muHVT: Case based computational geometry modeling toolkit using R

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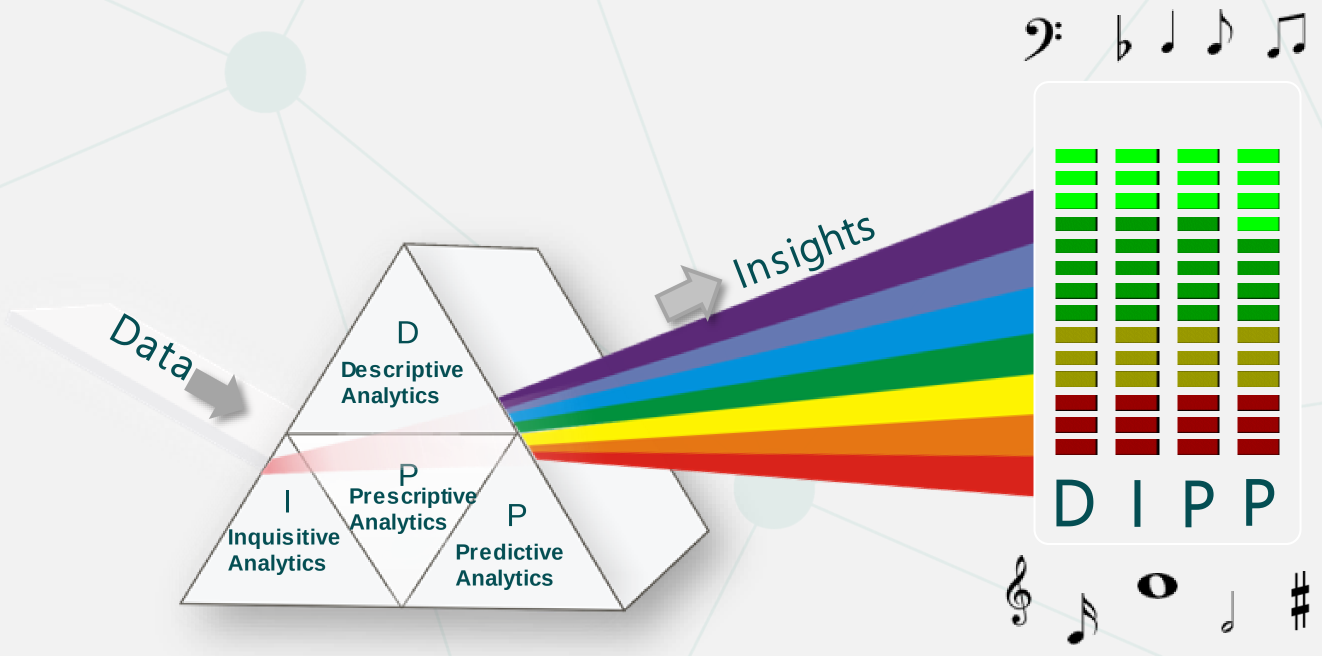
Agenda

- **The Enterprise Requirement for Complexity Science**
- A Point of View - Representation of a Complex System
- Use Case: Intelligent Reporting
- Demo

DIPP: **Prescriptive Analytics**, “what should we do”, “our best action”, ”evaluate this policy change”

Correct Perspective



Why Prescriptive Analytics for the Enterprise?

Source: Cartoonbank.com

Default view in Decision Sciences: **Comfortable**.. But **Deceiving**

- **Mechanical View / Complicated Mindset**
  - "Assembly Line", rules and recipes on components
  - Complicated: Computer, Phone, Car, Rocket, Clocks
  - The classic **Additive** regression model: $Y = a + B_{x1} + B_{x2} + e$

- Are the systems we manage so **tame**?
  - **Mandelbrot**, "Clouds are not spheres, mountains are not cones"
- The world is complex whether we like it or not – **Get Real**

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Our Entire AI Revolution Is Built On A Correlation House Of Cards

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I write about the broad intersection of data and society.

