Physarum Polycephalum Network Construction

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Physarum polycephalum

- Acellular slime mold
  - Protist—neither animal, plant, nor fungus

- I study the diploid plasmodial form, visible to human eye
  - One cell—a coenocyte, billions of nuclei

- Genetically similar plasmodia will fuse together
  - Doesn’t mind being divided into pieces

- Amoeboid movement over surfaces
  - leaves behind a network of tubes connecting food sources
When oats are placed in the locations of major cities in the Tokyo area, *Physarum* creates a similar network to the real Tokyo train system (Tero et al. 2010)

*Physarum* creates networks that can be expressed in graph theory

- Graph theory can model a lot of things
  - Transportation systems
  - Neural networks
  - Biological pathways
  - Disease transmission
  - Social media friendships
  - The internet

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Graphs model networks, are made up of:

**Nodes (or vertices)**
- Represents a type of object
- Food sources are nodes

**Edges**
- Connect nodes
- Represent relationships between nodes
- Plasmodial tubes between food sources are edges

Edges can have “edge weights”, which is a metric of the relationship between the two nodes the edge connects.

Edge weight is length of the plasmodial tubes.
Optimal Foraging Theory

Organisms should forage in a way to maximize energy and minimize cost.

It is relatively easy to design a transport network with high efficiency and low cost (minimum spanning tree—connect the dots with the shortest lines possible)... but these networks are very fragile if something happens.

A good network might have a third consideration—redundancy—to be able to function despite network stress.
Redundancy increases cost with no immediate benefit to efficiency... but if disturbance occurs, redundancy can prevent a massive drop in efficiency, or network failure

For *Physarum*, disturbance means affecting the plasmodial tube network removal of nodes, edges
Quantifying Physarum Networks

- **Cost**
  - Surface area of Physarum—pixel count

- **Efficiency**
  - Average shortest path in the network
  - Edge weight is length of tube divided by surface area of tube
  - Lower value = more efficient

- **Redundancy**
  - Probability of disconnecting part of the network if one random edge is removed
  - Lower value = more redundant

Cost = 5 + 2 + 1 + 3 = 11

Efficiency = \[ \frac{2 + 4 + 5 + 6 + 1 + 7}{(4(4-1))/2} \] = 4.16

Redundancy = 1/4 = 0.25
Methods

Grew plasmodia on an oat media
  • Cut out circular nodes

Built a machine for taking time lapse of ten petri dishes concurrently
  • Arduino microcontroller rotates a spinning plate 36 degrees, then tells the camera to take a photo

After taking a time lapse, used Python to sort each frame into the correct folder for video

Haven’t got to disturbance yet
Next step:

For each frame of the time lapse, apply a mask to filter out everything but Physarum, then count yellow pixels—then plot a chart through time.

Further in the future:

Thesis computer vision to identify nodes (circular food media) and edges (plasmodial tubes)
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