

# Communicability-derived layout and community detection in complex networks

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Renato Fabbri<sup>1</sup> and Ernesto Estrada<sup>2</sup>

## Abstract

This paper describes the use of the communicability measure for the achievement of layouts and community detection in complex networks.

## Keywords

Complex networks, communicability, community detection, layout algorithms, interactive visualization

## Introduction

### *Related work*

### **The communicability framework**

### *Preliminaries*

### *Layouts*

### *Community detection*

## Results

### *An interactive interface*

We implemented the framework described in the previous section using scientific, database and web resources, making it available within a web page<sup>1</sup> for use through simple mouse-driven actions and requiring no software installation beyond a web browser. The software has been named ComNetVis (from Communicability-based Network Visualization) and is exemplified in Figures 1, 2, 3, 4, and 5. In this section we describe its functionalities and the underlying technologies.

In using ComNetVis, the analyst first uses a drop-down menu to select a network of interest, s/he may also upload a new network using the same menu. Then s/he sets parameters for the calculation of the communicability angles, as illustrated in Figure 2, although default settings are reasonable, specially for a newcomer. The next step is to set the community detection algorithm. To do so, the user selects a dimensionality reduction method, and a target dimensionality in which clustering is going to be performed. Accordingly, s/he selects a clustering algorithm and the minimum and maximum number of communities of interest, as illustrated in Figure 3. The last step, before the achievement of the visual mapping, is to set the node-link layout algorithm: the user selects a dimensionality reduction method, and the number of dimensions of the layout, as illustrated in Figure 4.

Theoretically, any dimensionality reduction method and any clustering algorithm can be used. In this interface, to encompass a reasonable collection of techniques, and enable the proof-of-concept, we implemented five

dimensionality reduction methods (PCA<sup>1</sup>, t-SNE<sup>2</sup>, Locally Linear Embedding<sup>3</sup>, ISOMAP<sup>4</sup>, and MDS<sup>5</sup>), and three clustering algorithms (k-means, Ward's hierarchical<sup>6</sup>, and spectral<sup>7</sup>).

Once the “render network” button is hit, the network node-link representation is mapped to the screen according to the selected settings. Subsequent usage relies on manipulation of the visual mapping, using control elements presented with the canvas, by means of mouse operations. These procedures are illustrated in Figure 5: changing overall node size or proportionality to degree; changing node and link transparency; visualization of the centroid and best sphere center and surface; download of image and of communities; changing the colors and the number of communities.

**Underlying software technologies:** Components of ComNetVis are written in a combination of JavaScript and Python: Vue.js (set up by Nuxt.js) is used for the front-end client, the back-end is a Flask Python server, used to perform specialized or heavy calculations. A secondary server, a FeatherJS, is used to facilitate database-related operations and real-time multi-user interaction. The data is stored in a MongoDB database, while the multi-user interaction is deactivated for now to avoid unnecessary complexity. The communicability-related calculations for community detection and network layout are performed by the Flask server. The fast WebGL 3D rendering on the canvas is performed using Babylon.js.

<sup>1</sup>Institute of Mathematics and Computer Sciences, University of So Paulo, So Carlos, Brazil

<sup>2</sup>Department of Mathematics and Statistics, University of Strathclyde, Glasgow G11HX, United Kingdom

### **Corresponding author:**

Renato Fabbri, Institute of Mathematics and Computer Sciences, University of So Paulo, So Carlos 13566-590, Brazil.

Email: renato.fabbri@gmail.com



**Figure 1.** The ComNetVis interface: (1) drop-down menu for selecting or uploading a network for analysis; (2) widgets for setting the communicability calculations; (3) widgets for setting the community detection; (4) widgets for setting the node-link layout; (5) the render button to display the network; (6) toolbar with controls for fine-tuning the visualization and downloading the image and communities; (7) interactive table holding information about the communities; can also be used to set the visualization on the canvas; (8) canvas with the node-link representation of the network. (9) text areas for further information about the visualization achieved. Notice that nodes shown belong to six communities, each with the color and size denoted in the table (7). These elements are further described in this section.

Use cases

Conclusions and further work

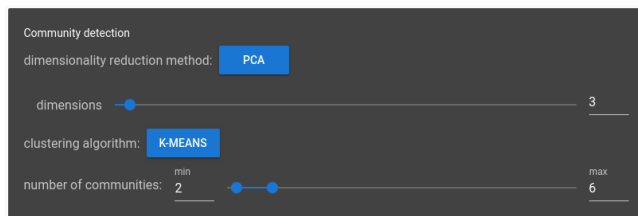
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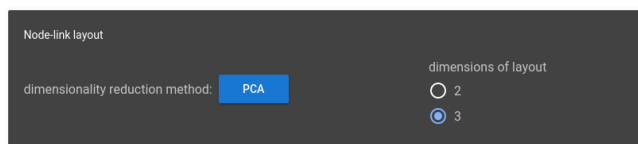
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**Figure 2.** The initial step of the ComNetVis usage is to apply the communicability calculation to an input network. The button at the top is for network uploading and selection. In the gray box the user chooses the inverse temperature and the minimum angle.



