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3D radial layout for centrality visualization in graphs

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Abstract. This paper presents new methods of 3D visualization of graphs that allow to highlight nodes structural centrality. These methods consist in projecting, along the vertical axis, 2D graph representations on three 3D surfaces: 1) a half-sphere; 2) a cone and 3) a torus portion. The transition to 3D allows to better handle the visualization of complex and large data that 2D techniques are generally unable to provide. The 3D radial layout techniques reduce nodes and edges overlap and improve, in some cases, the perception of nodes connectivity by exploiting differently or better the display space.

Keywords: Radial layout · Immersive graph visualization · Centrality visualization

1 Introduction

Social network analysis is defined as a methodology that studies relationships between social actors [10]. It allows to model and visualize these networks of actors using graphs. Thus, within a network, we can often find groups actors according to a certain affinity [12] and isolated actors. However, the interpretation of this sociogram of affinities and/or rejections is sometimes not easy [11, 8]. Indeed, to interpret the affinities and rejections that can be observed in a network, one should take into account, on the one hand, personal and social factors which determine the form and content of relationships, and on the other hand, processes of the interaction between different actors.

Thus, it is common to determine metrics, in the field of graphs, that characterize the affinities or the rejections that can be observed or the importance of each actor in the network, and find a visualization technique that allows to highlight these metrics.

For this, many 2D graph visualization techniques are useful to visualize affinities in networks or to visualize the importance or the role that each actor plays in the network. However, when faced with large and complex data, these techniques are generally unable to provide appropriate visualization due to a lack of display space for example.

Therefore the analysis becomes complicated. It is then necessary to increase the data display space, and for this it is possible to adapt certain 2D techniques to 3D [4, 6], which still remains a vast area to explore [13].

In this paper, we illustrate our contributions to the transition to 3D from a 2D technique which allows to highlight the importance of nodes in the graph by their centrality.

2 Community management and graphs

Community management is an approach that consists in monitoring, controlling, influencing and defending the interests of a personality, a company or a brand on social networks. Thus, when analyzing a given social network, a community manager would need to understand the structure of this network; to identify different types of actors; to understand the nature of links of the neighborhood of certain actors; etc.

It is a business perspective that must be analyzed and transformed into a technical problem [5]. The network to be analyzed would therefore be a graph where each member would be represented by a node and where the edges between nodes could, for example, be friendship relations. In this graph, we would need to find the most important nodes, that is to say nodes which make bridge between others or the most central nodes, etc.

So, the importance of a node in a graph depends on the business interest and it can be characterized by a number of metrics such as centrality measures. In this paper, we are interested in two of them: the betweenness centrality and the closeness centrality [9]. The betweenness centrality is based on the frequency at which a node is between pairs of other nodes on their shortest paths. The closeness centrality shows, for its part, how close a node is to all the others in the graph.

3 2D visualization of centrality

The early work of [2], on graphs visualization, show the highlighting of betweenness and closeness centralities. [3] then propose a 2D radial approach by materializing the notion of centrality by concentric circles to illustrate the importance of nodes in the graph. This approach is based on an extension of stress minimization algorithm (MDS) [1, 7] by including radii of circles determined from the centrality values of nodes. So, nodes having a strong value of centrality are in the center and those of weak value to the periphery. They also propose to emphasize the center of the network or else its periphery. The central emphasis is to make more distinctive nodes that are in the center of circles, which concentrates all the other nodes on the periphery. On the other hand, the peripheral emphasis spreads nodes of the periphery.

