TOWARDS A GEOMORPHOLOGICALLY-PLAUSIBLE SPATIALIZATION OF GRAPH DATA

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Introduction

Spatialization, the imposition of spatial representation and structure on non-spatial data, has been a useful tool in information visualization. It has often been applied to large corpuses of documents, potentially mining hidden space, time or attribute relationships or a combination of these (e.g. Bruggmann et al, 2020). Spatializations often use map (e.g. the example above) or landscape visual metaphors (e.g. Russwurm and Moore, 2015 for university teaching curriculum and associated teaching difficulty).

For these spatializations to work as data communication media, they need to be cognitively plausible (Skupin and Fabrikant, 2003). For the (natural) landscape metaphor in particular (but also for topographic maps that represent surface terrain by contours and hillshading), this means that the spatialisation needs to be geomorphologically plausible (Fabrikant et al 2010; Liebmann et al (2014) add to this morphological basis with a geological metaphor - surface colour rendering of non-spatial attributes derived from a geological strata schema).

Fabrikant et al (2010) have investigated how the landscape metaphor works cognitively, in particular if landscape spatializations are effective due to a shared ontology of “common sense” geomorphological landforms (hills, valleys) and process (tectonics, erosion, deposition). They found that neither spatialization developer or user used their understanding of geomorphology in relation to the spatialization and the data it depicts, signposting a role for geomorphologists in facilitating future landscape and topographic map spatializations (Smith et al, 2022).

Many transformation techniques have been used to transform multi-dimensional non-spatial data into 2D spatial data, to be rendered as maps or landscapes. Bruggmann et al (2013) apply a self-organizing map (SOM) process, subsequent to a cartogram stage. Xin et al (2021) follow the dimension reduction stage by a kernel density (KDE) and fractal noise process to generate synthetic surfaces. Gronemann and Juenger (2012) specifically worked with clustered graphs subjected to a tree mapping process.

Of particular interest in the current abstract context, Salvini et al (2011) subjected a graph of cities and their inter-relations (based on air passenger volumes) to a force-directed placement algorithm before segmenting the graph by clustering and performing areal allocation via a multiplicatively weighted Voronoi (MWV) algorithm. The strength of links was visually communicated through boundary representation (Salvini at al 2011). Russwurm and Moore (2015) used MWV to allocate area to unconnected work task seed points in an abstract space, an approach that will be applied here to a network graph of music bands and their inter-connections via musicians, which was originally plotted with aid from a force-directed process (Figure 1).

This project is an exercise in using naïve geomorphological landform and process knowledge to synthesize topographic map-based visualizations of non-spatial phenomena. The next section sets out the application and data context that will underpin the spatialization (graph data of bands that were part of the Dunedin music scene in its heyday). Then there will be an exploration of two geomorphologically-plausible algorithms to construct the spatialization from the graph data, before some concluding thoughts.

Application and Data Context

The Dunedin music scene from the late 1970s to the early 1990s was heavily associated with the albums and songs coming out of the Flying Nun NZ record label (as well as a thriving live music scene), with bands such as The Chills known and renowned internationally. To commemorate this period in NZ music history, an exhibition, "Kaleidoscope World: 40 Years of Flying Nun in Dunedin" is currently running. One of the exhibits, a network graph capturing the complex interlinkages of the bands and musicians in a healthy music scene, will be described initially, as it is the source of data and locations for the proposed spatialization.

The data source of the graph itself was "The Sound of Dunedin Band Chart" (styled as a Gantt chart) by Robert Scott, one of the musicians of the scene. This is a temporal graphic from 1997-1993, the most active years, with bands represented in the timeline during their years of existence. Each band entry was annotated with the names of band members. In his covering note, Scott laid down the challenge "… I've avoided trying to join up the bands and members with little lines (someone else can try that)", and this is what we set out to do.

A JSON data file was compiled to capture the network of bands and musicians, recording them as nodes, and associations between them as links. Attributes of year started and duration of existence were attached to the band nodes. A force-directed graph was constructed from the data using the d3.js Javascript visualization library, with adjustments made for legibility. Over 150 bands featuring nearly 400 musicians were represented in the full graph (a subset of this graph is shown in Figure 1).