**Figure 3.** Settings of the community detection: the dimensionality reduction method; the target dimensionality in which the communities are going to be found; the clustering algorithm; and the minimum and maximum number of communities.



**Figure 4.** Settings of the layout: the dimensionality reduction method and the number of dimensions of the layout, which can be 2 or 3.

## Ranking of the algorithms by computational cost

The dimensionality reduction methods, listed from slowest to fastest, are: MDS, Isomap, Locally Linear Embedding, t-SNE, and PCA. By far, PCA is the fastest of these methods<sup>2</sup>.

The clustering methods, listed from the one that scales worst to best: spectral, Ward's hierarchical, k-means<sup>3</sup>.

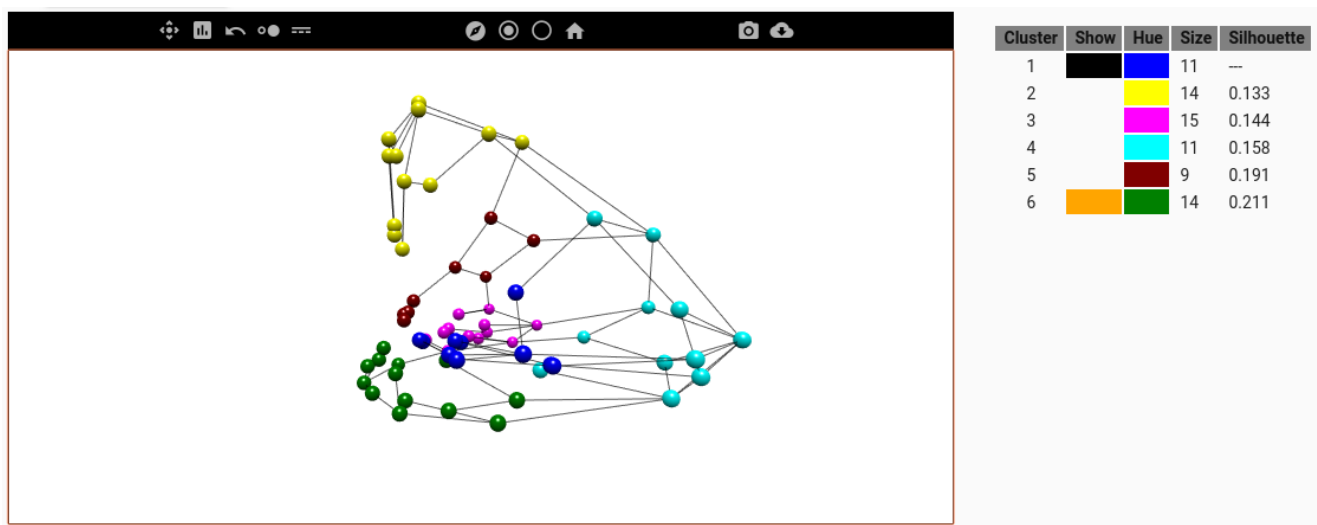
## Notes

1. Available at: <http://rfabbri.vicg.icmc.usp.br:3000/communicability>.
2. As described in <https://umap-learn.readthedocs.io/en/latest/benchmarking.html>.
3. As described in <https://scikit-learn.org/stable/modules/clustering.html#clustering>.

## References

1. Jolliffe I. *Principal component analysis*. Springer, 2011.
2. Maaten Lvd and Hinton G. Visualizing data using t-sne. *Journal of machine learning research* 2008; 9(Nov): 2579–2605.
3. Roweis ST and Saul LK. Nonlinear dimensionality reduction by locally linear embedding. *science* 2000; 290(5500): 2323–2326.
4. Tenenbaum JB, De Silva V and Langford JC. A global geometric framework for nonlinear dimensionality reduction. *science* 2000; 290(5500): 2319–2323.

5. Borg I and Groenen P. Modern multidimensional scaling: Theory and applications. *Journal of Educational Measurement* 2003; 40(3): 277–280.
6. Murtagh F and Legendre P. Ward's hierarchical clustering method: Clustering criterion and agglomerative algorithm. *arXiv preprint arXiv:11116285* 2011; .
7. Von Luxburg U. A tutorial on spectral clustering. *Statistics and computing* 2007; 17(4): 395–416.



**Figure 5.** Second phase of ComNetVis usage which takes place with the network mapped to the canvas. The network can be rotated or translated by click and drag or Ctrl-click and drag, respectively, in the canvas. The toolbar, above the canvas, holds three sets of buttons. The first set of buttons, at the left, enables: increase/decrease of node size; emphasize node size proportionality to degree; reset node proportionality; increase/decrease node transparency; and increase/decrease link transparency. The middle set of buttons enables: show/hide centroid; show/hide best sphere center; show/hide best sphere surface; and recover initial position. The last set of buttons enables: save image; and download communities as a CSV file. The table, to the right, allows the analyst to change the number of communities associated to the network, and to change the color of the community, by clicking on the columns “Show” and “Hue”, respectively. The “Size” of each community changes in the table when the user changes the number of communities. The “Silhouette” score is a measure of how consistent are the clusters: higher values are associated to better clusters.