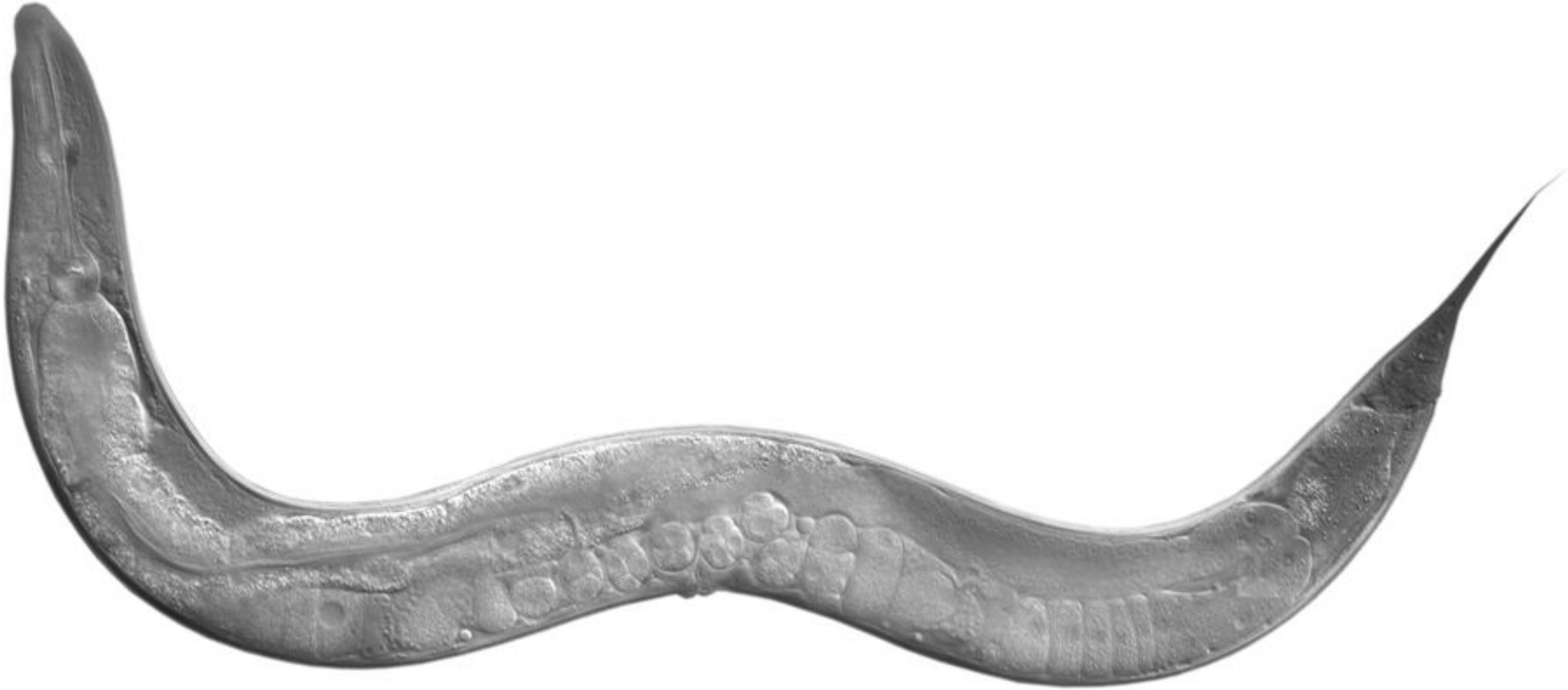


Community Detection in the C. elegans Connectome

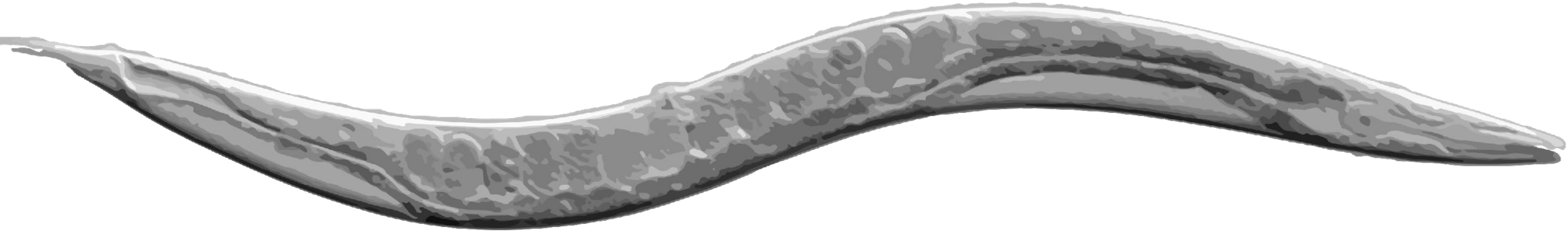
BY MARK HORENI

My Research

Previous work the C. elegans connectome with link analysis

Was curious about community detection in this data set

Currently working on alternative artificial neural network structures that are closer to biology



The Data

280 neurons (humans have 100 billion)

