Original manuscript version:
Lally, Nick. 2022. "Sculpting, cutting, expanding, and contracting the map." *Cartographica.*
https://doi.org/10.3138/cart-2021-0013

Sculpting, cutting, expanding, and contracting the map

Abstract: *shaping* is a web-based tool that enables direct manipulations of cartographic space in order to sculpt, cut, expand, and contract map regions. Breaking with rigid Euclidean understandings of projected space found in GIS, these operations support creative cartographic work that understands space as fluid, dynamic, relational, and situated. Each operation is described in detail along with possible use cases informed by literature in geography and cartography. Most manipulations of space found in *shaping* can be translated into QGIS, enabling the transformation of vector and raster layers of geographic information. By enabling direct and real-time manipulations of cartographic space, *shaping* acts as an expressive tool that engages geographic information. It is also an example of how accessible tools can be built that are interoperable with existing GIS while still being useful on their own.

I. INTRODUCTION

The tools we use to store, sort, analyze, and represent geographic information constrain the creative possibilities for cartographic visualizations of space. This is not surprising considering that the technical affordances of any software platform influence and limit its expressive possibilities. While the technical possibilities of geographic information systems (GIS) constantly evolve and certain users have always pushed beyond what was previously thought possible, GIS offers limited visual possibilities for space as a matter of concern. Specifically, users are mostly stuck with a strictly mathematical understandings of projected space. Different projections offer users myriad ways to translate locational coordinates between the complexities of geodesy to the flat plane of the map, but they only offer generalized transformations. What cartographic expressions of space might we engage with different tools to sort and represent geographic information? How can theories of space that proliferate in human geography be engaged visually through such tools and what might they contribute to the growth of creative geographies?

Creative or art-informed approaches to geographic inquiry often take maps as a starting point. The centrality of visuality to maps, with their aesthetic concerns and creative possibilities, makes maps a sensible expression of creative spatial experimentation. Maps can serve as documents of experimental spatial practices, art, data, and ideas (Thompson, Kastner, and Paglen 2008); bring visions of alternative futures to fruition (Noterman 2021); become part of rich visual storytelling practices (Roth 2020; Caquard 2013); and be vehicles for aesthetic experimentation. But barring a handful of notable exceptions, some outlined below, creative mapping often centers a "basemap" strictly defined by GIS understandings of projected space.

Situated experiences of space that a mapmaker might want to express, however, might differ significantly from what a top-down and rigid projected space might offer. Theoretical work in geography offers some possibilities for imagining space otherwise, but we might also look to art as inspiration for cartographic futures. While some innovative work in cartography deploys polyvocality in order to express complex understandings of spaces and events (Pearce and Hermann 2010), in painting we also find what we might term polyspatiality and polytemporality. In other words, painters sometimes bring disparate spaces and times in relation to each other as a means to express geographic concepts and thought. Consider, for example, Julie Mehretu's swirling, cacophonous, and energetic paintings that juxtapose multiperspective architectural and planning drawings with iconography, expressive brushstrokes, and geometric shapes to develop a complex and dynamic sense of place. Similarly, Mark Bradford's collaged, cut, layered, palimpsets made up of signs, flyers, and billboards collected on the streets create gridded patterns that echo the visual grammar of maps. Kathryn Brown (2010) has called Mehretu and Bradford's work 'absorptive maps,' referencing their ability to express relational concepts of urban life that extend beyond what is possible in traditional cartography. Brown writes, "As examples of absorptive maps, the collages and paintings of these two artists epitomize multiplicities of perspective, of layering, of narrative, and of community. The claim to objective knowledge enjoyed by maps is undermined by the insistence on subjective engagement with particular locations and the traces left by those who pass through them" (111). Maps, plans, symbols, and perspectives are appropriated, cut, shaped, and juxtaposed not only for aesthetic purposes, but also to express geographic ideas and concepts. Geographic concepts of relationality, contingency, history, and movement work in and through the canvas, built up with abstracted geographic information in order to reimagine the possibilities of the map.