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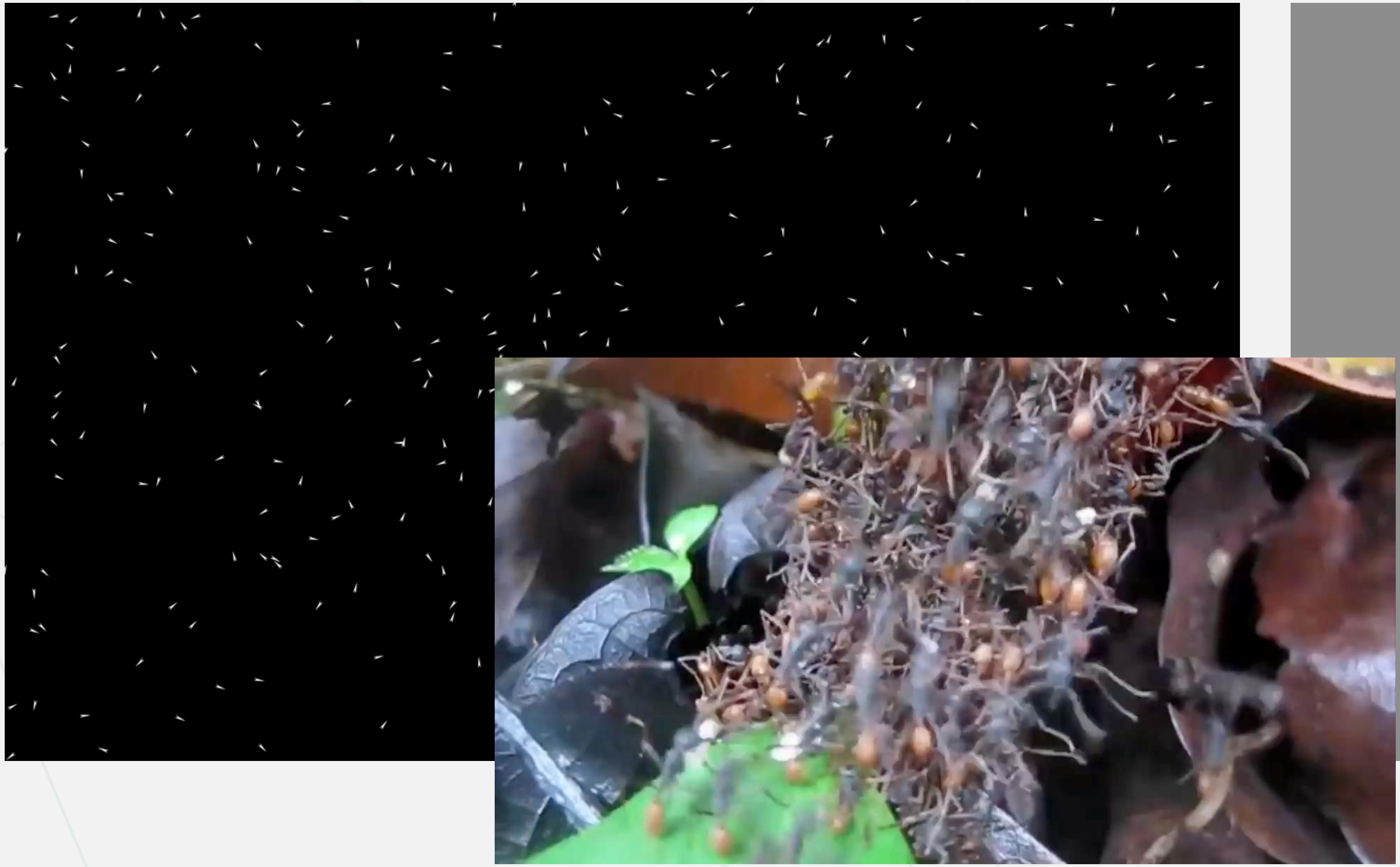
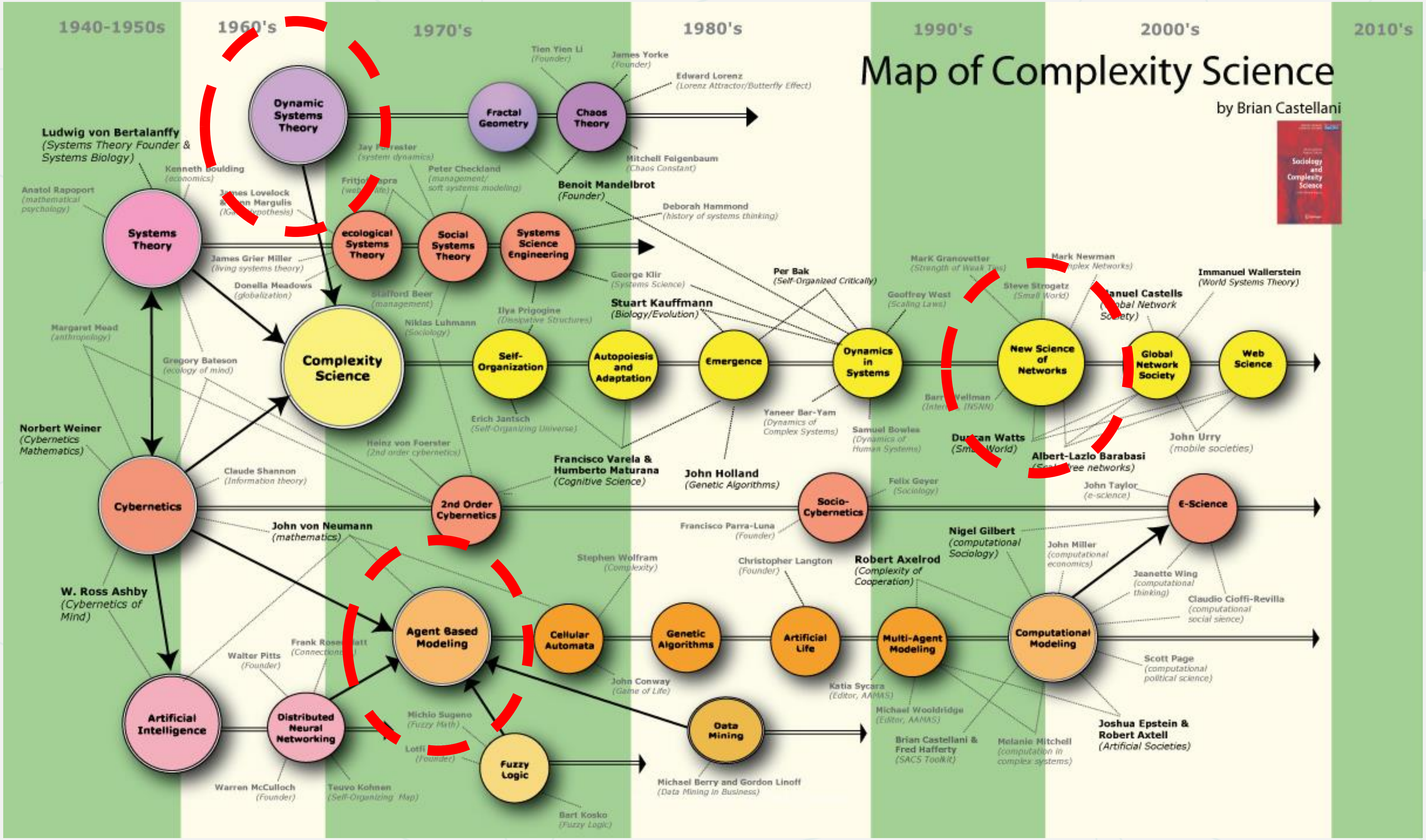
Examples of Complex Systems

