Dynamic Graph Visualization on WebGL

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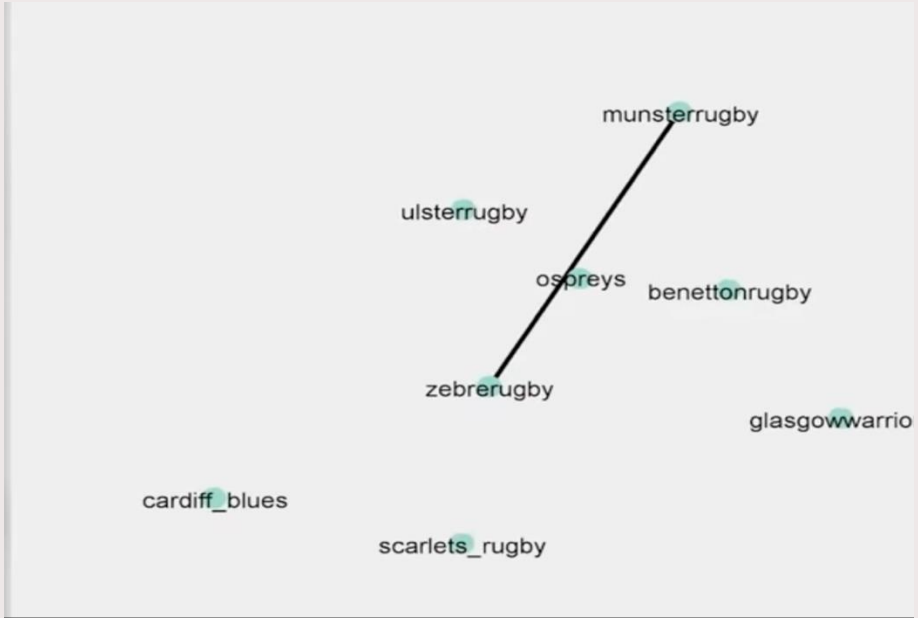
Dynamic Graph Visualization

- Evolution of relationships between entities.
- A temporal graph is used to store events between entities.
  - Entities are encoded as node in a static graph
  - Events between entities are encoded as undirected edges
- An offline dynamic graph has complete knowledge of all event details in advance.
- Modeling the distance between entities.

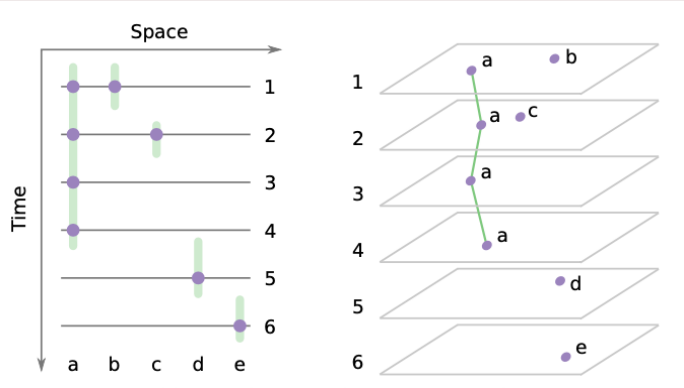
Dynamic Graph Visualization Demo

Rugby teams' competition network



Dynamic Graph Approaches

- Time-sliced Graph
  - Static graph in every snapshot
  - Advantage in structured data--- Vandebunt
  - Loss of information about potential events
  - Difficult to determine slicing creiteria

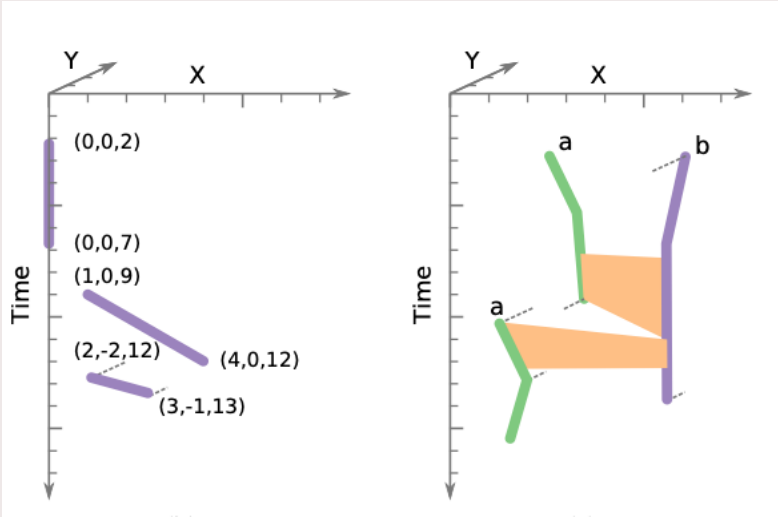


Dynamic Graph Approaches

- Integrated Diagram
  - Convert time into distance in 3D space
  - Preserve all details of temporal network
  - Visualization in Time-Space cube

