Controlled Evolution of Collaborative Networks: Is it a Good Idea?

http://a-nikolaev.github.io/docs/poster-netscix-2017.pdf

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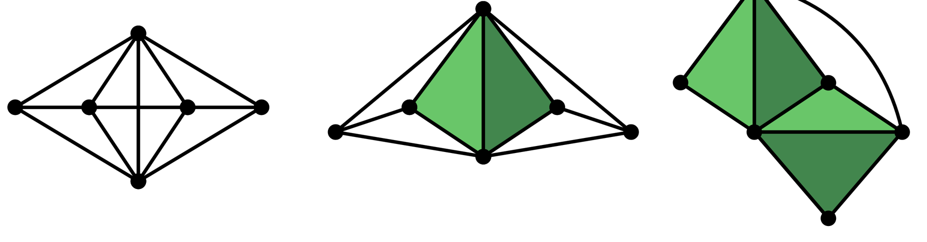
Simplicial complex networks

Abstract symplicial complex (SC) is a collection of sets Δ with the property that if a set $F \in \Delta$, then all subsets of F belong to Δ as well. A set $F \in \Delta$ is called a **face** of the complex. And a **facet** of a complex is a maximal face that is not contained in any other faces.

Graphs are a special case of SCs containing *sets of size at most 2* (i.e. nodes and edges).



In this work, **collaborating teams are modeled as facets** of the SC. Thus collaborations of any size can be captured.

Neutral network growth model

RANDOM MUTATION:
- with 25% probability: **Add a new person** to an existing team sampled uniformly at random.
- with 25% probability: **Make a new team** by taking a union of all people from two or more already existing teams, and sampling their subset.
- with 50% probability: **Split an existing team** into two, assigning the team members randomly.

NEUTRAL (NOT GUIDED BY A METRIC) NETWORK GROWTH PROCEDURE:
- Start with a simplicial complex with one node.
- Apply RANDOM MUTATION to the network until the stopping condition is met.

Stopping conditions: (a) when the network has been "mutated" the required number of times, or (b) when the number of nodes in the network reaches the required limit.

Degree distributions

Facet degree of a node is the number of facets (teams) the node belongs to. **Edge degree** of a node is its degree in the underlying graph (=the number of neighbors).