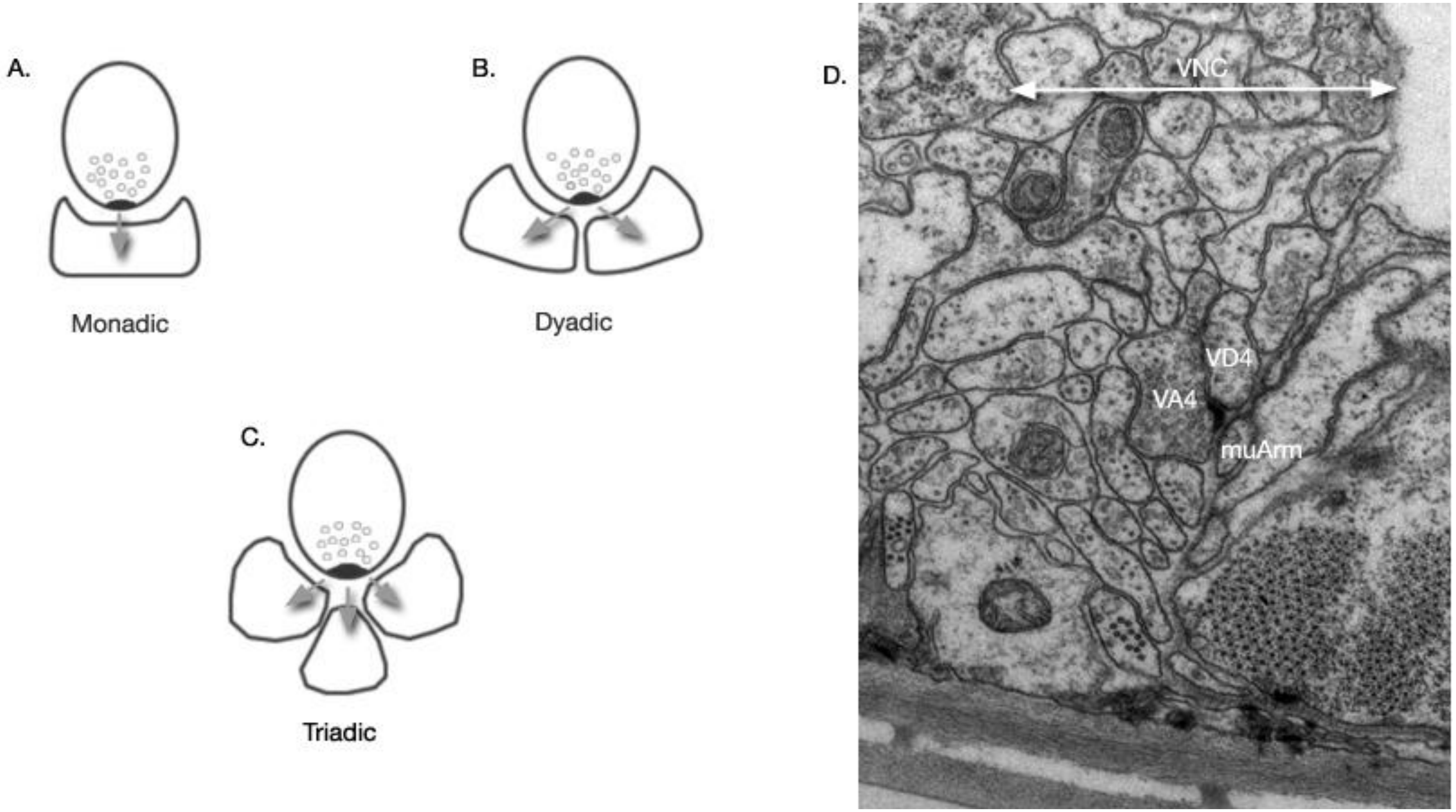
6393 chemical synapses

890 electrical junctions

1410 neuromuscular junctions

Neurons can be either Sensory, Inter, Motor, or