    node -> trajectory

    edge -> connection surface



Dynamic Graph Computation

- Force-directed algorithm
  - Node Repulsion

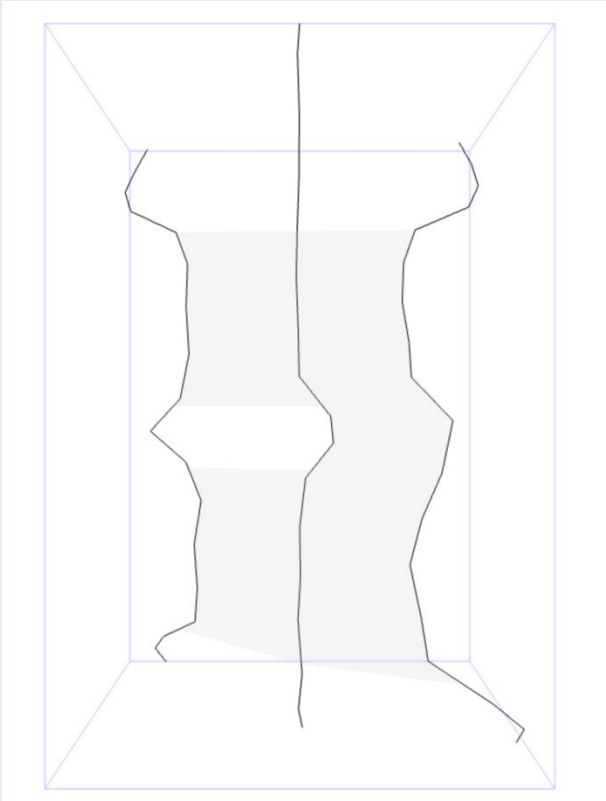
  force repels trajectories from each other

$$F_u^r(u, v, d) = \left(\frac{d}{||p_u - p_v||}\right)^2 (p_u - p_v)$$

  - Edge Attraction

  force attracts the node of edge toward each other, decreasing the length of the edge

$$F_u^c(e, d) = \left(\frac{||p_u - p_v||}{d}\right)(p_v - p_u)$$



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Dynamic Graph Computation

- Time Straightening

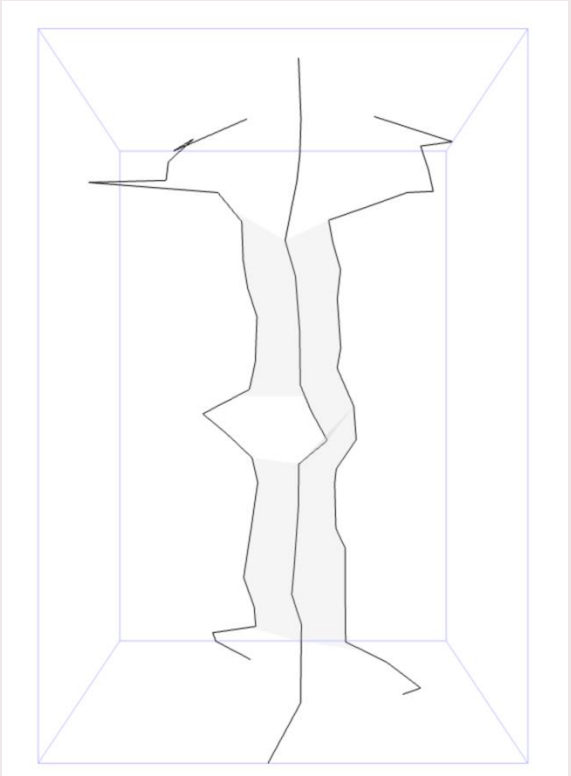
force smooths node trajectories, reducing node movements over time

- Straightning: smooth line segment globally

$$f = \sum_{j>i}(v_{2D}(\frac{\frac{\pi}{2}-\theta}{\theta}))$$

- Smoothing: smooth line segment locally

Pull the node closer to the centroid of adjacent nodes



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Model Framework --- Data Structure

- Computation units for nodes and connections in Time-Space Cube.
  - Allowing potential improvement in parallel force computation.

- Iteratively computes the forces until convergence
  - Adds or removes bends in the node trajectory during each cycle
  - Imposes constraints on maximum movement and acceleration
  - Corrects the time coordinate with real dataset

Model Framework --- Visualization

- WebGL
  - high-performance rendering 3D graphics on GPU
  - Advantages on animation of graph evolution
  - Renders surfaces using triangle strips

    Serializes the node coordinates into the vertex shader
  - Server-Client environment accelerating the computation speed

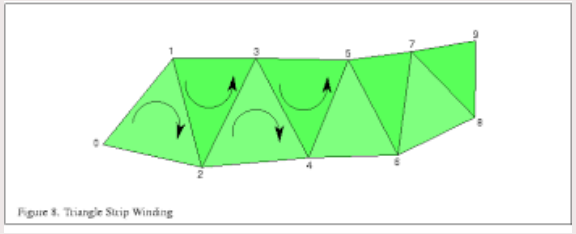

Figure 8. Triangle Strip Winding

Challenges

- High Computation Complexity of Node Repulsion
  - $O(b^2)$ for b bents
- Hyperparameter Tuning
  - Time-Space conversion factor τ
  - Desired Distance between nodes δ
- Initial Replacement
  - Preventing large movement at the begin and end time

Improvement

- Exploiting WebGL Parallel Computation on Node Repulsion
  - Splits force calculations among nodes and computes them in parallel
- Hyperparameter Tuning
  - AutoTau
- Initial Replacement
  - Pre-computes the average node connections to initialize clusters.

Measurement Metrics

- Crowding
  - The number of times nodes pass close to each other in animation.
- Movement
  - The average 2D movements of nodes.
- Stress
  - Measures how well the Euclidean distances in the graph layout preserve the shortest path distances in the original graph.

Dataset

- Vandubent: Student relationship across seven different timeframes.
  - Time-sliced
  - 32 nodes and 49 connections
- Rugby: Competition news of rugby teams on Twitter (X) over a year.
  - Continous
  - 12 nodes and 888 connections(merged repeated news)
- Dialog: Dialog from all chapters of book “Pride and Prejudice”
  - Continous
  - 118 nodes and 3481 connections

Demo

Q&A