Art practices that engage with maps give a sense of what becomes possible when one is allowed to freely manipulate geographic information. The printed map, for example, can be crumpled, torn, stretched, and collaged. Such manipulations can be means to explore spatial topologies, bring distant spaces into close relation, and combine previously non-overlapping temporalities. But these operations are necessarily destructive to the data that underlies the printed map. In other words, such operations are abstracted from the geospatial data that makes the printed map possible. Even when similar operations are performed on a computer—in image editing software, for example—those operations are not reflected in geographic information and find few possibilities for expressions within a GIS. The work presented here aims to occupy some of the space between the expansive possibilities for spatial expression promised by art and the limited grammars for visualizing complex spaces found in GIS.

Inspired by various art practices and spatial theory in geography, and informed by the limitations of existing GIS, in this article I present *shaping*, a web-based prototype that allows for the direct manipulations of cartographic space. The three main operations of *shaping* are sculpting, cutting, and algorithmic expansions and contractions. These operations are described individually below, alongside possible use cases. I show how these manipulations can be translated into QGIS, enabling them to operate on geographic information. In the section that follows, I synthesize literatures in geography that inform this work, before turning to the specificities of *shaping*.

II. IMAGINING OTHER SPACES

While Euclidean understandings of projected space are central to existing GIS, there have been a number of efforts to visualize space otherwise. Waldo Tobler in his 1961 dissertation, for example, explored alternative methods of distance that could be used to transform space. For Tobler (1961), cost distance, temporal distance, and other social distances were more promising in understanding social behavior than those distances offered by Euclidean measures. Sometimes these distances would take visual, cartographic form. In his dissertation, Tobler reprinted two maps from William Bunge's dissertation from the previous year. The first is an isochrone map that shows travel distances from downtown Seattle, while the second translates the isolines into perfect circles, transforming the space of the map in the process. Bunge's (1988) interest in alternative measures of distance would continue in his *Nuclear War Atlas*, where he describes a "topological space collapse" brought on by the threat of nuclear destruction. Bunge invites us to imagine a world that is shrinking unevenly as particular faraway places are brought into close relation through vectors made possible by weapons of war.

Topological understandings of space, where points are defined in relation to each other using distances that might differ from their taken-for-granted Euclidean measures, have found visual expressions through multidimensional scaling (MDS). Arguing that "any relation defines a space," Anthony Gatrell (1983) used MDS extensively to explore various types of relational spaces in his book *Distance and Space: A Geographical Perspective*. In MDS, points are defined by their distance relationships with other points. An MDS algorithm uses a distance matrix to find an arrangement, in two or three dimensions, that best reflects those distances. In other words, the algorithm seeks an arrangement of least tension where the relationships between points best reflects the (re)defined distances. The results are an understanding of space that is relational, echoing theoretical understandings of space in human geography, as space is not an empty container with precisely locatable coordinate positions. Rather, the shape of space is defined by the relationships between various phenomena.

In contrast to MDS, which relies on an arrangement of points, cartograms resize areal units of the map based on data of interest to the cartographer. One common application is to resize electoral districts according to their populations in order to minimize the visual prominence of sparsely populated, usually rural areas. Scapetoad (http://scapetoad.choros.place/), a popular software package for generating cartograms, and the Gastner-Newman (2004) algorithm on which it is based, both use electoral maps as use-case examples. Most implementations of cartograms similarly visualize data using this value-by-area method, but they can also be used for other purposes. Weber Reuschel, Piatti, and Hurni (2014), for example, developed a workflow that uses Scapetoad to enlarge areas of a map where points are densely clustered. These points, which represent locations in literary texts, only become legible when parts of the maps are expanded using the cartogram algorithm. This creative appropriation of the cartogram technique opens new possibilities for thinking about cartographic space freed from the confines of rigid coordinate systems.

While MDS and cartograms are promising methods to manipulate the space of the map, they do not allow for direct manipulations of space and geographic information. They do, however, carve out a promising middle ground between the open experimentation of painterly approaches and the strict confines of projected space. Although offering the possibility of stretching, folding, or sculpting space, they do so based on a set of strict instructions working on the data they are given. For the cartographer to change the visualization of space, they must do some experimentally, by changing the data that is fed into the algorithm and seeing the results. Both hold immense promise for visualizing spaces otherwise, but offer little in the way of hands on transformations of those spaces. *shaping* aims to give more control to the cartographer interested in the expressive possibilities that manual manipulations of space offer, which could very well be used productively in conjunction with existing methods like MDS and area cartograms.

