Polygonally Anchored Graph Drawing

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Abstract

We investigate force-directed graph drawing techniques under the constraint that some nodes must be anchored to stay within a given polygonal region associated with it (i.e. some positional information is known). The low energy layouts produced by such algorithms may reveal geographic information about nodes with no such knowledge a priori. Some applications of graph drawing with partial positional information include location-based social networks and rail networks, where the geographical locations need not be precise.

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1 Introduction

We explore polygonally anchored graph drawing, where some nodes may have positional information in the form of a polygonal region. In particular, we use the standard force-directed graph layout algorithm by Fruchterman-Reingold [4], modified to restrict nodes to their associated "anchor" region (if specified). The low energy layouts produced by such algorithms may reveal geographic information about nodes with no such knowledge a priori. Some applications of graph drawing with partial positional information include location-based social networks and rail networks. Work by social scientists supports the idea that one's social network (of family, friends, coworkers, etc.) is one of the best predictors for the region they identify with [1]. And in rail networks, stations and connections are often associated with the area they bring service to, so their placement in a map may be ambiguous [7, 2].

Related work has considered anchored graph drawing, where the input graph is assumed to have full positional information that must be respected in some way [6]. Other works have used centroidal forces as we do to keep a node inside a given region [8].

We investigate three different metrics of forces used to constrain a node to its associated region. We call this region its *anchor*, and a node with an anchor is called a *vessel*. In the Fruchterman-Reingold algorithm, repulsive forces between nodes and attractive forces between adjacent nodes are applied iteratively until the global "temperature" of the system decays to 0, a quantity that controls the amount of displacement [5]. Our modification is to introduce an additional force from the vessel nodes to their anchors that is applied in each of these iterations. In order to ensure that the vessel remains tethered to its anchor region, we apply a displacement force towards the region (where exactly is determined by the metric), multiplied by a sufficiently large constant to act as if it were an "infinite force".

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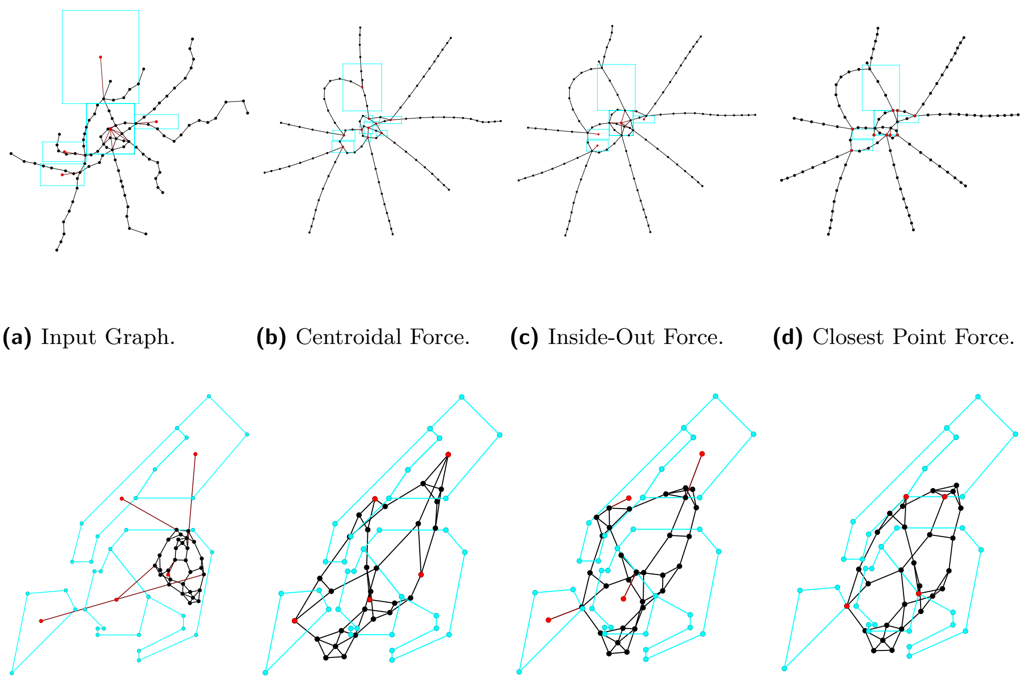

(a) Input Graph. (b) Centroidal Force. (c) Inside-Out Force. (d) Closest Point Force.

Figure 1 The black nodes and edges denote the original input graph, while the teal denotes the anchor regions. The anchoring forces are shown with a red edge connecting the vessel to the last point to pull it (the red node may overlap the vessel). The top image shows an input graph of the Vienna subway map with real geographical locations, where the 10 stations with intersections/transfers are anchored geographically. The bottom image shows a social network in Queens, one of the 5 boroughs of NYC. 5 nodes are then anchored to one of the 5 boroughs.

In the first metric that we call the *centroidal force*, every point in the anchor region applies an displacement force (the displacement vector from the vessel to the point) on the vessel node. We show later that this metric is identical to applying one singular force from the anchor's centroid, scaled up by the anchor's area. Hence, this force degenerates into the case where the anchors are simply points, which has been explored in prior work [3].

The second metric, *inside-out force*, is similar to the first in that we pull a vessel node inside to the anchor's centroid, but we only apply this force if the vessel is outside the anchor region (and so zero force is applied if inside).

Finally, the third metric is the *closest point force* that also applies zero force if the vessel node is already inside the anchor region, but otherwise applies a force from the closest point in the anchor to the vessel.

We now show that applying a force from all points in a region is indeed equivalent to applying one singular force from the region's centroid, scaled by the region's area. Let $v = (v_x, v_y)$ be a vessel point attached to an anchor point (x, y). Then the force vector F we apply on the vessel is $F = C \cdot \langle x - v_x, y - v_y \rangle$ for some large constant C.

Let P be the region defined by an anchor with area A. Its centroid will be given by the point $c = (c_x, c_y)$, where

$$c_x = \frac{\iint_P x\, dx\, dy}{\iint_P dx\, dy} = \frac{\iint_P x\, dx\, dy}{A}, c_y = \frac{\iint_P y\, dx\, dy}{\iint_P dx\, dy} = \frac{\iint_P y\, dx\, dy}{A}$$

If every point (x, y) in an anchor region P applies a force $C \cdot \langle x - v_x, y - v_y \rangle$ on the vessel point, then the total force applied will be

$$F_x = \iint_P C \cdot (x - v_x)\, dx\, dy = C \cdot \iint_P x\, dx\, dy - Cv_x \cdot \iint_P dx\, dy = CA(c_x - v_x)$$
$$F_x = \iint_P C \cdot (x - v_x)\, dx\, dy = C \cdot \iint_P x\, dx\, dy - Cv_x \cdot \iint_P dx\, dy = CA(c_x - v_x)$$

Notice that this force is equal to just one force being applied from the centroid c, scaled up by the anchor's area A.

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