Towards data-based artworks in geovisual analytics

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Abstract

This work builds upon the research agenda for cartography and Big Data, specifically linking to data-based artworks in a geovisual analytics context. Art is a medium that potentially affords easily-assimilated, complex and flexible representations of data. The generation of such artworks using two fractal-based methods is initially described, supported by the example of New Zealand cities and city streets. On one hand, the use of head/tail breaks to extract "natural cities" and within them, "natural streets" captures emergent organic hierarchies based on size as well as producing shapes of aesthetic value. On the other hand, attribute and geometric parameters associated with spatial data can be used to build fractally-generated "objects of beauty" such as the Barnsley fern leaf (in effect becoming a multivariate symbol such as the Chernoff face). These are the building blocks of the artwork, which finally undergoes a style transfer process (using the convolutional neural network-based Google Deep Dream). Since the artwork is explicitly built on data, it would be possible to place this display in a linked and brushed geovisual analytics tool. This paper ends with a discussion of the possibilities of art-enabled geovisual analytics.

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1 Introduction

Spatial data is increasingly generated and consumed in quantities that stretch established map-making conventions. The challenge posed by this Big Data (characterised by high velocity and variety as well as volume) has been recognised by cartographers. In a research agenda on visual analytics for Big Data, the potential of artworks for complex and flexible representation of data was set out [2]. Humans can quickly assimilate the contents of an artwork, picking out salient features as well as prevalent patterns, whilst enjoying the spectacle. If data was transformed into art, any patterns and anomalies would be communicated effectively. However, the original spatial and non-spatial context needs to be provided, to ground the artwork (for which data representation rules have been loosened) with "known" displays such as maps and graphs.This abstract will end up by exploring the linking and brushing conventions of visual analytics tools as a setting for data artworks. First though, we will look at how artworks can be generated from geographic data using fractals.

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2 Generating data artworks

2.1 The use of fractals to extract spatial structure

On the question of how to transform data into displays with aesthetic value, use of fractals was suggested [2]. Since Mandelbrot devised and applied fractal maths in both aesthetic (Mandelbrot set) and geographic ways (fractal dimension of the GB coastline) [6], it has been used to recreate the visual form of many other natural (terrain, stream networks, flora) and to a lesser extent, manmade geometric structures (e.g. the form of the city [13]). Thus, there is an overlap between the aesthetic and the geographic here that can be exploited in the systematic generation of artworks.

The above examples of fractals are based on explicit geometric form, which limits the agency of fractals in the current context. As an alternative frequency-based fractal generation technique, head / tail breaks are predicated on a general law that there are many more objects of smaller magnitude than there are objects of larger magnitude, and what is more, the relationship of frequency and magnitude of objects follows a power law [3][4]. For example, geographically, there are many more small settlements than there are large settlements, and within those settlements, there are many more short streets than there are long ones.

Methods have been developed to calculate the footprints of settlements, bottom-up, from the triangulation of street network junction points [5]. The shorter triangle edges indicate denser networks found in larger settlements. These settlements ("natural cities") are isolated by splitting the edges into those above the mean edge length (the "head") and those below the mean (the "tail", which form "natural" city patch triangulation shapes of aesthetic value).

This group of settlements is then split on the basis of area, into those above the mean area value ('head') and those below that mean ('tail'). In the second round, the head is itself divided into two by its own mean value. The process continues recursively until there is one instance left in the head, the largest settlement. If applying a similar process to a population of streets, recursive division would similarly occur, based on mean street length.This effectively performs a head / tail break classification of settlements (or streets), capturing the natural hierarchy (spatial structure) of these built elements.

2.2 The use of fractals to generate objects of aesthetic value

As mentioned, this is a recursive fractal process based on frequency according to size rather than geometry. Fundamentally, it widens the geographic scope of phenomena that could be captured by fractals, particularly many man-made objects (e.g. buildings) that have regular (i.e. non-fractal) geometry. Furthermore, these frequency-based fractal properties can be transferred to geometry-based fractal properties of objects (e.g. the Barnsley fern, fractal tree [15]) in a fractal-based artwork. Geometrically, fractals are capable of generating artifacts of beauty [5]. We have seen this process, with head / tail breaks used to isolate beauty in geography, based on the features above, to create 'natural cities' and 'natural streets' with a correspondingly naturally emergent hierarchy from the bottom up [4].

