Two new types of visualization for mutualistic communities based in k-core decomposition

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Abstract. The bipartite graph is the most popular visualization of mutualistic networks. This plot underlines the existence of two guilds of nodes. Links between them are difficult to follow even with a reduced number of elements, and it is almost impossible to discover organizational patterns. As a result, it is uncommon finding graphs of big bipartite networks in the literature.

These shortcomings are even worse for networks with real time, strongly non linear interactions, such as mutualistic newtorks. Their internal structure is very important to understand their behaviour and resilience. For instance, it is quite important to know how central is a node and how its removal may trigger a cascade extinction [1].

We have developped two new kinds of visualization, *polar* and *ziggurat* plots, based on *k-core decomposition*. The idea was succesfully applied to very large networks [3] to reduce the ammount of displayed information. Our solution does not reduce information, as mutualistic networks have less than 1000 nodes. Instead, the decomposition discovers an internal organization that has its roots in topological properties.

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1. Introduction

The structure of mutualistic networks is critical to understand their behaviour and resilience. The available toolkit, however, is not as complete as in other fields of network science. Mutualistic communities have a set of properties that are not fully grasped with the generic tools.

The most common visualization is the bipartite graph. It underlines the existence ot two communities, but links between species are difficult to follow even with a reduced number of nodes. It is not easy identifing the innermost

core and almost impossible to guess the centrality of species. As a result, it is uncommon finding graphs of networks with more than ten species per guild in the research literature, but typical mutualistic networks are bigger. The bipartite graph is useful for affiliation, but mutualism is not a soft relationship. Interactions among species build a real time, strongly non linear network.

The depiction of the interaction matrix is a more useful approach, widely used in nestedness analysis. The disposition of species, from more to less connected, makes appear patterns. Very nested species are located in the upper left corner and it is easy to identify pure generalists and specialists. It is not so clear when the species lies between these two extreme classes.

K-core analysis may be a powerful technique to tackle these shortcomings. It has been successfully applied to very large networks, as a way to discover their structure and reduce the amount of information to visualize. Despite the fact that the size of mutualistic communities is very small in comparison, they share the onion layer like organization.

2. K-shell decomposition and k-magnitudes

K-shell decomposition identifies the different internal *shells* and decomposes the network, layer by layer [4]. The *pruning* algorithm is the most commonly used: Nodes of degree one are pruned in a recursive way, until no *1-degree* node remains. The set of removed nodes is the *1-shell*. The *2-shell* is built in the same way, prunning *2-degree* nodes, and so on. The highest value of k, i.e ks_{max}, correspond to the *core* $ks_{max} \equiv C^{A,B}$. For each *k-shell* there are two subsets, one per guild (A and B), that we call KS_j^A, KS_j^B where j is the *k-shell* index.

To measure distance from a node to the innermost core of the opposite guild, we have defined the k_{radius} as the average of the distances to all the nodes in that core.

$$k_{radius}^A m = \frac{1}{N_{C^B}} \sum_{j \in C^B} dist_{mj} \qquad m \in A \qquad (1)$$

where N_{C^B} is the number of species in C^B. For species that belong to guild B we compute average distances to C^A. The minimum possible radius value is 1 for one node of the maximum shell directly linked to each one of the maximum shell set of the opposite guild.

We define a second *k-magnitude*, the k_{degree}:

$$k_{degree}^{A}m = \frac{1}{\mid B \mid} \sum_{j} \frac{1}{k_{radius}j} \quad m \in A, \forall j \in B \mid w_{mj} = 1 \qquad (2)$$

These two magnitudes are the basis to build up the new visualizations.

2.. 1   Polar and ziggurat diagrams

K_{radius} and k_{degree} are the basis for two new types of visualization designed specifically for mutualistic networks. We have called the first one **Polar Diagram**. It shows species centrality and provides a quick overview of network distribution. It is useful to compare different networks.
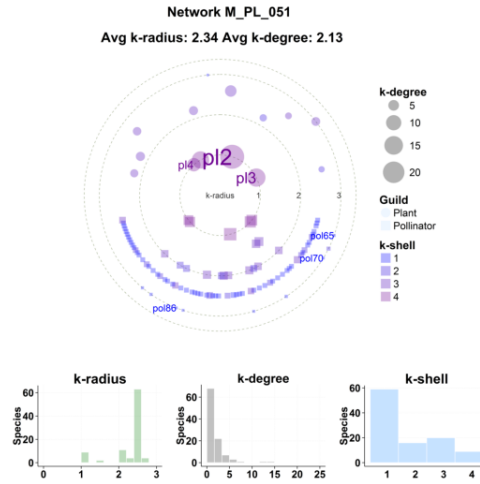

Figure 1: Plant-pollinator network in Southern Andes by Vazquez (1982). Source: Web of Life [5]

Species are depicted with their centers located at k_{radius}. Angles have no meaning, they are assigned at random to reduce overlap, with each guild lying on one of the half planes. Areas are proportional to k_{degree} and color represents *k-shell*. Links are not included.