Thus, figure 1 shows the highlighting of closeness and betweenness centralities with a famous social network studied by Zachary [14]. This network describes friendship relations between 34 members of the karate club of a U.S. university in the 1970s. It is therefore represented by a graph of 34 nodes and 78 edges and its 2D visualization makes it possible to clearly and unambiguously distinguish all the nodes and edges thanks to the uniform radial visualization, to the central

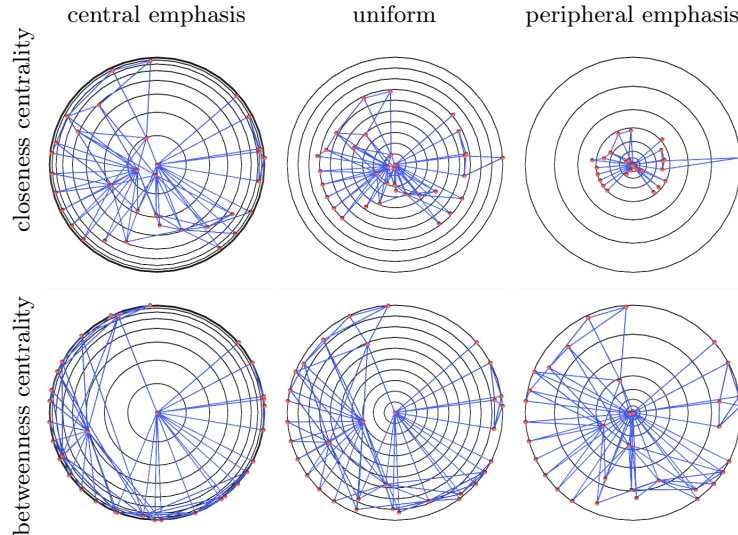


Fig. 1. Radial visualization of the karate club (34 nodes and 78 edges) [14]

emphasis and to the peripheral emphasis. Indeed, « center and periphery are emphasized using transformed radii $r'_i = 1 - (1 - r_i)^3$ and $r'_i = r_i^3$ ($0 \leq r_i \leq 1$ and $0 \leq r'_i \leq 1$), respectively » [3].

However, faced with data comprising a few hundred nodes and edges, it will be impossible to distinguish certain nodes and edges. As an example, we have considered a larger graph of 419 nodes and 695 edges. This graph represents a network of actors who fund projects together. Thus, one actor is in relation with another if they fund all together the same project or a set of projects.

Figure 2 shows the highlighting of closeness and betweenness centralities of our example. The result of this graph shows the inability to see the connectivity of some nodes, because some edges hide others, which makes the network analysis a little more difficult.

4 3D extension of graphs radial visualization

To extend these radial representations to the 3D domain, we propose to project them, along the vertical axis, on three different 3D surfaces so as to always keep the radial 2D view in top view. The three projection surfaces are: 1) a half-sphere, 2) a cone and 3) a torus portion. Each projection constitutes a 3D object with which one can interact. Thus, adding a third dimension to 2D radial representations allows to better distinguish the nodes connectivity.

In this paper, we are only interested in nodes placement and we will denote by *central nodes* the nodes that have a normalized centrality value equal to 1, *intermediate nodes* those with a normalized value belonging to $] 0 ; 1 [$ and *peripheral nodes* those that have a normalized centrality value equal to 0.

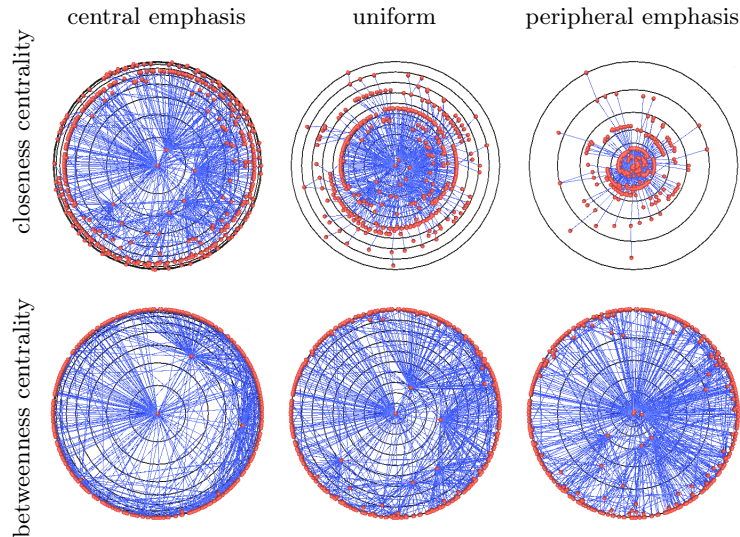


Fig. 2. Radial visualization of a larger graph (419 nodes and 695 edges)

4.1 3D extension of the uniform view

From the point of view of nodes distribution along the vertical axis, the spherical projection spreads out less the central nodes compared to the peripheral nodes. So the more nodes are on the periphery, the more they are spread out, which increases the visibility of gaps between them. The conical projection distributes nodes uniformly while the one on the torus portion spreads out less peripheral nodes. Figure 3 shows the result of uniform projections based on closeness and betweenness centralities.