Climate, Animals, Brains, Cells, Cities, Ecosystems, Supply Chains, Traffic, Economies, Firms & Customers

Agents, Feedback, No Central Coordinator, Emergent, Self Organize, Learning



Complexity Science



First Principles: Complexity Science

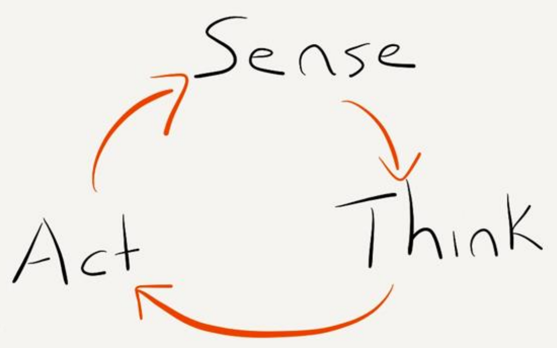
- **Properties**
  - Simple components or **Agents** (simple relative to the whole system)
  - **Nonlinear Interactions** among components usually caused by **Feedback Loops**
  - **No central control**
  - **Emergent** behaviors
    - Hierarchical(**Layers**) & **Network** design patterns
    - **Information Processing**
    - Dynamics: Study of continuing changing structure and behavior – **STATES & Self Organization**
    - **Learning** / Evolutionary / Adaptation

- **Study of Organisms (Ecology)**
  - Computation model inspiration = **Robotics** (Sense, Plan, Act)

Use Case: Intelligent Reporting

- Dealing with Networks (**organism**)
  - Possible **Unanticipated** Consequences and difficult to predict
  - **Novelty Detection** key characteristic
    - Shannon Entropy "Surprise"

- **Monitor** at the case level, states and trajectories
  - **Case** = profile of a contextual set of inter-dependent variables, a situation of the case-object
  - Start with a Robust **Sensing** Apparatus
    - Visualize states and trajectories of the case-object