a combination

Synapses



Characteristics about the graph

Directed

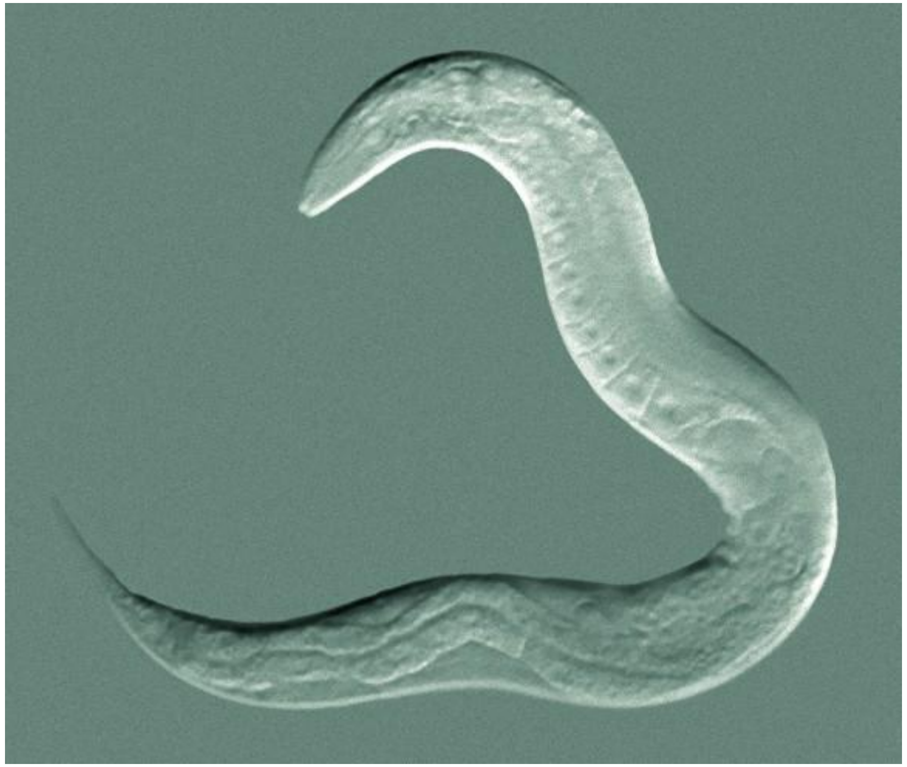
Not a true “Feed Forward Network”

