Animating Disease Spread with Location Type

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1 Introduction

One of the applications of graph drawing is visualising disease spread in a population. Specifically, event-based graph animation can help visualise contact tracing model simulations. Building on the DynNoSlice algorithm [4,3], we propose a way of incorporating two types of relationships useful in epidemiology into a dynamic graph embedding: the vector-infected relationship as well as the 'location of infection' relationship. We focus on a Covid contact tracing model [2], which provides information on an infected person's infection status, who they were in contact with and the place or setting where they were infected. These characteristics are accounted for in the presented algorithm, and encoded, respectively, with colour (including saturation), insertion of edges (denoting either the location, or the infection relationship), and grouping of nodes with using the 'cluster' type elements. Graphs are embedded synchronously on a $2D$ plane, and in a space-time cube, with planes as time slices arranged perpendicularly to the time axis T. Variations of the algorithm use graph forces in either *2D* or *2D + T*, component filtering, and node highlights to accentuate various aspects of the model.

2 Clusters and cluster forces

We propose an additional *cluster* graph element. It facilitates visual encoding of commonalities between nodes. Related nodes become *members* of a cluster, attracted towards its *pole*, represented as a location node in a *2D* embedding. Non-cluster-specific forces in the algorithm follow the DynNoSlice algorithm [4,3] and are in *2D + T*. The presented algorithm introduces a number of new forces to position clusters in the embedding, and which also are functions of regular nodes' relationships to cluster pole nodes, other cluster member nodes and non-member nodes. A member node, also marked out with an edge inserted between it and its pole, is affected by the following forces:

1. A node-to-node attraction force is applied between the pole node and the cluster's member nodes.
2. A circumference repulsion force, itself a node-to-edge force, repelling nodes from an abstract polygon superimposed on the circumference, modelled after the PrEd algorithm [1].

$$F(v,(a,b)) \longleftarrow \frac{(\gamma - \|p_v - v_e\|)^2}{\|p_v - v_e\|}(p_v - v_e)$$

$$v \in (a,b),\ a \neq v, b \neq v,\ \|p_v - v_e\| < \gamma$$

Where p_x is the position of node x, γ is the desired distance from a node to an edge, and v_e is the position of node v on a line which is defined by the edge (a,b).

3. A node-to-pole repulsion force is applied to every non-member node (all nodes that are unassigned to a cluster).

$$F^r_u(v,u) \longleftarrow \left(\frac{\gamma}{\|p_v - v_e\|}\right)^8 \widehat{vu}$$

γ is the desired distance between two nodes, p_u and p_v are the positions of the member node and the pole node respectively, and $\widehat{vu}$ is the unit vector pointing in the direction from p_u to p_v. The exponent value of 8 was determined through experimentation on our data sets.

Variations of the algorithm allow for the pole nodes to be pinned to one location in *2D*, which then affects the space-time cube synchronised view. Then the algorithm generates forces that are different in *2D* and *2D + T*.

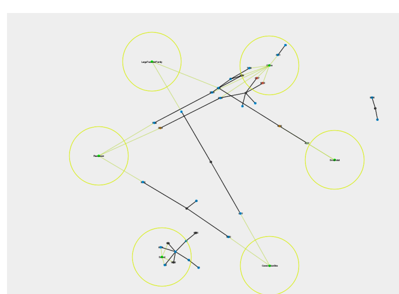
3 Functionalities

The implementation offers a range of options to highlight, filter or compare data set features from the perspective of location. Each of these options creates a dynamic graph animation corresponding to its space-time cube drawing. One of the algorithm variations is implemented as *Continuous with Multiple Locations Attraction*.

Given multiple location nodes n_i (where n stands for a cluster's index), each embedded as a cluster pole node, represent a given set of locations. All nodes associated with location i will be encouraged to stay within the i'th cluster's circumference. If there are enough vectors pulling node n_i in the attracted node's component away from the i'th cluster, there is a chance that n may be pulled out of the circumference.

Infection status	Colour encoding
Exposed	
Asymptomatic	
Presymptomatic	
Symptomatic	
Severely symptomatic	
Recovered	
Dead	

Colour scheme for nodes



6 location nodes pinned in $2D$

References

1. Bertault, F.: A force-directed algorithm that preserves edge-crossing properties. Information Processing Letters **74**(1-2), 7–13 (2000)
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3. Simonetto, P., Archambault, D., Kobourov, S.: Event-based dynamic graph visualisation. IEEE Transactions on Visualization and Computer Graphics **26**(7), 2373–2386 (2020)
4. Simonetto, P., Archambault, D., Kobourov, S.: Drawing dynamic graphs without timeslices. In: International Symposium on Graph Drawing and Network Visualization. pp. 394–409. Springer (2017)