Robotics

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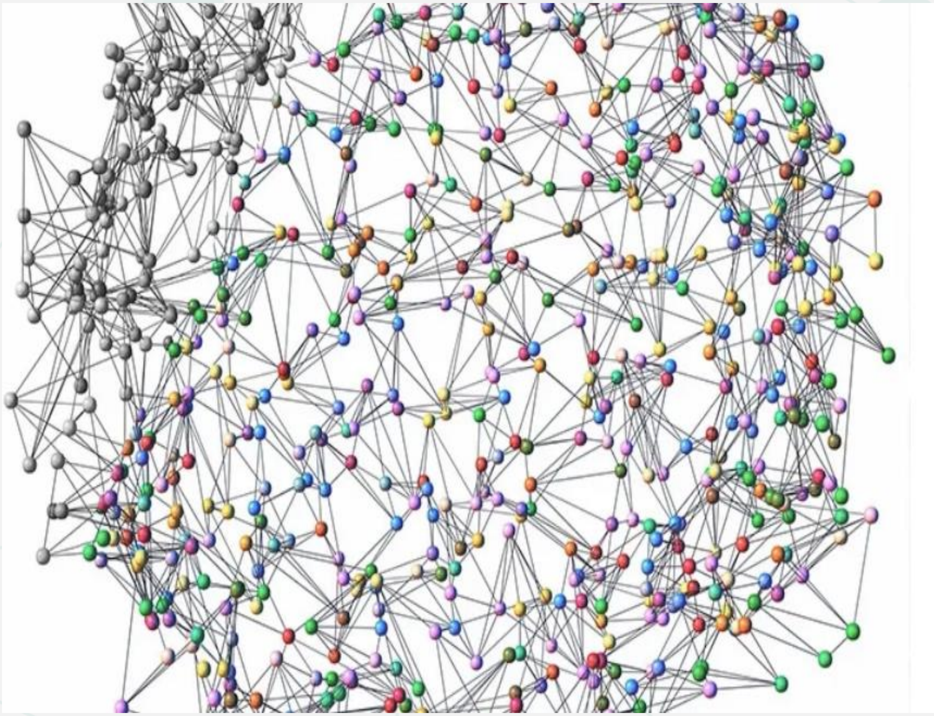
Why complex system **representation** an issue?

- The intricate nature of complex systems currently poses great difficulty in an unsupervised representation across different domains
- Some of these existing problems include:
  - Organized Simplicity
  - Disorganized Complexity
  - Organized Complexity
- Now, how do we tackle these problems?



Emergence in a Complex System

"These new problems and the future of the world depends on many of them, requires science to make a third great advance, an advance that must be even greater than the nineteenth-century conquest of problems of organized simplicity of the twentieth-century victory over problems of disorganized complexity. Science must, over the next 50 years, learn to deal with these problems of organized complexity."

\- Warren Weaver, 1948

- This is what **emergence** is all about; the overall effect of the interactions between all the components of the "organic whole"
- These changing interaction leads to a **dynamic** emergent behavior over time

Case Based Modeling for a Complex System

- Multiple behaviors emerge in a complex system
- Behaviors are divided into discrete **cases** based on structural similarity giving a condensed representation of the system
- The above process are repeated in a **hierarchy** for a microscopic view into the sub-behaviors of the system
- This is achieved using the following techniques from our muHVT package on CRAN:
  - **Unsupervised learning** (Vector Quantization),
  - **Computational geometry** (Voronoi regions) and
  - **Multi-dimensional scaling** (Sammon's Projection)

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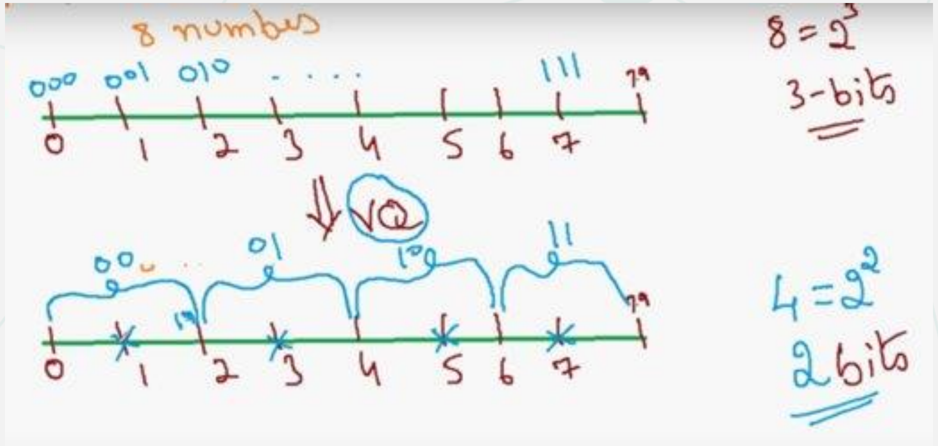
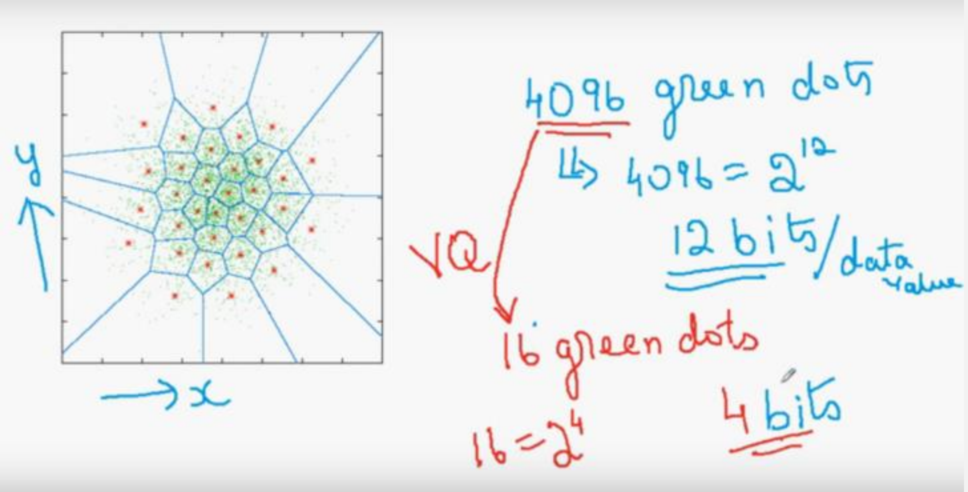
Vector Quantization