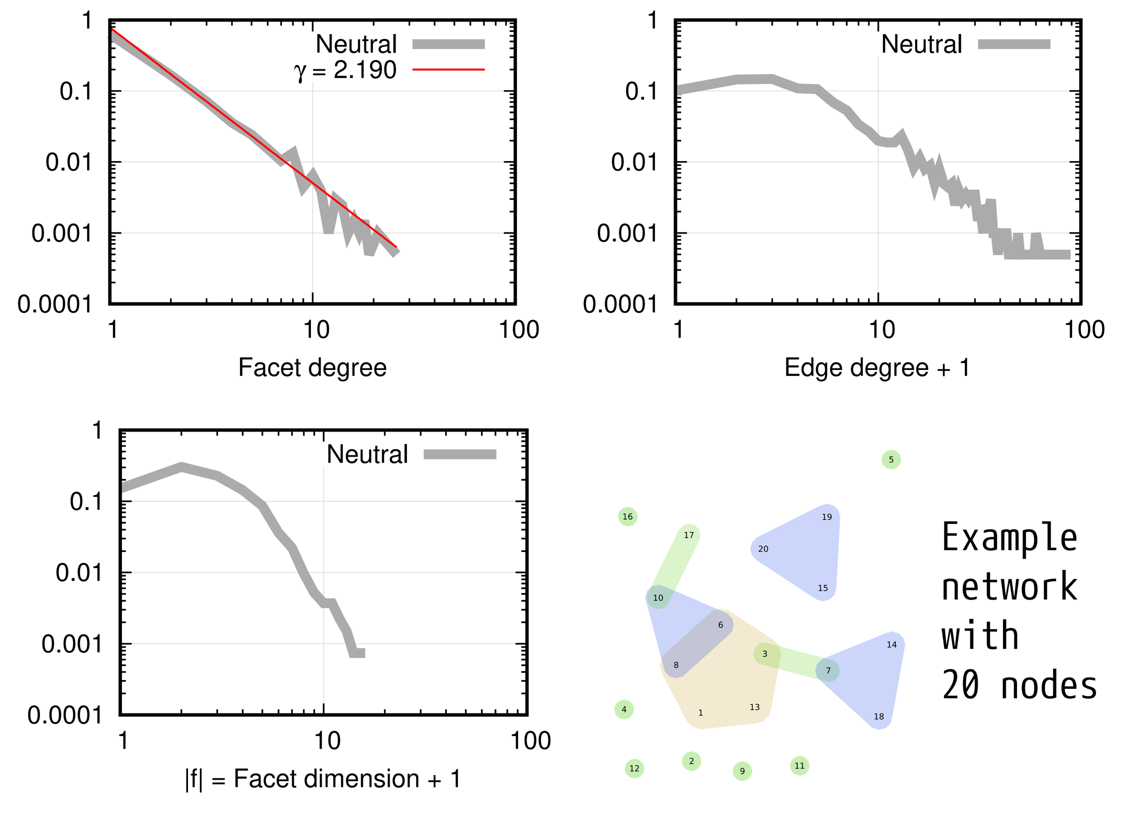
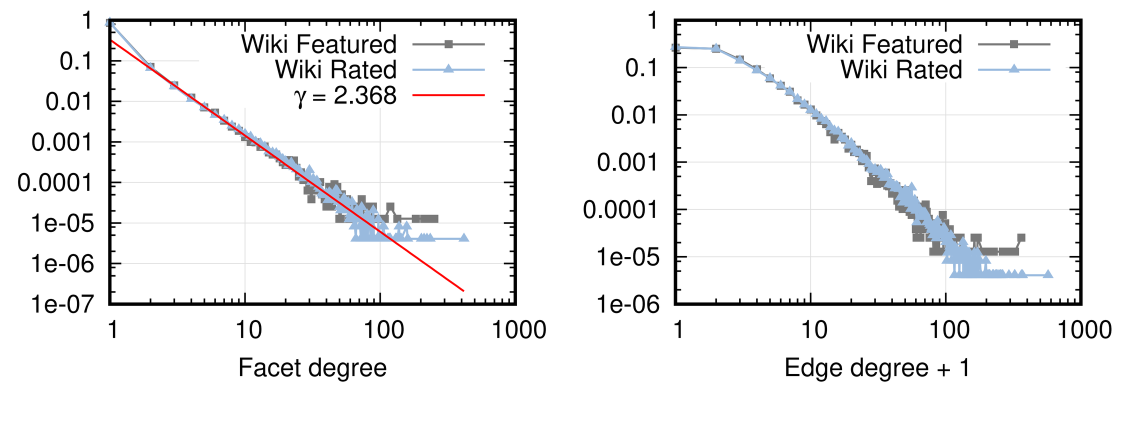


