from the Portuguese" and William Blake "Tiger,Tiger"
- Activity: Internet Anagram Server
- 1D and 2D Symmetry; Dimensions
- Motivate "Canonical Movements" and Operations (Translation / Rotation / Reflection / Glide Reflection)
- Friezes / Lattices / Wallpapers / Kolams / Sona Art / Fibonacci Kolams / Ethno-mathematics
- Saty Raghavachary

Orientation

- To be Written up
- Activity: Frozen Light: https://imaginary.org/program/frozenlight
    - links to Paulus Gerdes "Light + Mirrors" method of creating Sona patterns
    - Girih Art from Isfahan: https://3dwarehouse.sketchup.com/search/?q=girih&searchTab=model
- Questions:
- Can this be lined to Peano's "Monster Curves"?
    - By creating smaller and smaller grids, (repletion / scale..) can we create Koch snowflake like drawings from Sona art? (Gerdes, page 22 - 2)
- Use R to do some of this:
    - Deldir for Mandalas

Modularity

- To be written up

Proximity

- Kandinsky Math Artist: Examine his artistic credo and motivate
- Motivate the idea of "Proximities" and Metrics to measure Proximity
    - Manhattan Distance; Euclidean Distance ; Great Circle Distance; Hamming Distance as examples of distance metrics
- Emotional and Psychological effect of Proximity
- Motivation for Voronoi Diagrams
- John Snow and the epidemic in Soho
    - Analysis using Voronoi diagrams in R (R Package: deldir)
- Florence Nightingale and her Coxcomb chart and how she could have used a Voronoi diagram
- Multi-dimensional Distances:
    - **Support Vector Machines**:
    - Andriy Burkov Machine Learning in 100 Pages
    - [Math for Machine Learning] (https://mml-book.github.io/)
    - Alexandre Kowalcszyk's SVM Tutorial
    - Sorting Veggies based on touch and crouching at table level. Then stand up and use eyes. Motivate `kernel trick` from this exercise; tie up to TRIZ (Another Dimension) + Childhood story of Hide and Seek in the attic.
    - Projection as **shadow** to explain distance of support vectors from separation hyperplane
- Classroom and Outdoor Assignments:
    - Using Proximity and Machine Learning together:
        * Use Wekinator
        * Wekinator Projects at Maker.Pro
    - **"Painting with Distance"**
        * Exercises with Strava
        * Exercises with Google Literature Trips
        * Voronoi Self-Portrait using GeoGebra or R + deldir following Fronkenstin
        * Kolams on a Map: City centres as pulli-s:
        * Use the work of Darrah Chavey and Madhuri Bapat (Bridges Conference)
        * Kolam based story illustration

Connectivity

- Set up Barabasi's cocktail party experiment in class with chocolate instead of wine.

    - Coin tossing to set up meetings; (2 heads to talk => p=0.25 etc.); 3 minutes per meeting
    - Also have one handy juicy rumour to spread.
    - How long does it take for each person to have had chocolate? Average of one meeting...
    - Discussion on how this is an *Erdos-Renyi model*, since pure randomness was the basis for any encounter being fruitful

- Vimeo Video Six Degrees of Separation
- Introduction to Networks and Graphs Dmitry Zinoviev
- Live coding in R with the tidygraph package

    - Structure (Node/ Link / Directed / Undirected /....)
    - Dynamic Processes:

        * Random Networks - Erdos-Renyi model
        * Small World: Watts - Strogatz model
        * Hubs and Power Laws - Barabasi - Albert model
        * Preferential Attachment (Rich get Richer)
        * Matthew Effect from the Bible

- Readings from : Networks, Market and Crowds - Easely and Kleinberg
- Activity:

    - Check out the Kevin Bacon number of your favourite actor
    - Find a Keven Bacon in Srishti Foundation Studies Programme

        * Collect Data from across college, import and plot, analyze and comment
        * Use this online tool at databasic.io Connect the Dots or **better still** at GraphCommons
        * Use R and tidygraph
        * ~~Use this online tool at Network Repository~~ Too Complex for now.

- Import any of the Sample Network Data Sets that make sense

    - Take your favourite Literary Work / TV Serial / Movie and create a Network Database for it.