- VQ on a 1D Number Line
  - Compression technique, tries to reduce the number of bits being used to encode the numbers

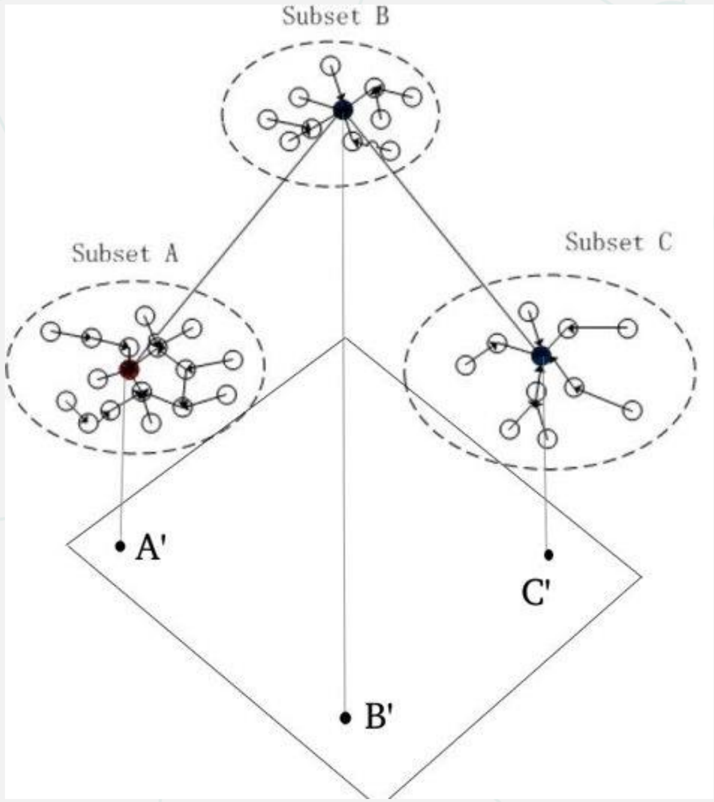


- VQ on a 2D Plane
- 1. The plane above contains 4096 green dots which can be represented in 12 bits per data value
  - 2. These 4096 dots have been replaced by 16 green dots which can be represented in 4 bits per data value