Figure 1 is a real mid size network. Nodes are unlabeled, except the three ones with smaller k_{radius} and the three ones more distant. A reduced number of nodes have a high k_{degree}, while most species are peripheral.

The idea behind the **Ziggurat Diagram** is splitting species in sets by their k_{shell}. Each of these groups are represented as small ziggurats. The maximum k_{shell} is located on the left side, the others are arranged following an almond distribution. Nodes of shell 1 are scattered around. We get a clear
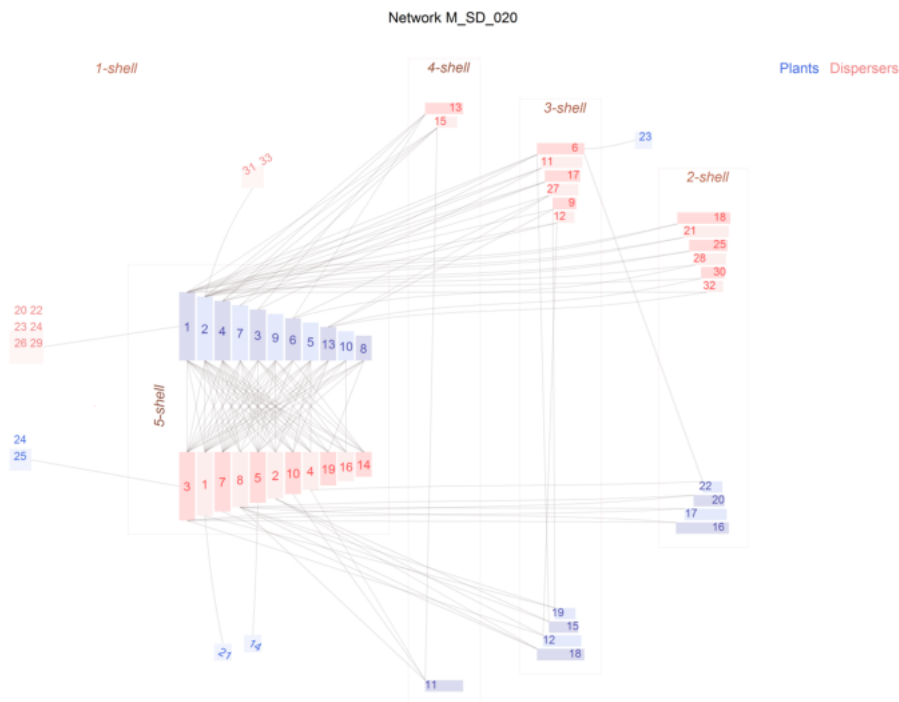
Figure 2: Seed dispersal network in Sierra de Cazorla, Spain. Jordano P. unpublished. Source: Web of Life [5]

view of structure and interconnections. The almond shape leaves a wide space in the center of the graph to depict the links and they do not ovecross the boxes of the different species.

The network of Figure 2 has 58 species and 150 links. The ziggurat gives a clear glimpse of its internal organization with 5 shells and a tiny external layer *1-shell*. Strong patterns may be visually discovered, for instance how almost species are directly connected to *5-shell* while ties between species of the same *k-shell* are uncommon. This property is called nestedness and is a disctintive feature of mutualism.

References

[1] S. Saavedra, D. B. Stouffer, B. Uzzi ans J. Bascompte, *Nature* **478**, 233-235 (2011).

[2] A. James, J. W. Pitchford and M. J. Plank, *Nature* **487**, 227-230 (2012).

[3] J.I. ALVAREZ-HAMELIN, L. DALL'ASTA, A. BARRAT, AND A. VESPIGNANI, *arXiv preprint* **cs/0504107**, (2005).

[4] S. N. DOROGOVTSEV, A. V. GOLTSEV AND J. F. F. MENDES, *Physical Review Letters* **96**, (2006).

[5] M. FORTUNA, R. ORTEGA AND J. BASCOMPTE, *arXiv preprint* **abs/1403.2575**, (2014).