Emerging from the growth of critical GIS have come calls to rethink the technologies of GIS. R.E. Sieber (2004), for example, outlined a path towards GIS/2, which could incorporate competing epistemologies and polyvocality. Mei-Po Kwan (2002) explored how GIS could be deployed in feminist research without undermining feminist epistemologies. Cope and Elwood (2009) argued for a mixed-method approach to GIS that incorporated qualitative research methods. Recently, there has been growing interest in expanding possibilities for visualizing space otherwise. Some of this recent work recounts earlier experiments with more-than-Euclidean space—Tobler and Bunge are two common interlocutors in those discussions—while suggesting paths forward. O'Sullivan, Bergmann, and Thatcher (2017), for example, show how exemplary quantitative work can be a source for reimagining GIS in ways that compliment social theoretical conceptions of space. Similarly, Poorthuis and Zook (2020), drawing lessons from the quantitative revolution, argue that so-called smart technologies can be redeployed in order to explore relational and other non-euclidean spaces. Bergmann and Lally (2021) have suggested the broadening of GIS into geographical imagination systems (gis) that can incorporate humanistic modes of inquiry where phenomena are not singular and space is not absolute. They argue for the creation of accessible tools that can engage with relational, topological, situated, and other non-euclidean theories of space—*shaping* aims to add to this proposed toolkit.

Recognizing these epistemological limits of existing GIS has led some scholars to develop methods and technologies that realize other forms of mapping. Knowles, Westerveld, and Strom (2015) developed a method they call "inductive visualization" that does not start with the limited spatial possibilities of GIS. Instead, they began diagramming spatial narratives with physical media, like pencils and paper, which allowed them to then choose visualization methods that best represented their research subjects' complex conceptualizations of space and place. Enescu, Montangero, and Hurni (2015) also avoided GIS and its limits as they developed methods to map dreams, where places can be distorted, combined, and uncertain. Westerveld and Knowles (2020) analyzed stories where relationships between places were described, but many exact locations were unknown, leading them to conceptualize a topologically-organized GIS. Similarly, McGlynn and Payne (2020) develop spatial visualization methods that deemphasize distance while visualizing spatial relationships in their Pseudo-Spatial Chart Program. In my own work with Luke Bergmann (2021), we developed a browser-based program that allows users to engage with MDS in order to visualize relational and topological spaces. Instead of just reorganizing a series of points, we were able to use MDS to reshape the map, which was made possible, in part, by the increasing availability of computing power to end users.

In geography and beyond, the conditions for expanding the possibilities for visualizing space are promising for a number of reasons. First, the computing power of the average browser supports complex calculations and visual possibilities, allowing for experiments with visualizing space to be easily distributed and accessed online. Second, the proliferation of more accessible programming libraries—like p5.js used to program *shaping*—means that there are more possibilities to more easily create tools. Third, within geography, there are a growing number of scholars trained in both GIS and human geography interested in pushing forward other ways of engaging social and political issues through GIS (Wilson 2021). And fourth, adjacent to geography, the growth of digital humanities, with its accordant interest in spatial question, means there is a growing audience of scholars who seek accessible ways to explore complex questions through forms of mapping. *shaping* is a prototype that builds from these conditions and aims to help imagine what else could be possible through the development of new mapping tools. Additionally, as described below, I aim to suggest frameworks through which new tools can be built and connected to existing GIS.

III. *SHAPING*

OVERVIEW

shaping is a web-based tool written in JavaScript and HTML/CSS. It works in a user's browser and aims to be accessible to non-technical users and those versed in the use of GIS alike. It uses the p5.js library (https://p5js.org/) for many of the interactive and visual functions. p5.js is an open source JavaScript implementation of the Processing language, which is aimed at visual arts and designers seeking accessible entryways to visual and interactive programming. Maintained and developed by its community of users, p5.js offers several contributed libraries that offer mapping functions. Although none of the mapping libraries are used in *shaping* and while p5.js was not originally developed for geospatial functionality, libraries like p5.js are one of many paths towards expanding the possibilities for cartographic visualizations of space.