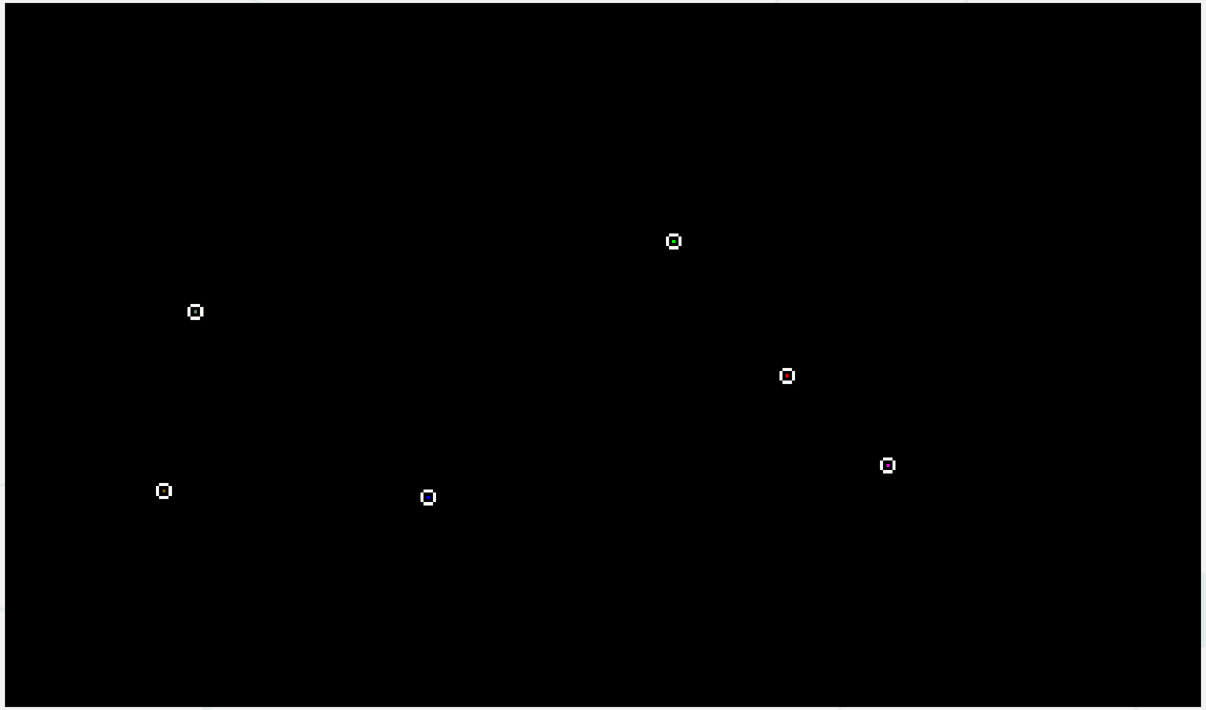


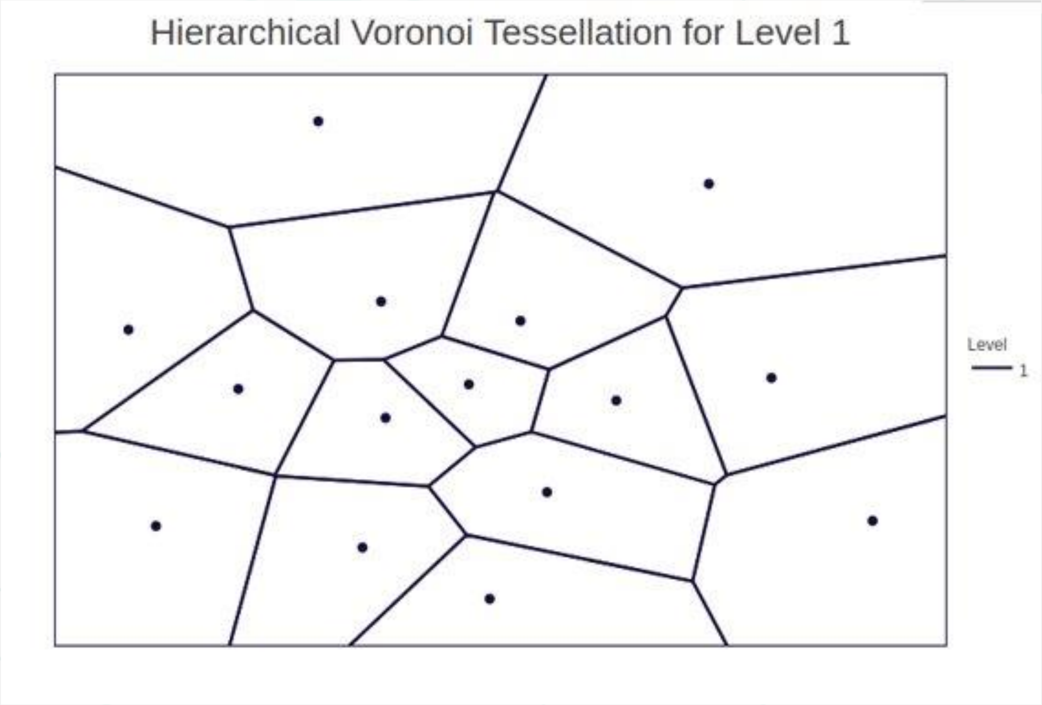
Dimensionality Reduction

- Sammons projection
  - Projects points from a space of higher to lower dimensionality
  - Preserving the structure of inter-point distances in n-dimensional space.
  - Minimization of the error function involves distance between the points in original space and corresponding distance after projection