Includes cycles, but no self loops

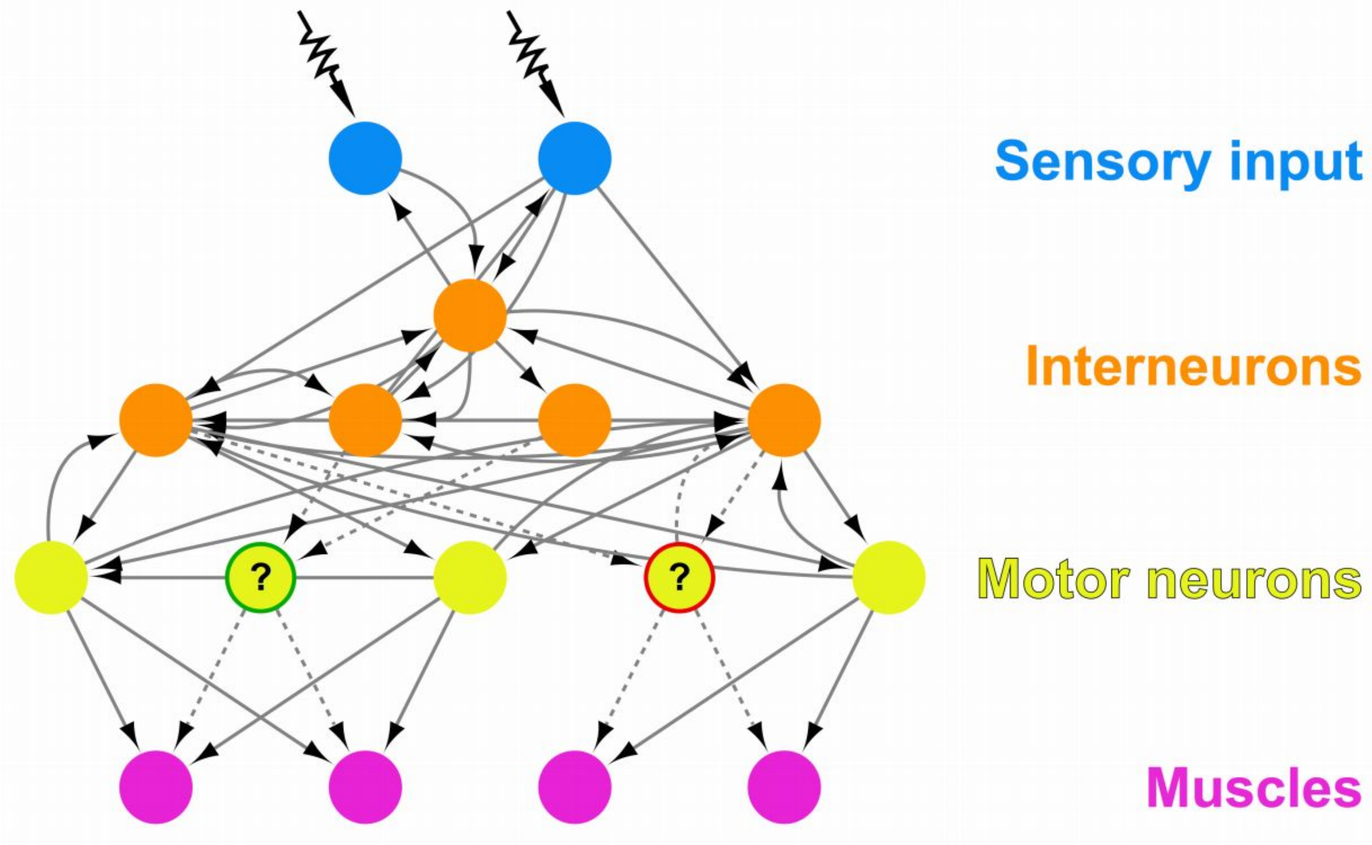
Weighted

Densely connected

Shows a high degree of modularity



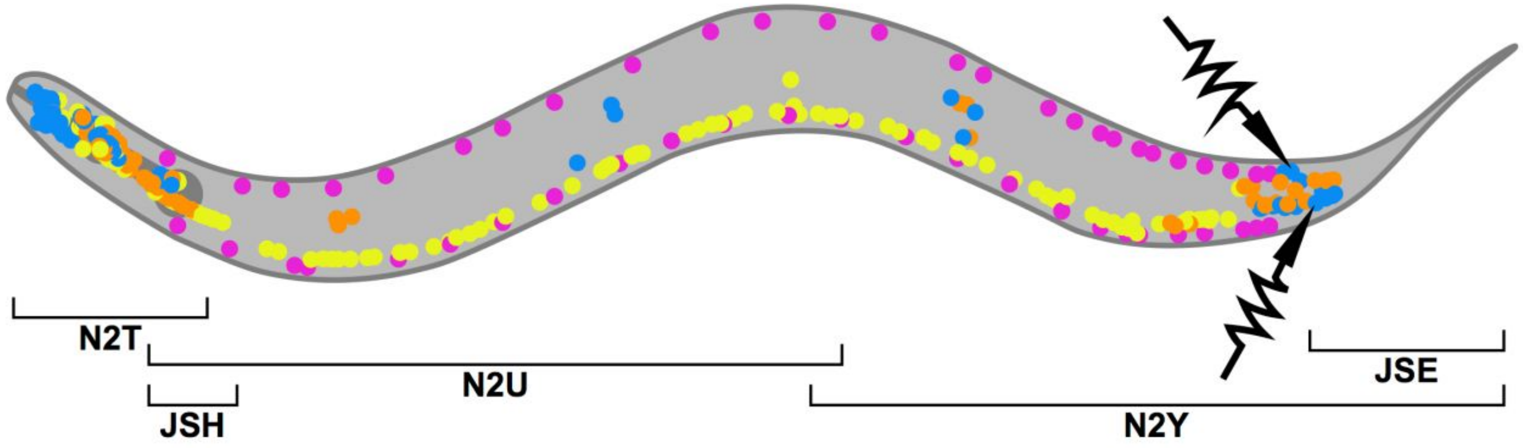
Visualization



More Visualization

https://elegans.herokuapp.com/

http://wormweb.org/neuralnet#c=BAG&m=1



Modularity

Metric to determine communities

Number between -1 and 1 of how strong communities are

Global Property

Goal: Maximize Modularity

$$Q = \frac{1}{2m} \sum_{ij} \left[A_{ij} - \frac{k_i k_j}{2m} \right] \delta(c_i, c_j),$$

