A SPATIAL ANALYSIS OF SELECTED ART: A GISCIENCE-HUMANITIES INTERFACE

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the UCGIS 2019 Symposium:
The Geospatial Humanities: Transdisciplinary Opportunities for the GIScience Community

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Geography, in part through cartography—such as map making and decorating—and now through visualization in geographic information systems (GISs), maintains a historical connection to art. Mathematics, in part through geometry—such as origami, Archimedean polyhedra, Gaussian cyclic supercharacter images, and more recently Escher’s non-Euclidean (i.e., hyperbolic) prints—and now through computational mathematics (i.e., scientific computing that produces, for example, pictures of fractals), also maintains a historical connection to and rich affiliation with art. Because art tends to focus on pattern rather than randomness (even for Pollock’s drip and pointillism paintings), spatial autocorrelation—attribute values of neighboring geographic locations are far more similar than those of more distant locations—a fundamental concept of geospatial information science, almost always is conspicuous in art paintings. This connection allows spatial statistics to be extended to the geohumanities and spatial humanities, as well as to humanistic mathematics, by an integration of geography’s and mathematics’ interfaces with art.
Cybergeo: European Journal of Geography

Transversalités - les 20 ans de Cybergeo

Daniel A. Griffith

Spatial autocorrelation and Art
ESF uses a set of synthetic proxy variables, which are extracted as eigenvectors from a spatial connectivity matrix that ties geographic objects together in space, and then adds these vectors as control variables to a model specification.

These control variables identify and isolate the stochastic spatial dependencies among georeferenced observations, thus allowing model building to proceed as if the observations are independent.
Constructing eigenfunctions for filtering spatial autocorrelation out of georeferenced variables:

\[ MC = \left( \frac{n}{1^T C 1} \right) x \]

\[ Y^T (I - 11^T/n) C (I - 11^T/n) Y / Y^T (I - 11^T/n) Y \]

the eigenfunctions come from

\[ (I - 11^T/n) C (I - 11^T/n) \]
ESF Theorem

The first eigenvector is the set of real numbers that has the largest MC achievable by any set for the geographic arrangement defined by the spatial connectivity matrix $\mathbf{C}$.

The second eigenvector is the set of real numbers that has the largest achievable MC by any set that is orthogonal and uncorrelated with the 1st eigenvector.

So on through the $n^{th}$ eigenvector, which is the set of real numbers that has the largest negative MC achievable by any set that is orthogonal and uncorrelated with the preceding $(n-1)$ eigenvectors.
THE MEANING OF ESFs

global          regional          local
VISUALIZATION OF EIGENVECTOR \( \mathbf{E}_{k,k} \)
Paintings by Artist Susie Rosmarin

San Antonio Museum of Art 2010 exhibit *Psychedelic: Optical and Visionary Art since the 1960s*: a mind bending op art painting that stood out.
eigenvector $E_{5,5}$

simple ESF

eigenvector $E_{207,208}$
APPROXIMATING ESFs

A CASCADING APPROACH FOR EIGENVECTOR SPATIAL FILTER CONSTRUCTION FOR LARGE SPATIAL TESSELLATIONS

Yongwan Chun & Daniel A. Griffith

64th Annual North American Meetings of the Regional Science Association International
Vancouver, BC, November 8-11, 2017

Diagram showing the relationship between the size of square subsets and the EIG response regression CPU time (in seconds).
5-by-5  8-by-8  10-by-10  20-by-20