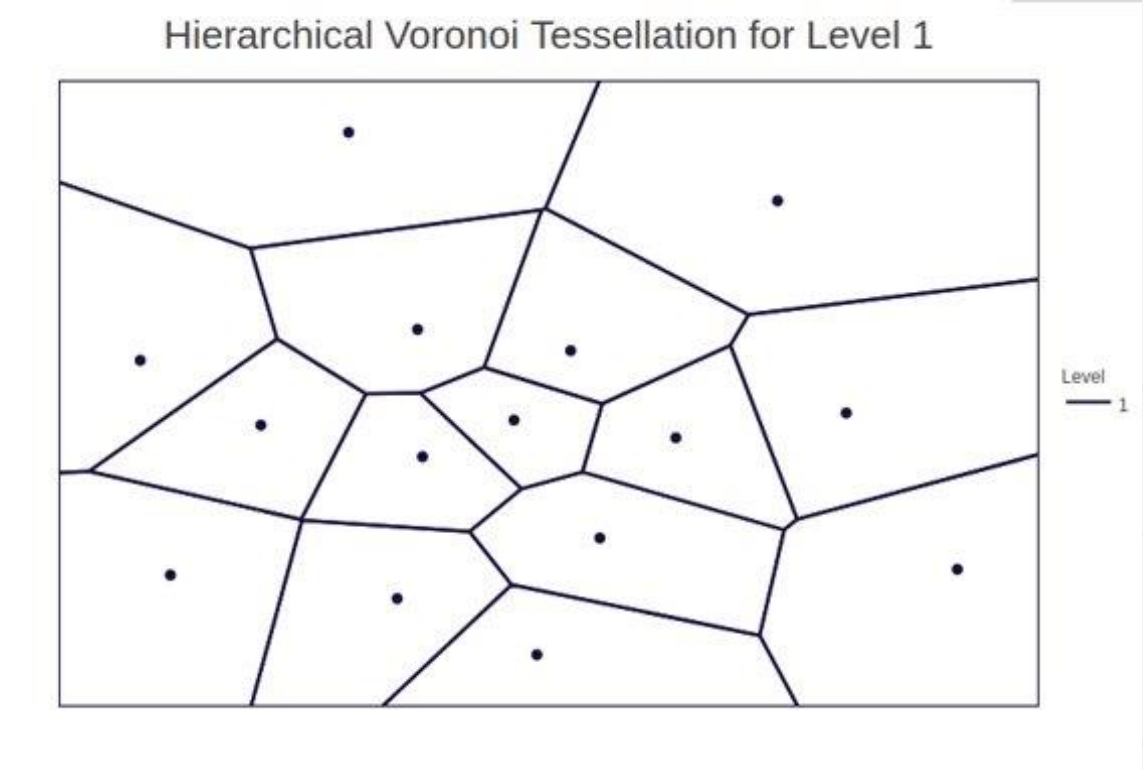
Voronoi Tessellations

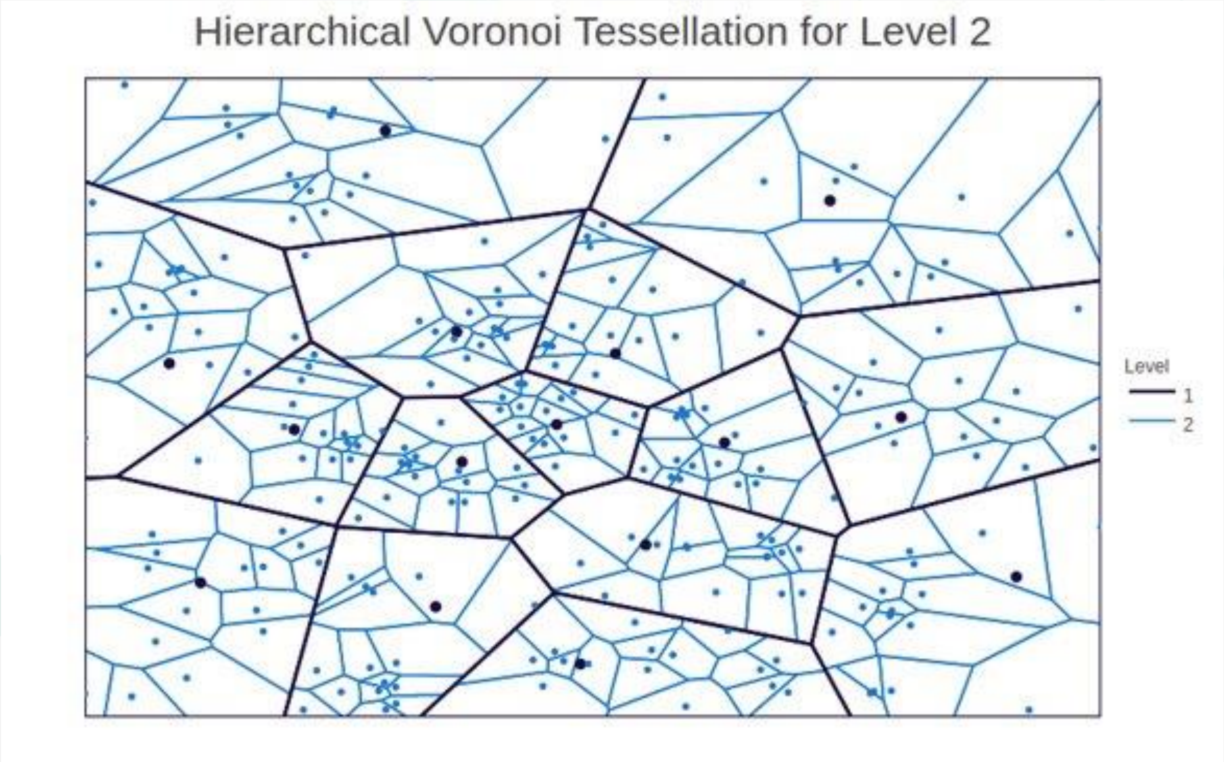




Presence of geometric arrangements in nature