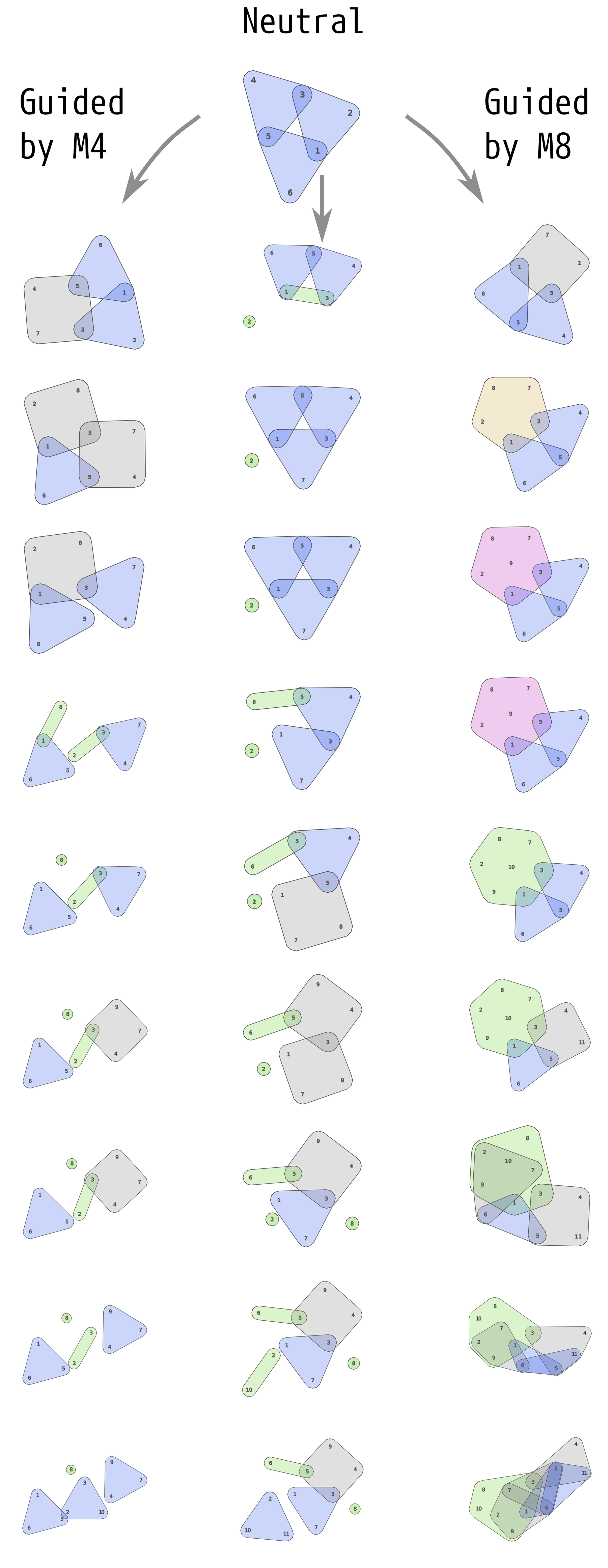
Figure 1: Neutral (not guided) generation procedure. Facet degree distribution. Edge degree distribution. Facet size distribution. Obtained from a network generated in 8000 mutation operations.

How realistic this model is? Wikipedia talk pages discussions exhibit similar distribution properties:



Guided network growth model

METRIC-GUIDED NETWORK GROWTH PROCEDURE:
- Start with a simplicial complex with one node.
- Sample three RANDOM MUTATIONS of the current state of the network, and proceed with the one that maximizes the metric.
- Repeat until the stopping condition is met.



Multitasking is discouraged. All teams **became disjoint**, new team members were introduced.

Teams are formed and split, the process is ambivalent, **no specific goal or direction.**

Accumulation of new teams and members. **Not worried by overloading** with too many tasks.

Guiding metrics:

Previously, the authors considered [1] the following performance-measuring functions (all sums over f go over all *facets* of the complex and $d(v)$ is the facet degree of the node v). Now we use them to guide the network growth:

$$\mathbf{M1}\,(\Delta) = \prod_v \left(1 + \frac{1}{d(v)}\right)^{d(v)}$$

$$\mathbf{M2}\,(\Delta) = \prod_f \frac{1}{|f|} \cdot \sum_{v\in f} \left(1 + \frac{1}{d(v)}\right)^{|f|}$$

$$\mathbf{M3}\,(\Delta) = \prod_f \left(1 + \frac{1}{\sum_{v\in f} d(v)}\right)^{\sum_{v\in f} d(v)}$$

$$\mathbf{M4}\,(\Delta) = \sum_f \left((|f|-1) \cdot \prod_{v\in f} \frac{1}{d(v)}\right)$$

$$\mathbf{M5}\,(\Delta) = \sum_f \left(H_{|f|} \sum_{v\in f} \frac{1}{d(v)}\right)$$

$$\mathbf{M6}\,(\Delta) = \sum_f \left(\sum_{v\in f} \frac{1}{\sqrt{d(v)}}\right)^2$$