As a graphic in 2D space, the graph is in some sense a spatialization, though with limited geographic cognition cues. In constructing a true spatialization, we wanted to produce a map that is redolent of the geography of the time of the music scene and also represented its strong attachment to place. For that reason, the NZMS 1 national map series was chosen for styling (Figure 2), with Dunedin (just to the west of the extract) and its surrounding natural area (of tectonic origin, including the Otago Peninsula shown) containing rich geomorphological information. The band data is the principal generator of terrain for the spatialization, with interlinkage via musicians.

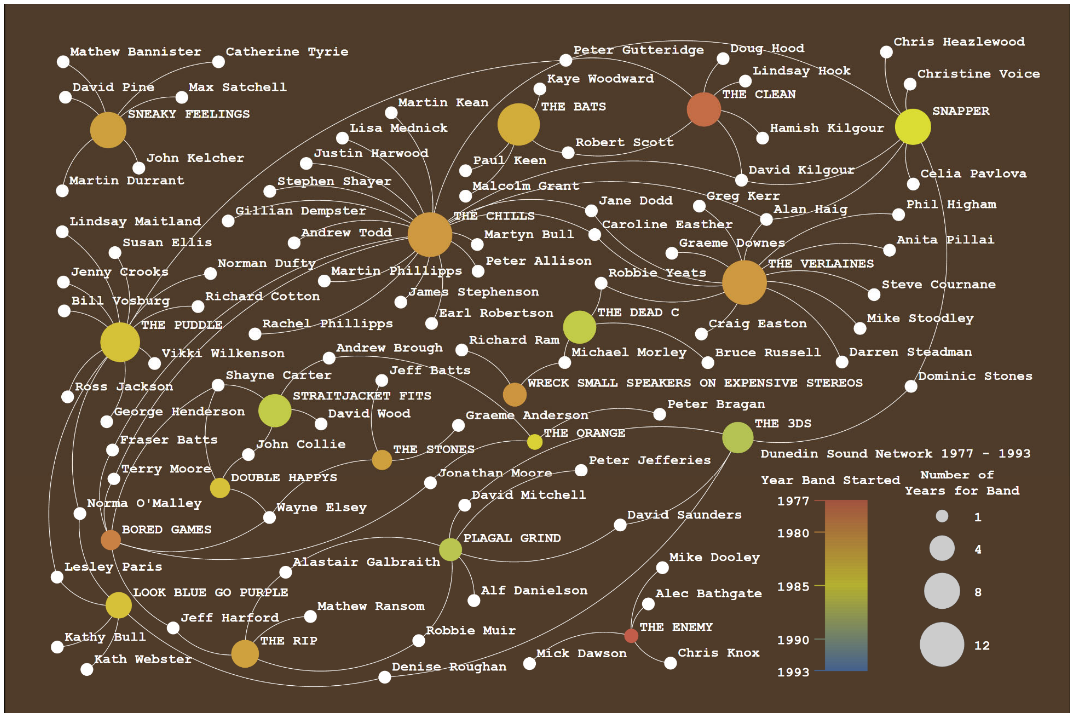

Figure 1: A subset of the Dunedin Sound Network 1977 – 1993 graph of bands interconnected via musicians, with bands symbolised by colour for start year and size for duration of existence (colour design by Ella Sutherland).

Figure 2: Extract from the NZMS 1 map series (1979; from mapspast.org.nz).

Figure 3 is a conceptual graphic indicating one way in which the music graph configuration could be adapted into a geographically and geomorphologically rich topographic map. Here, the bands would correspond with the peaks in the landscape, their height corresponding with year of origin, the area they occupy proportional to number of years of existence. Links to other bands would be in the form of transport infrastructure, from tracks to roads, with musicians residing as settlements at the confluence of paths from the band(s) they were a part of (another geographic metaphor is at play here in that the larger number of paths converging, the larger the settlement). An additional layer of information could come in the form of annotation, labelling music style clusterings in the same way that land cover is labelled in the original topographic map (e.g. "sandhills and marram grass" near Allans Beach in Figure 2).