        * Visualize it either with or without tech tools From Teach Engineering, this Activity
        * Can also use Graph Comics !

- Network Science Ideas:

    - Use NetLogo to Examine and Understand some Network Science Models :

        * Friendship Paradox, Kevin Bacon Number
        * Random Networks, Clustering, Small Worlds, Preferential Attachment, Scale-Free networks
        * Mathew Effect from Bible
        * Euler Walk, Bridges of Konigsberg
        * Hamiltonian Walk and Journeyman Problem
        * Bidding Market Game in NetLogo as a view to **Stock Market** workings

    - Real World Examples:

        * CityLab Blog: How Cars Divide America
        * Disease Propagation Game
        * Disease Propagation and Epidemics and Percolation Theory : Kevin Smiler - Going Critical - Models for Disease Diffusion
        * "“How to Win Friends and Influence People”: Diffusion Simulation Game and PDF
        * Read one Stock Market Crash / Bubble Story TBD
        * Read and Analyze Frigyes Karinthy's Short Story *Chains*
        * Cambridge Analytics story? TBD

- Activities:

- Try to replicate Steve Millgram's experiment to motivate Small World
- We are Fine TBD
- Analyze BMTC routes in R using DiagrammeR : Data Source
- Tristan Mahr - Secret Santa is a graph traversal problem
- Use Arduino / Makey Makey + Phone BT to create a "connected set of streets" in class
- Network Theory in Art : Make Paper/ Rangoli / Thread Kolams and Sona Art using a printout of a Map as a background
- Use and analyse/depict one dataset from the Stanford Large Network Dataset Collection SNAP

- References
  - Albert-Laszlo Barabasi's book "Linked"
  - David Easley, "Networks, Crowds and Markets"
  - Robert A. Hanneman and Mark Riddle - "Introduction to social network methods"
  - Hiroki Sayama, "Introduction to the Modeling and Analysis of Complex Systems"
  - Dmitry Zinoviev's Little Network Science Lab
  - Networked Life by Michael Kearns: Online Video Version
  - Mark Newman: Networks
  - Marcia Ascher: Ethnomathematics
  - Paulus Gerdes: Lunda Geometry

- Visualization
  - Ognyanova, K. (2019) Network visualization with R and Tutorial PDF
  - Network Repository http://networkrepository.com/graphvis.php
  - Fun Stuff with Network Science
  - 60 Graph Visualization Libraries
  - Meeks, E., & Krishnan, M. (2013). An interactive introduction to network analysis and representation
  - Database for Social Networks in Movies http://www.moviegalaxies.com

Rationality

Human Behaviour and Game theory

- Alexander Dumas " The Three Musketeers" as a Manifestation of "Prisoner's Dilemma" (Chapter 5)
- Presh Talwalkar's article on the South West Airlines episode
- Public Behaviour and extract from V S Raghunathan's "Games Indians Play"
- Axelrod Experiment and Strategy
- Play Prisoner's Dilemma Game on Nicky Case Website Trust Game
- Schelling Segregation Experiment (Nick Case website)
- Hotelling's experiment from Presh Talwarkar's Book
- Schelling Points as an "Emergent Phenomenon" (Preface of Thomas Schelling's Book, example on Audience Seating)
  - Visit to local "urban ghetto"
  - Blockchain or Email + Timer based stock exchange:
    - random cheating, personal values and strategies

    - 4R (Reward, Risk, Regret, Repetition)

- Wishlist: Create Bitcoin economy in class using a captive Bitcoin installation

- Generative Adversarial Networks (GANs):
  - Use Game Theory in to create faces to be used in Illustration
  - Nvidia AI Playground: GANimal and GauGAN
  - The GAN Lab - The GAN Zoo

Sound

Fourier Series and Music Synthesis

- Wordsworth's "Solitary Reaper" and "Tower of Babel"
    - Motivate Music as common emotional language; PsychoAcoustics
    - Gallopin' Gertie Bridge: https://www.youtube.com/watch?v=j-zczJXSxnw
        * Vibration and Resonance, Idea of Acoustic Length / Natural Frequency
        * Example of Childhood Swing: How did Dad/Mom know when to push your swing?