Central to *shaping* is the place it occupies in various types of workflows. Users can, for example, use the web interface to manipulate a map image and export the results directly to an image file. A workflow like this requires no knowledge of GIS, projections, or the specificities of geographic information. In this scenario, *shaping* works like simplified image editing software, allowing for a small number of functions relevant to the exploration of spatial concepts, as outlined in the subsections that follow. Manipulating a raster map image entirely in the browser does pose distinct cartographic challenges. For example, existing text may become distorted and line weights may become awkwardly uneven. But this workflow can still be generative for creative approaches to manipulating layers of map imagery. Additionally, it allows for the quick rendering of unique maps by geographers and others not versed in the technical grammars of GIS. *shaping* also offers a workflow that connects it to QGIS, as described in section IV below.

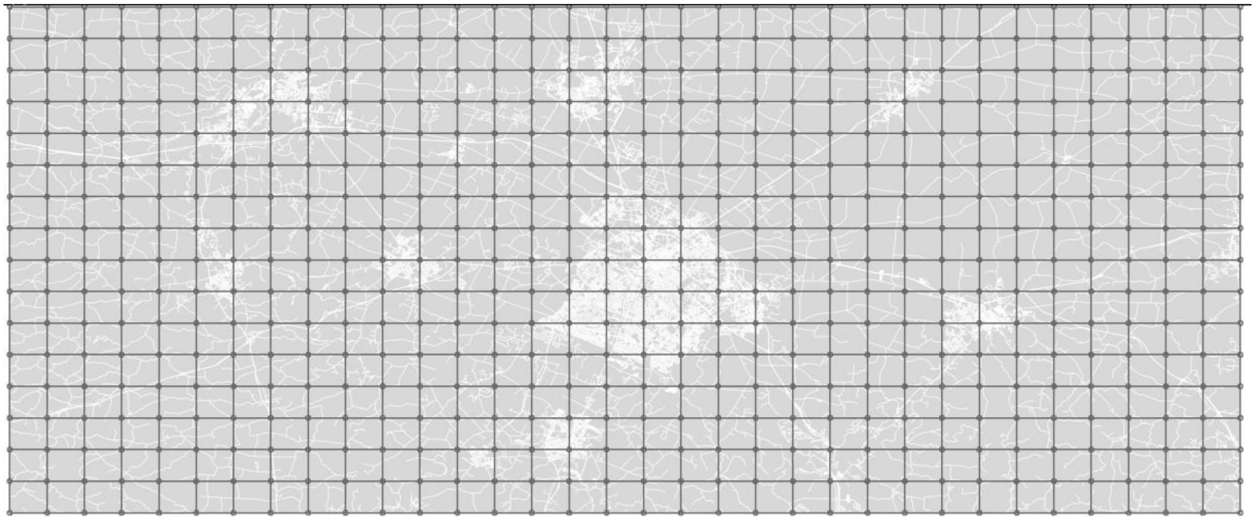

Figure 1: Grid of control points in shaping

When first encountering *shaping*, the user is invited to add an image (likely, but necessarily representing a map) by dragging it into the editing interface. After adding a map image, a grid of control points are added on top of the image. Users can modify the vertical or horizontal density of control points by defining the number of rows or columns of the grid. Figure 1 shows a dense grid of control points overlaid on a map image. The grid can be toggled on and off with the "Show Grid" checkbox, allowing the user to see the map without the grid and control points, which is useful to see a clear view of the modifications without the visual interference of the grid. With the "Move Control Points" button depressed, users can click-and-drag to move control points individually, anchoring them to different places on the map image. Once the control points are arranged to the user's liking, they can then explore the various functions that allow transformations of the map, as described in the following subsections.

Technically, in *shaping*, the control points define the vertices of a mesh of squares to which a map image is applied as a texture. The texture is rendered in an HTML canvas element using WebGL (enabled by p5.js), which utilizes a user's graphics processing unit (GPU), facilitating the fast rendering of interactive graphic elements. The transformations of the map surface undertaken by the user are performed in real time, allowing for the direct manipulations of space that are currently impossible in existing GIS. Those transformations are covered in detail below, with possible use cases for each. The use cases are not meant to be exhaustive, rather, I hope they serve as starting points for thinking creatively and expansively about the possibilities afforded by new geospatial tools.