An NZ road network example has been derived from crowdsourced OpenStreetMap data (https://www.openstreetmap.org) (Figure 2, top-left), following the workflow used in [4]. Boundaries of the cities in the top tiers of the natural cities hierarchy were then used to clip the road network, prior to the derivation of a natural street hierarchy for each city.

As well as generating natural looking geometric forms, head / tail breaks have parameters that can be used to generate fractals. These are both essential building blocks in transforming spatial data into artworks. As an example, a fern leaf fractal generated by Iterated Function

System (IFS) [15] have displacement, rotation and scaling functions (Table 1) that can be linked to spatial data (Figure 1). For the ferns generated in Figure (2, top-right), natural city parameters have been used as follows: scaling has been linked to number of breaks, angle of fronds to percentage size of head and overall orientation to North (pointing right) and South Islands (left) (Figure 1). This is in effect turning fractal graphics into complex symbols, similar to Chernoff faces [9] and cartographic ray glyphs [7].

Table 1 Fern IFS code in matrix format [15]. In the table, 2a and d are used for scaling, 2b for orientation and 3d / 4d for frond angle

w	a	b	c	d	e	f	p
1	0.00	0.00	0.00	0.16	0.00	0.00	0.01
2	0.85	0.04	-0.04	0.85	0.00	1.60	0.85
3	0.20	-0.26	0.23	0.22	0.00	1.60	0.07
4	-0.15	0.28	0.26	0.24	0.00	0.44	0.07

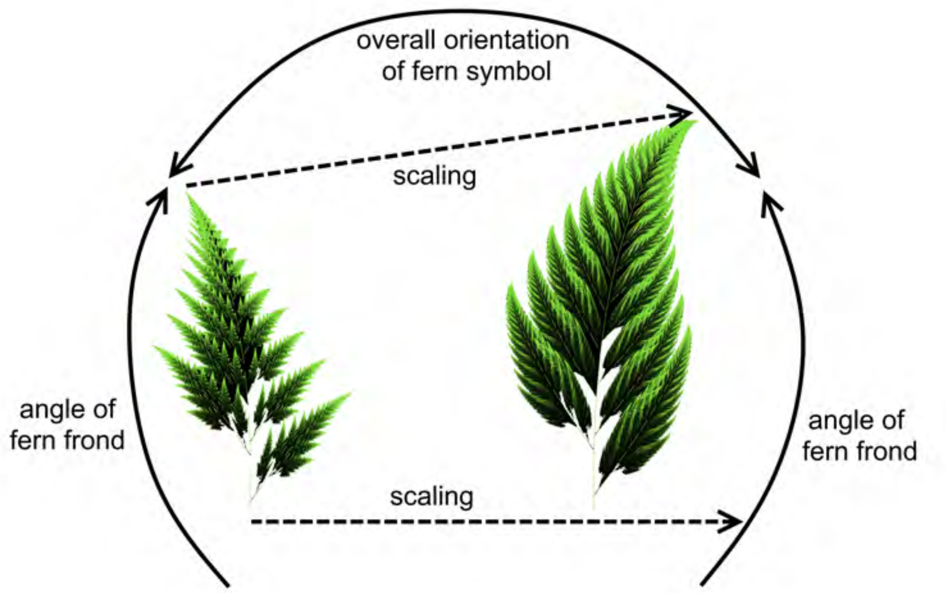

Figure 1 The Barnsley fern leaf as a multivariate symbol

2.3 Artistic styling using convolutional neural networks

The aesthetic forms so generated are used as the basis for style transfer using a convolutional neural network [12], Google Deep Dream (https://deepdreamgenerator.com/), a tool for blending in colour and structural style from other photographs and artworks. In Figure 2, the natural cities and streets have been stylised with a classic artwork, while the fractal generated ferns have been blended with a forest photograph. The results manage to artistically render the data-derived display whilst retaining the city shapes and in the case of the left instance, the most important (longest) streets are apparent. Ultimately, stylings can be chosen to promote the aspects that art is good at, visually conveying phenomena, their underlying meaning and processes (e.g. images of transportation and the built environment to augment natural cities and streets).