When one changes the angle of view of the uniform spherical projection, one perceives much better the position differences of the peripheral nodes. So a uniform elevation over a half-sphere can provide both the benefits of uniform 2D representation and the peripheral emphasis. However it does not improve much the way of visually dissociating the central nodes from each other, since they are on top of the half-sphere. Moreover, edges between the center and the periphery are inside of the projection surface and some are hidden in dense areas.

The projection on the torus portion allows to better distinguish the central nodes. Moreover, we have an excellent view of edges between the center and the periphery, compared to the spherical projection, for with this approach, edges are outside the projection surface but some can also hide certain intermediate nodes. However, there are edge overlaps in dense areas, but less significant than those observed with the spherical projection.

The conical projection is an intermediate version of spherical and the torus portion approaches with a particular property for edges. Indeed, when one changes the angle of view, it moderately provides a visualization of the central and pe-

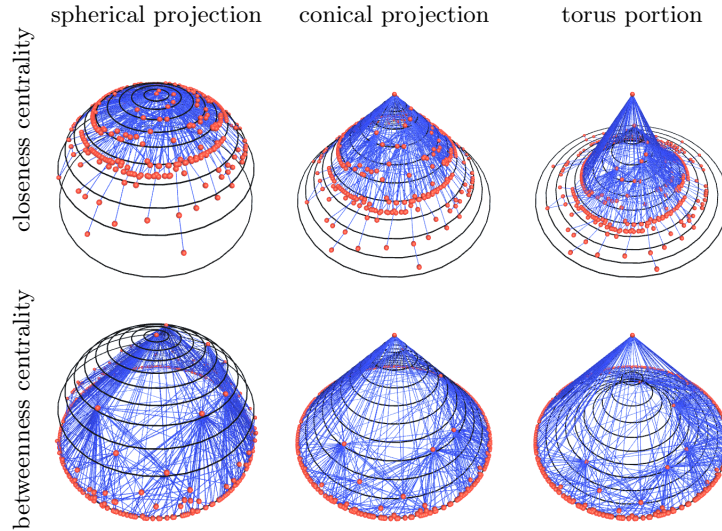


Fig. 3. Uniform 3D radial visualization (419 nodes and 695 edges)

ripheral nodes. With this approach, edges are mainly on the projection surface and are very visible, compared to the spherical approach.

Thus, an elevation on the half-sphere, on the cone and on the torus portion of the 2D uniform view provides, in addition, the benefits of the 2D representations emphasizing the center and the periphery.

4.2 3D extension of the central emphasis

Figure 4 shows the result of the projection of the 2D views that emphasize the center. The spherical elevation of the central emphasis evenly distributes the intermediate nodes on the lower part of the half-sphere. Compared to the 2D representation, the combination of the spherical elevation and the central emphasis helps to mitigate the crushing of the intermediate and peripheral nodes. Thus, thanks to 3D, we reduce the crushing of the 2D radial view that emphasizes the center. Unlike the uniform elevation, the elevation of the central emphasis gives good visibility of edges between the center and the periphery. However, certain edges of the central nodes are hidden towards the periphery by the edges of the intermediate nodes, because they are much more inside the projection surface.

However, by combining the conical projection and the central emphasis, we reduce a little nodes crushing on the periphery and we improve the visibility of edges between the center and the periphery. So, thanks to the cone, we reduce a little the crushing of the 2D radial view that emphasizes the center, compared to the spherical approach where the crushing reduction is more important.