Hierarchical Voronoi Tessellations





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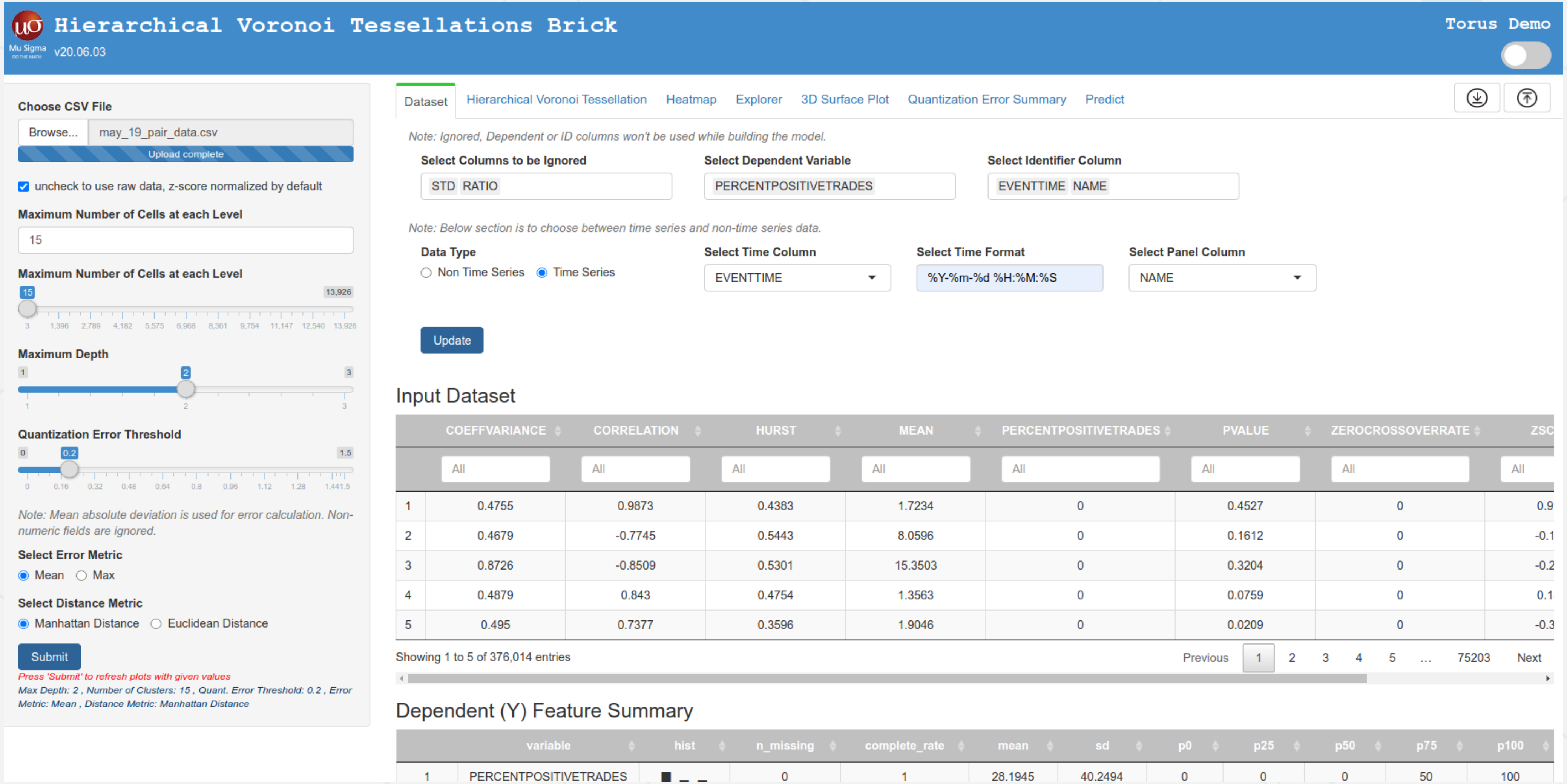
Shiny interface for **muHVT**



Thank you