Figure 3: Conceptual graphic combining music graph configuration with topographic map styling.

Towards spatialisation

This scheme seems intuitive, through the conceptualization and manifestation of time and importance. Music bands and landforms both have a time of creation, a period of existence, before ceasing to be. More years of band existence means more space in the map and prominence is given by added height to the earlier, significant pioneering bands, though the vertical (i.e. that suggested by relief) timeline is perhaps counterintuitive for communicating the year the band started, in that a bottom to top direction agrees with space-time cube convention. Therefore, is such a scheme geomorphologically plausible?

Starting with landform, we propose to use the simple sigmoidal hill profile forms imbued with fractal noise applied in Russwurm and Moore (2015). This produces morpholological forms of the limited complexity of the naïve static geomorphology shared by developer and user. But for geomorphological plausibility there is also a need for a shared "common sense" knowledge of, and interpretation via, geomorphological process. Two process algorithm scenarios are presented here: one is a simple mountain uplift generation mechanism for the spatialization, the other, an equally simple young volcano scenario. The general approach is that the bands are added to the abstract space, in temporal order and one at a time, geomorphic process being applied to its areal segment of space, calculated and updated by MWV.

Mountain uplift algorithm:

```
input (bands[], years[], durations[], graph_locations[]):
  ordered_bands OB[] = sort bands[] by their corresponding years[]
  formed_bands FB= []
  disbanded DB= []
  for each OB:
       place current point on map at corresponding graph_location[]
       calculate MWV for areal allocation
       add OB[current] to FB
       for each DB:
            calculate MWV for areal allocation
            apply uplift (OB.years[current] – OB.years[current-1])
            apply erosion(OB.years[current] – OB.years[current-1])
       for each FB:
            if FB.years[current] + FB.duration[current] <=OB.years[current]:
                calculate MWV for areal allocation
                apply spread(FB.years[current]+FB.duration[current] - OB.years[current-1])
                move FB[current] to DB
            else:
                calculate MWV for areal allocation
                apply spread(OB.years[current] – OB.years[current-1])
            apply uplift (OB.years[current] – OB.years[current-1])
            apply erosion(OB.years[current] – OB.years[current-1])
  return spatialized_map
```

Young volcano algorithm:

```
input (bands[], years[], durations[], graph_locations[]):
  ordered_bands OB[] = sort bands[] by their corresponding years[]
  formed_bands FB= []
  disbanded DB= []
  for each OB:
       place current volcano on map centred on corresponding graph_location[]
       calculate MWV for areal allocation
       add OB[current] to FB
       for each DB:
            calculate MWV for areal allocation
            apply erosion(OB.years[current] – OB.years[current-1])
       for each FB:
            if FB.years[current] + FB.duration[current] <=OB.years[current]:
                calculate MWV for areal allocation
                apply spread(FB.years[current]+FB.duration[current] - OB.years[current-1])
                move FB[current] to DB
            else:
                calculate MWV for areal allocation
                apply spread(OB.years[current] – OB.years[current-1])
            apply erosion(OB.years[current] – OB.years[current-1])
  return spatialized_map
```

The mountain uplift algorithm is supposed to represent the "earlier is higher; duration is larger" scheme described at the end of the last section. Uplift occurs at a faster rate than downward erosion, with areal spread only occurring during the time of band existence. In the young volcano algorithm, a volcano is initialised upon the band's inception, then subjected to spreading (through eruptions) during the band's existence, which stops when the band ends. A persistent erosion process ensures that the older band volcanoes are lower in the landscape, which makes this algorithm the more geomorphologically realistic.

Concluding thoughts

This contribution has set out a scheme on how to create spatializations that use topographic map and landscape metaphors with cognitively-plausible geomorphology landform and process built in. Some "common sense" solutions have been presented, but it remains that not a lot is known about what a naïve ontology of geomorphological landform and process actually is (Fabrikant et al, 2010). Once the topographic map music spatialization has been created, it will be tested for usability, but a part of that will be an assessment of the "straw person" algorithms presented here as a means to establish the shared geomorphological knowledge base between developer and user.

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