The projection on the torus portion of the central emphasis crushes all the intermediate and peripheral nodes and only highlights the central nodes. Also,

it provides a better view of the edges between the center and the periphery, compared to the conical elevation of the central emphasis. However, it is much more complex to identify the edges of the peripheral nodes, unlike the spherical and conical projections that emphasize the center.

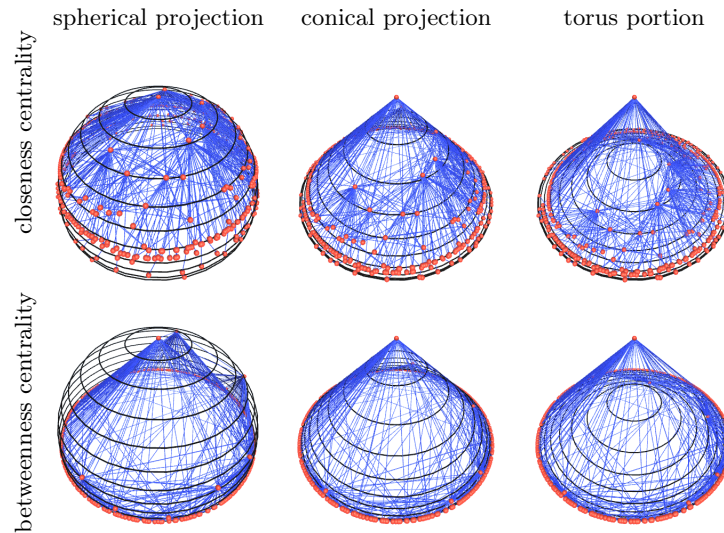


Fig. 4. 3D radial visualization that emphasizes the center (419 nodes and 695 edges)

4.3 3D extension of the peripheral emphasis

Figure 5 shows that the combination of the peripheral emphasis and elevations on a half-sphere, on a cone and on a torus portion gather the central nodes on the upper part of the projection surface and spread out the peripheral nodes.

For the spherical and conical elevations of the peripheral emphasis, the intermediate nodes can still be seen even if they are grouped together. On the other hand, with the elevation on the torus portion of the peripheral emphasis, some intermediate nodes are hidden by the edges of the central nodes. Unlike the spherical and conical elevations that emphasize the periphery, the elevation on the torus portion of the peripheral emphasis always gives a view of the center and the periphery but with sometimes a little overlap.

4.4 Discussion

A uniform spherical elevation provides the same benefits as the uniform 2D view and the one emphasizing the periphery from different angles of view. With uniform conical projection, we have a good view of the edges between the center and the periphery. The projection on the torus portion provides an excellent view

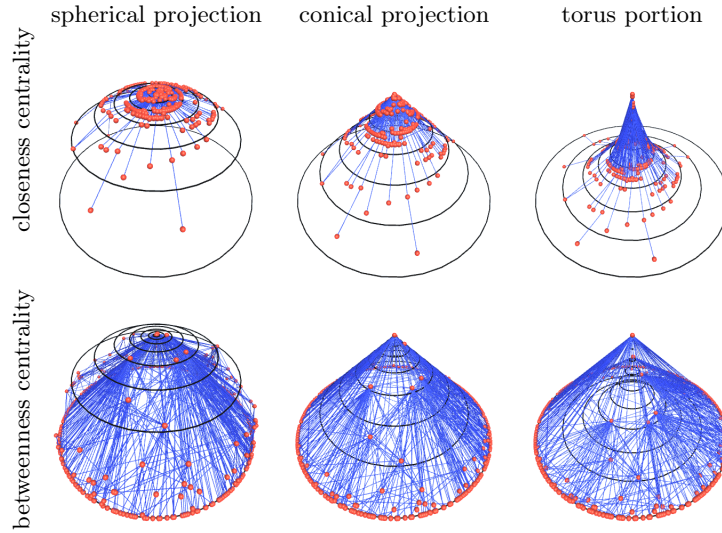


Fig. 5. 3D radial visualization that emphasizes the periphery (419 nodes and 695 edges)

of the center and the periphery. Thus, the uniform spherical projection gives the same advantages as the peripheral emphasis, the uniform projection on the torus portion the same advantages as the central and peripheral emphases, and the uniform conical projection is an intermediate version of the spherical and torus portion approaches.