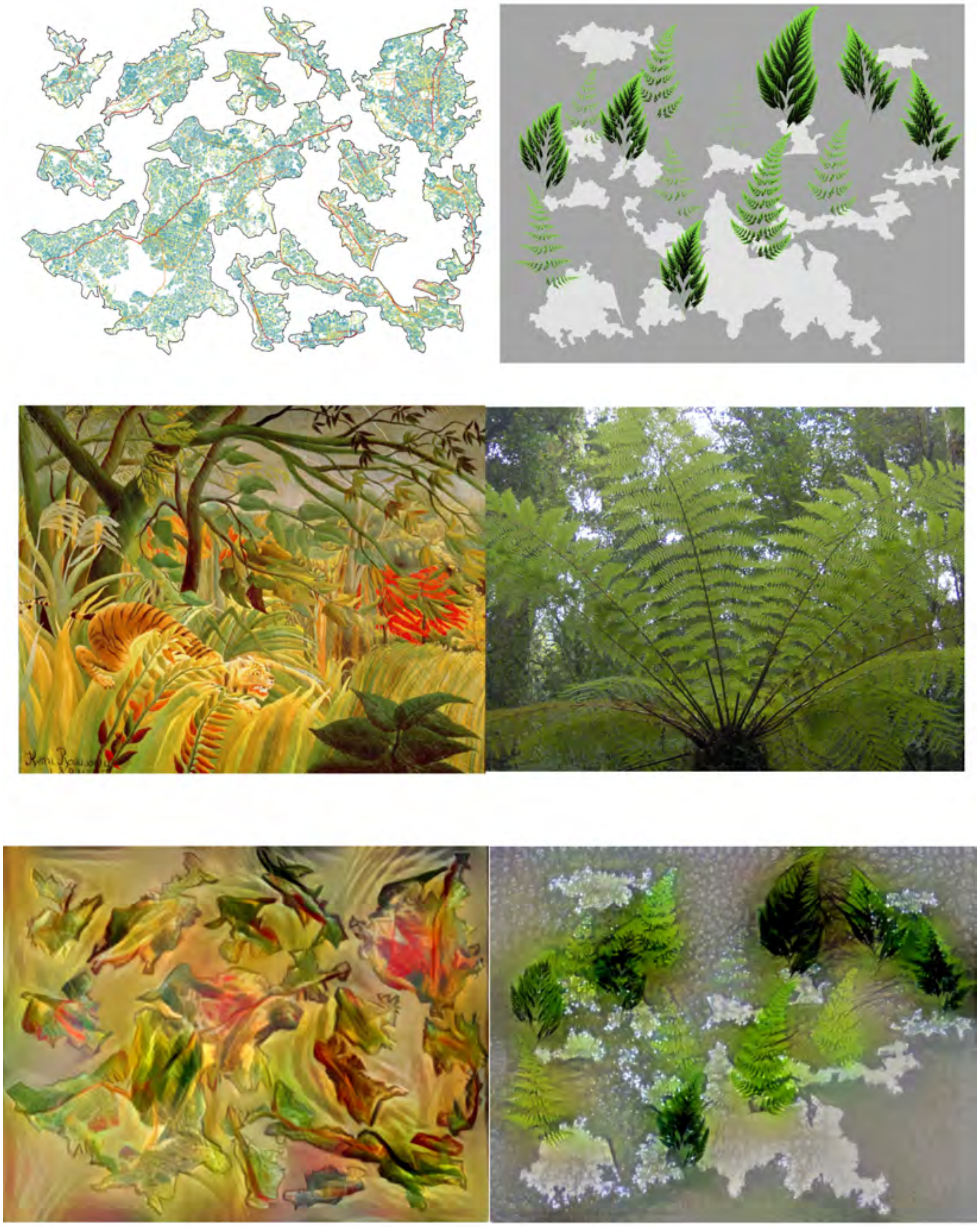

Figure 2 Down the left, the Natural City boundaries and streets have been styled with Henri Rousseau's "Tiger in a Tropical Storm" (1891) using Google Deep Dream to produce the artwork along the bottom whilst retaining the major street structure. Down the right, the city fractal ferns and natural city forms have been blended with an NZ fern forest photo (Laura Matthews, Flickr)

3 Towards Art in Geovisual Analytics

Geovisual analytics tools (e.g. GeoViz [8] and eXplorer [10]) are designed for visual exploration of large and complex datasets, whilst supporting an analytical process and reporting (storytelling) of findings [11]. They feature techniques such as linked displays (which can include a choropleth map, scatterplot, parallel coordinate plot etc.) and brushing (manipulation - e.g.selection - of data in one display affects related data in other displays) [14].