- Activities:
    - Measure vibration frequencies from common objects and tabulate "Acoustic Length" of objects
    - Using Simple Network Graphs to construct Musical Scales
    - Arduino and Sound Projects TBD
    - Use Mozart's Random Music generator along with Makey-Makey to create movement and sound
    - Use R packages "seewave", "soundgen", "phontools" and "tuneR" to synthesise sound algorithmically in R

Music Theory Stuff

- Introduction to Sound Synthesis and Systems Theory
    - Complex Rotating Vectors, Symmetry and Fourier series
    - Decomposition and synthesis: Music
    - Ear as FFT analyser
    - **Eigen Functions** and how they are like an alphabet
    - Musical instruments and Timbre
    - http://andrewduncan.net/

SuperCollider and PureData Stuff

- Activity: SuperCollider for Algorithmic Sound Composition; SuperCollider Code Examples
- James Harkins Patterns in SuperCollider

Rhythm

- Music as synchronized and coordinated motion
    - Nathan D. Hesselink: Radiohead's "Pyramid Song": Ambiguity, Rhythm, and Participation and PDF and PDF Examples

Adaptation

To be written up
- John Holland
- Adaptive Equalizers?

Randomness

Probability, Frequentist and Bayes Estimation

- Hamlet "To be or not to be"
    - Motivate uncertainty, randomness, information gathering and experiments
    - Judea Pearl's "Ladder of Abstraction" (LOA): Observation; Association; Imagination.
    - LOA - Observe:
        * Plot of Traffic Data, Histograms
        * Means, Variances and Medians
        * Poisson Process

- Is Randomness good?
    - Randomness as "Fairness" : Sharing Mangoes during Childhood
    - Creating Randomness ; Randomness as a Tool
    - Experiment design: Blindness
    - MonteCarlo experiment to calculate pi
    - Generating Random Numbers as Modelling in Monte Carlo methods

Hypothesis Testing and Design of Experiments

- Observational and Interventional
- LOA - Associate:

    - College Survey:
        * Set up Hypothesis
        * Design Randomized Observational Sampling Experiment
        * No of Readings/Samples to get good Confidence Intervals
        * Standard Errors, CI
        * Motivate Allen Downey Stat Test

- LoA - Imagine: Counterfactuals with Facebook Prophet or Google CausalImpact

Bayesian Estimation

- Bayesian Estimation using Harry Potter
- David Robinson: Understanding empirical Bayes estimation (using baseball statistics) http: //varianceexplained.org/r/empirical_bayes_baseball/
- Rasmus Baath Bayesian Estimation in R
- tidybayes: Bayesian analysis + tidy data + geoms https://mjskay.github.io/tidybayes/
- Become a Bayesian master with bayestestR
- Predict which house of Hogwarts people will belong to, based on personality test (https: //fabiandablander.com/r/Bayes-Potter.html)

Estimation

Interpolation / Regression / Averaging

- Use Greek Chorus and the Sutradhar concept as an introduction to Interpolation and Regression:
- Legally Blonde: Greek Chorus in Popular Culture
- The Greek Chorus Explained
- Indian Drama and the Sutradhaar

- Motivate the idea of "Missing Data" and Interpolation
- *Robert Grant's website* : generate random dataset by painting it: http://www.robertgrantstats.co.uk/drawmydata.html
  - Use random data for regression/interpolation in Excel or in R or jamovi
- Continue with Regression, Learning, Estimation
- Link this to Support Vector Machines
- Wisdom of Crowds, Averaging
- Stephen Stigler: Seven Pillars of Statistical Wisdom

Universality

- How the same Model shows up in different places and domains

  1. Physics/ Urban Traffic: Tipping Points / Thresholds
  2. Networks: Power Laws; Clustering; Small Diameter; Navigation across a netwrk by individuals with only local knowledge i.e. with no idea of the complete picture of the network structure
  3.