The 3D transition of 2D representations that emphasize the center or the periphery also has considerable advantages. Indeed, the spherical and conical projections of the central emphasis allow to reduce the crushing of the 2D view and to have good visibility of the edges between the center and the periphery. The projection on the torus portion of the central emphasis representation provides an excellent view of the center and the periphery, compared to the spherical and conical approaches.

The projection on different 3D surfaces of the peripheral emphasis allows to spread the peripheral nodes to improve the visibility of their edges. So, the elevation on the torus portion of the peripheral emphasis provides the same benefits as the central and peripheral emphases thanks to 2D and 3D respectively, unlike the spherical elevation of the peripheral emphasis which only provides the benefits of the peripheral emphasis. The conical elevation of the peripheral emphasis also provides, but moderately, the same benefits as the peripheral and central emphases. A summary of the pros and cons of each approach is presented in table 1.

However, some nodes and edges are less visible in dense areas according to the projection surface. Indeed, with the spherical projection, the edges are inside the surface and some edges hidden, and there are others that cross the half-sphere. On the other hand, with projections on the cone and on the torus portion, the

majority of the edges are respectively on the projection surface and outside the surface and there is less overlap compared to the spherical approach. With the combination of the peripheral emphasis and the projection on the torus portion, some intermediate nodes are less visible due to the edges of the central nodes, unlike the spherical and conical projections.

Table 1. Summary table of the different approaches.

	Uniform view	Central emphasis	Peripheral emphasis
2D approach	+ uniform nodes distribution according to their centrality value - too much node and edge coverings	+ central nodes spreading - covering of nodes and edges	+ peripheral nodes spreading - covering of nodes and edges
Spherical projection	+ good visibility of peripheral nodes - some edges are less visible	+ highlighting of the periphery and the center thanks to 3D and 2D respectively - covering of certain edges	+ double spreading of the peripheral nodes thanks to 2D and 3D spreads - loss of visibility of the center because of the surface type
Conical projection	+ good visibility of the center and the periphery - some edges are less visible	+ uniform 3D spreading of nodes thanks to the cone - some edges in periphery are less visible because of 2D	+ highlighting of the periphery and the center thanks to 2D and 3D respectively - some edges are less visible due to 2D
Projection on the torus portion	+ excellent visibility of the center and the periphery - some intermediate nodes are less visible	+ better visibility of edges between the center and the periphery - some nodes are less visible due to 2D	+ highlighting of the periphery and the center thanks to 2D and 3D respectively - some nodes are less visible due to 3D

5 Conclusion and outlooks

We described three new methods of 3D graph visualization which consist in projecting on three different surfaces, according to the vertical axis, the 2D radial representations [3] highlighting the notion of centrality. These methods are a first transition to 3D of the concept of 2D "radial layout". The results of this work show, while preserving the characteristics of the 2D radial view (which can always be perceived in "top view"): 1) that a uniform spherical elevation

gives a peripheral emphasis; 2) that a uniform elevation on a torus portion gives a central emphasis; 3) that an elevation on a cone provides the same benefits as the central and peripheral emphases, but less pronounced than elevations on the half-sphere and on the torus portion. These elevations also improve, in some cases, the perception of edges. In addition, the 3D transition of 2D representations that emphasize the center or the periphery allows to mitigate the crushing of 2D radial views according to the projection surface and to reduce the overlap of nodes and edges that can be observed with the 2D representations.

In the future, we will also study in detail the results obtained during the visualization of large data in terms of number of nodes and edges in order to identify the right approach to be used to visualize them. Moreover, we will work on improving the edges representation: either 1) by projecting them onto the surface in order to reduce the overlap of nodes or 2) by using the edge bundling algorithm to reduce the overlap of edges. We will also study other types of 3D surfaces and types of projections in order to identify the most appropriate approach or combination of approaches that could be used to visualize large and complex data.

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