Louvain

Each node starts in a community by itself

Put node *i* in a neighboring community

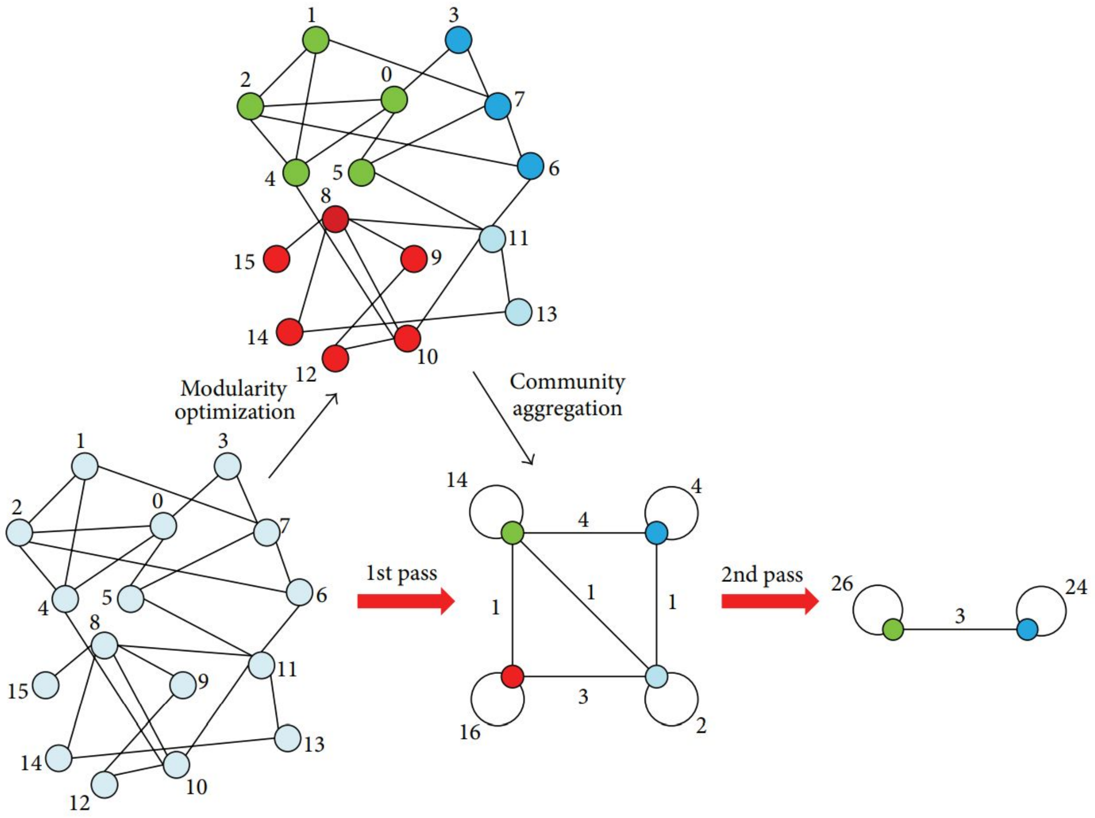
A change in Q is computed: $\Delta Q = \left[\frac{\Sigma_{in} + 2k_{i,in}}{2m} - \left(\frac{\Sigma_{tot} + k_i}{2m}\right)^2\right] - \left[\frac{\Sigma_{in}}{2m} - \left(\frac{\Sigma_{tot}}{2m}\right)^2 - \left(\frac{k_i}{2m}\right)^2\right]$

If the change is positive, *i* becomes part of that community

Once these communities are formed, communities themselves become nodes and intra community weights are treated as self loops, and inter community weights are treated as connections

Repeat

Example



Modularity optimization
Community aggregation
1st pass
2nd pass

V: a set of vertices
E: a set of edges
W: a set of weights of edges, initialized to 1
$G \Leftarrow (V, E, W)$
repeat
$C \Leftarrow \{\{v_i\} | v_i \in G(V)\}$
calculate current modularity Q_{cur}
$Q_{new} \Leftarrow Q_{cur}$
$Q_{old} \Leftarrow Q_{new}$
repeat
for $v_i \in V$ **do**
$Q_{cur} \Leftarrow Q_{new}$
remove v_i from its current community
$N_{v_i} \Leftarrow \{c_k | v_i \in G(V), v_j \in c_k, e_{ij} \in G(E)\}$
find $c_x \in N_{v_i}$ that has $max\Delta Q_{\{v_i\},c_x} > 0$
insert v_i into c_x
end for
calculate new modularity Q_{new}
until no membership change or $Q_{new} = Q_{cur}$
$V' \Leftarrow \{c_i | c_i \in C\}$
$E' \Leftarrow \{e_{ij} | \forall e_{ij}$ if $v_i \in C_i, v_j \in C_j, and C_i \neq C_j\}$
$W' \Leftarrow \{w_{ij} | \sum w_{ij}, \forall e_{ij}$ if $v_i \in C_i$ and $v_j \in C_j\}$
$G \Leftarrow (V', E', W')$
until $Q_{new} = Q_{old}$

Pseudocode

O(*N* LOG*N*)

Future Work

Use a directed version of the algorithm

See if the communities form a biological purpose

Make the algorithm work in parallel