References

1. General:

   - Francis Su, "Mathmatics for Human Flourishing", to be published Feb 2020

2. Symmetry

   - Doris Schattschneider
   - Brian Sanderson
   - Joe Rosen
   - Marcia Ascher "Ethnomathematics"
   - Paulus Gerdes
   - Darrah Chavey
   - Jay Kappraff
   - Kristopher Tapp's website and PPTs;
   - Rachel Wells
   - Warren Weaver
   - Prof. Naranan's PPTs

3. Fractals, Chaos and L-Systems

   - Frame and Golubitsky
   - Gary William Flake

4. Game Theory

   - Presh Talwalkar, "The Joy of Game Theory"
   - Robert Axelrod," The Evolution of Cooperation"
   - Brian Skyrms," The Social Constract"
   - V.S Raghunathan, "Games Indians Play"
   -

5. Sound

   - Trevor Cox
   - Daniel J Levitin: The Story of the World in Six Songs

6. Statistics

- Stephen Stigler: Seven Pillars of Statistical Wisdom
- David Spiegelhalter: The Art of Statistics
- Derek Rowbotham

7. Machine Learning

- Andriy Burkov Machine Learning in 100 Pages
- https://vas3k.com/blog/machine_learning/
-

Final Course Exercises and Projects

Project 1: Orchestral Manoeuvres ~~in the Dark~~ over Wi-Fi   Task: Create an experience to enable **multiple users to simultaneously use hand-phone gestures to create collaborative music/sound**. Viewers must use dance and/or gestures holding handphones, to create music together . **Each user must be able to control unique aspects of the music** to create a collaborative piece each time. There must be clear opportunities and instructions for collaboration based on a **Stag Hunt / Coordination Game**. **Tools:** `Software: Pure Data for sound synthesis; Android apps like Sensors2OSC for sensor data logging and sharing over WiFi  Hardware: WiFi network hotspot; Smartphones; Laptop or Raspberry Pi running PureData` **Ideas from our Course:** `Proximity; Game Theory / Stag Hunt; Networks and Graphs` **Resources:**
1. PureData Sound Synthesizer 2. Sensors2OSC

Project 2: Living on the Ceiling   Task: Use physical movement in the room along with smartphone sensor data to project a live Voronoi Diagram on the ceiling. (Hat tip to Anuja Gaikwad, FSP 2019-2020)

Tools: `Software: Processing; Android apps for sensor data logging and sharing over WiFi` 'Hardware: WiFi network hotspot; Smartphones; Arduino + Wi-Fi; Makey-Makey'

Ideas from our Course: `Proximity; Schelling Points`

Resources: 1. Processing 2. Mesh Library for Processing 3. How to make things with Make-Makey

Project 3: Nightmare at Room 307   Task: Create strange bloodcurdling sounds based on where individuals are standing in the room. Participants need to move, perhaps be blindfolded and wear headphones / earphones.

Tools: `Software: Geogebra or R/RStudio; Android apps for sensor data logging and sharing over WiFi  Hardware: WiFi network hotspot; Smartphones; Arduino with Wifi; Makey-Makey for position location based on footfall`

Ideas from our Course: `Proximity; Schelling Points`

Resources: 1. Theremin

Project 4: Friends (Season 65, Episode 12)   Task: Use this article in the Atlantic Magazine as inspiration: How friendships in Adulthood. Create a physical graph/network related installation, based on personal, or crowd-sourced, or fictitious but plausible friendship data, and show in an interactive way how these friendship networks change over time. Use our collected college network data, and inspiration from https://graphcommons.com as a starting point. Can embed electronic (lights) or computed elements (touch) , if desired from an aesthetic point of view or to create/enhance Viewer participation. The installation should show small changes over "time" and must be **wilfully and meaningfully degradable by viewers**. Water, ink, knives, or flame, rubber-bands and oil are possibilities. No acid.

Tools: Software: None specified. graphcommons.com and RStudio are possibilities. Arduino can also be used for embedding computational elements. Hardware: None specified. NO THERMOCOL.

Ideas from our Course: Networks and Graphs; Connectors and Hubs; Network Dynamics and Measures; Erdos-Renyi / Watts-Strogatz / Barabasi-Albert models; Power Laws

Project 5: Six Degrees of Separation   Task: Read the Skit/Play , "Six Degrees of Separation" by John Guare. Stage or show in some way, part or all of it.

Tools: Software: None specified Hardware: None specified. NO THERMOCOL.

Ideas from our Course: Networks and Graphs; Network Dynamics