$$\mathbf{M7}\,(\Delta) = \sum_f \sqrt{\sum_{v\in f} \frac{1}{d(v)^2}}$$

$$\mathbf{M8}\,(\Delta) = \sum_f |f|!$$

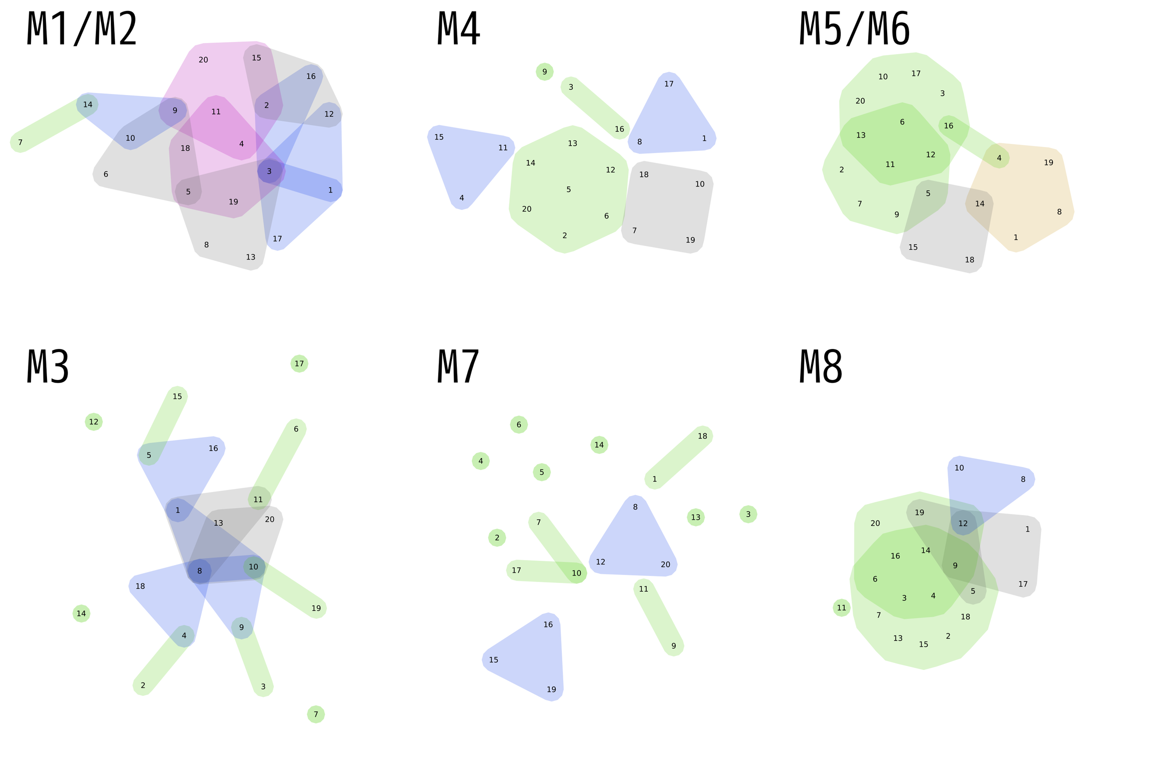
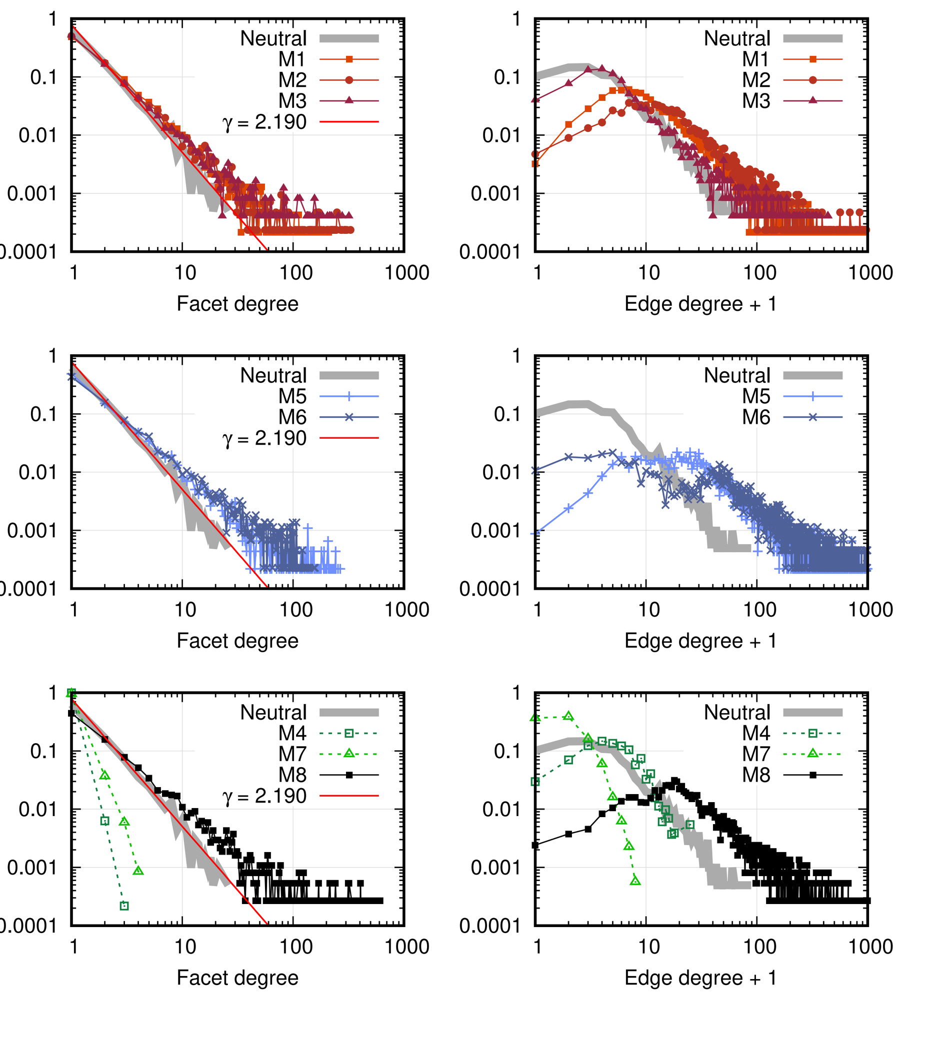