25-by-25  40-by-40  50-by-50  data
<table>
<thead>
<tr>
<th>name</th>
<th>painting</th>
<th>ESF-reconstructed painting</th>
<th>name</th>
<th>painting</th>
<th>ESF-reconstructed painting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unknown title #1</td>
<td><img src="image1.png" alt="Painting" /></td>
<td><img src="image2.png" alt="ESF-reconstructed" /></td>
<td>Spectrum #10, 2008 (see <a href="http://www.next-afterthis.com/2011/11/exhibition-hana-hillerovasusie.html">http://www.next-afterthis.com/2011/11/exhibition-hana-hillerovasusie.html</a>)</td>
<td><img src="image3.png" alt="Painting" /></td>
<td><img src="image4.png" alt="ESF-reconstructed" /></td>
</tr>
<tr>
<td>#412: Spectrum #9, 2008 (see <a href="http://www.minuspace.com/2009/01/susie-rosmarin-dance-galler-y-new-york-ny/">http://www.minuspace.com/2009/01/susie-rosmarin-dance-galler-y-new-york-ny/</a>)</td>
<td><img src="image5.png" alt="Painting" /></td>
<td><img src="image6.png" alt="ESF-reconstructed" /></td>
<td>#414: Yellow, 2008 (see <a href="http://www.next-afterthis.com/2011_10_23_archive.html">http://www.next-afterthis.com/2011_10_23_archive.html</a>)</td>
<td><img src="image7.png" alt="Painting" /></td>
<td><img src="image8.png" alt="ESF-reconstructed" /></td>
</tr>
<tr>
<td>Unknown title #2</td>
<td><img src="image9.png" alt="Painting" /></td>
<td><img src="image10.png" alt="ESF-reconstructed" /></td>
<td>Unknown title #3</td>
<td><img src="image11.png" alt="Painting" /></td>
<td><img src="image12.png" alt="ESF-reconstructed" /></td>
</tr>
</tbody>
</table>
## Remotely Sensed Images & Paintings

from Stephen Young

<table>
<thead>
<tr>
<th>name</th>
<th>Painting/image</th>
<th>ESF-reconstructed painting/image</th>
<th>name</th>
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</tr>
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<tbody>
<tr>
<td>Gobi Desert, China’s Inner Mongolia, surrounded by steep sand dunes</td>
<td><img src="image1.png" alt="Image" /></td>
<td><img src="image2.png" alt="Image" /></td>
<td>Monet: from the water lilies series (see <a href="https://learnodo-newtonic.com/claude-monet-famous-paintings">https://learnodo-newtonic.com/claude-monet-famous-paintings</a>, the original jpg image has undergone cropping; this image, as analyzed in this paper for research purposes, is believed to qualify for Fair Use.)</td>
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<td>(data downloaded from the European Space Agency; additional image processing by S. Young)</td>
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<tr>
<td>Thermal infrared and visible wavelengths</td>
<td><img src="image3.png" alt="Image" /></td>
<td><img src="image4.png" alt="Image" /></td>
<td>Rembrandt: The Night Watch (see <a href="https://commons.wikimedia.org/wiki/File:The_Nightwatch_by_Rembrandt_-_Rijksmuseum.jpg">https://commons.wikimedia.org/wiki/File:The_Nightwatch_by_Rembrandt_-_Rijksmuseum.jpg</a>, Wikimedia Commons)</td>
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<td>central PA image—red denotes warm, and green denotes forest dominated areas (raw data downloaded from the Global Land Cover Facility and processed by S. Young)</td>
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<td>November 15, 1999 Landsat ETM Ganges-Brahmaputra Delta image—a created RGB 741 image was converted to a black-and-white image; black denotes mangroves and white denotes water with silt (raw data downloaded from the Global Land Cover Facility and processed by S. Young)</td>
<td><img src="image5.png" alt="Image" /></td>
<td><img src="image6.png" alt="Image" /></td>
<td>Van Gogh: The Starry Night (see <a href="https://commons.wikimedia.org/wiki/File:VanGogh-starry_night.jpg">https://commons.wikimedia.org/wiki/File:VanGogh-starry_night.jpg</a>, Wikimedia Commons)</td>
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<tr>
<td>name</td>
<td>ESF-reconstructed</td>
<td>Kriging reconstructed (exponential &amp; K Bessel)</td>
<td>SAR reconstructed</td>
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<tr>
<td>Gobi Desert lakes</td>
<td><img src="image1" alt="Image" /></td>
<td><img src="image2" alt="Image" /></td>
<td><img src="image3" alt="Image" /></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rosmarin Unknown title #2</td>
<td><img src="image4" alt="Image" /></td>
<td><img src="image5" alt="Image" /></td>
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CONCLUSIONS & IMPLICATIONS

This paper summarizes little-known connections between geography (a la GIS), mathematics (a la matrix algebra), and art, **adding to the geohumanities, spatial humanities, and humanistic mathematics literature**.

Comparisons with output generated by geostatistical and spatial autoregressive techniques establishes that **MESF renders superior visualization outcomes**.

This paper initiates the establishment of a foundation for analytical art that utilizes spatial statistical theory and methodology.