The scope of displays that could potentially be used in a geovisual analytics context is immense. The ART conceptual cube (Figure 3a) was an attempt to express a 3D space of representations, with three axes of (geographic) Abstraction, (representational) Realism and arTistic (rendering) [1].

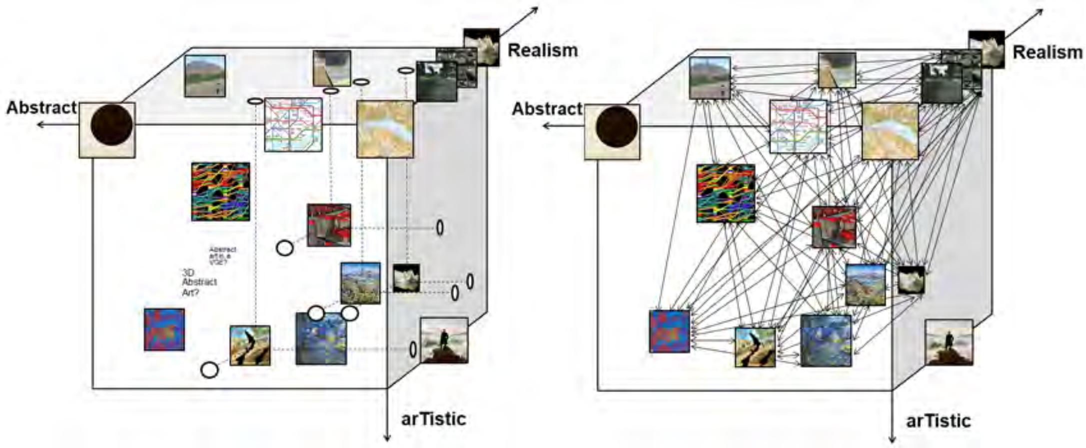

Figure 3 a) Locating abstract, realistic and artistic representations in the ART conceptual cube; b) with visual analytics linking

With the 2D map assumed to be at the origin of this 3D conceptual space, moving along the Abstract axis, one will encounter topological maps and graphs (e.g. London Tube Map), through to spatialisations, where geography is not present at all. The Realism axis moves through 3D scenes and Virtual Geographic Environments (VGE). The arT axis may at first offer comic-style renderings (e.g. non-photorealistic rendering) on the way to fine art and sound / music art. As such, the conceptual space may have value in revealing "empty spaces" for which there exist no current representation (e.g. abstract art in a 3D or virtual context?) and could therefore drive development towards a potentially valuable new visualisation technique. However, for this paper we are exploring the displays possible through synthesis at the far end of the arT axis.

The potential linkages for geovisual analytics is shown in Figure 3b, as many as there are pairings of displays. However, some of these may not turn out to be useful in practice. Regarding the links from conventional VA displays to artworks, we can exploit the fact that the artwork has ultimately been generated from spatial data, the same spatial data underpinning those maps, plots and graphs. The artworks would have to be generated prior to their use in a geovisual analytics tool as the neural net-based style transfer process takes time to run, breaking the real-time requirement for interaction. An alternative would be an artwork without style transfer but based purely on generated fractals such as the Barnsley fern, able to be updated in real-time (e.g. in quickly swapping variables for display). Brushing would be enabled if the artwork was spatially coded with the original underlying data. A brush linked from another display could visually manifest itself as the relevant parts of the artwork being in focus whilst non-brushed areas are blurred (or use of a spotlight, colour focus/ greyscale background).

3.1 Concluding thoughts

This extended abstract has explored how fractals can be used to applied to spatial data in order to derive spatial structure, geographic shapes of aesthetic value and spatial data-driven fractal objects that together form the basis of artworks. Finally, the spatial data foundation of these artworks has been discussed as the means by which they may be embedded in visual analytics tools. However, art is highly subjective, which may be an issue if you intend all of your audience to get the same message from the artwork. The severity of this issue needs to be looked into through cognitive and usability evaluations. These are the beginnings of a process that will eventually turn to Big Data in order to harness the power of art to discover and communicate patterns and anomalies, whilst supporting the current cartographic agenda.

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