Figure 2: Some typical networks with 20 nodes generated with the metric-guided generation processes.

Degree distributions - Guided



Observed properties

The following table summarizes the properties of the metrics M1-M8 observed from statistics on large networks and from visual inspection of small networks of size 20.

Metric	Overlapping teams (and avg. facet degee*)		# of teams (w.r.t. Neutral)	Team size (w.r.t. Neutral)	# of connect. components	Allows single big team
M1	**yes**	(**1.66**)	–	+	*few* (1–3)	–
M2	**yes**	(**1.73**)	–	+	*few*	–
M3	**yes**	(**1.71**)	+	0—**	some (2–6)	–
M4	*no*	(*1.00*)	——	+	some	**yes**
M5	okay	(1.31)	——	+	*few*	**yes**
M6	okay	(1.23)	——	+	*few*	**yes**
M7	*no*	(*1.03*)	+	–	**many** (> 10)	–
M8	**yes!**	(**1.81**)	–	+	*few*	**yes**

Table 1: (*) Average facet degree of a node is reported for small networks of size 20. For larger networks, M5 and M6 eventually catch up with M1-M3, but M8 still surpasses them all by the factor of 1.5–2.
(**) The metric M3 slightly decreases the team sizes with respect to the neutral generation process.

References

[1] A. Assarpour et al., "Measuring the strength of networks of teams: Metrics and properties", *2015 IEEE Conference on Computer Communications Workshops (INFOCOM WKSHPS)*, pp. 414–419, IEEE, 2015.