SCULPTING

Once the control points are set to a user's preference, whether by accepting the default grid, changing the size of the grid, or moving the control points, a user can choose the "Sculpt" function by pressing the appropriate button. Now, moving the control points distorts the space of the map, as pictured in Figure 2. It does so simply by changing the shape of the mesh squares, which distorts the part of the image mapped to each square. The "Sculpt" function can be used in combination

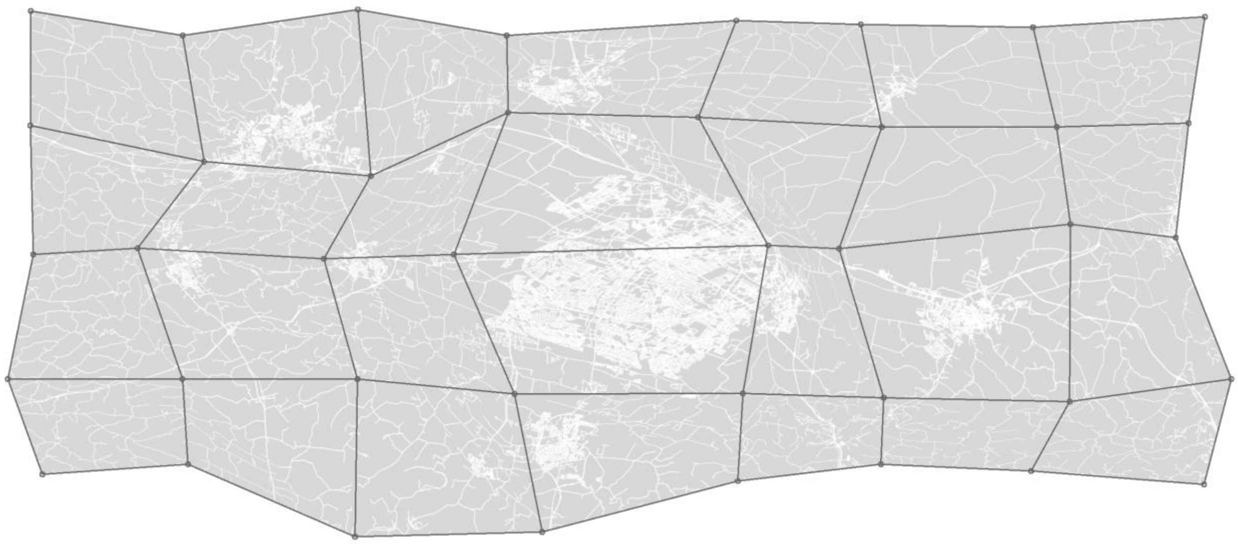

Figure 2: A map sculpted in shaping

with any other function, which means a user can, for example, algorithmically expand a map region, then change the location of the expanded control points. This function gives the cartographer full control over the shape of the cartographic space of their map. Changing the density of the control point grid and carefully placing each control point gives the mapmaker a precise method for sculpting the map as they see fit.

SCULPTING USES

The sculpting function can be used to increase the legibility of a map in a way similar to other cartographic generalization operators. It is common, for example, to move or displace geographic elements when they overlap or crowd others (Roth, Brewer, and Stryker 2011). Geographic elements can also be exaggerated as a means to maintain legibility, particularly when key geographic elements become very small at smaller scales (ibid). The use of ScapeToad by Weber Reuschel, Piatti, and Hurni (2014), as mentioned above, similarly exaggerates areas of a map to show closely crowded geographic features. *shaping's* sculpting function can be used in a similar fashion to these other efforts to increase cartographic legibility.

In a world map of airline routes, Daniel Huffman (2018) decided to reshape parts of the world to increase legibility, using what they describe as a cartogram. While not a cartogram in the traditional sense of conveying information through the size of areal units, the use of the term signals to the absence of the type of functionality offered by *shaping's* sculpt function. Huffman writes, "Instead of being beholden to reality, and the true size and shape of the Earth's landmasses, I made a cartogram. By resizing and reshaping different areas, I could both alleviate overcrowding and better distribute the world on either side of the gutter" (Huffman 2018, n.p). While Huffman used Illustrator to make the transformation, a similar transformation could be undertaken using *shaping*. This would allow a cartographer to return to a GIS, whether to add new data layers, to take advantage of automated labeling, or to mix raster and vector layers. In this way, *shaping* promises a more robust workflow where a cartographer can return to transformed geographic information within a GIS.

In addition to improving legibility and cartographic communication, the sculpting feature can be used to capture situated and variable understandings of space. The variability in how spaces are experienced, understood, and represented often becomes apparent in mental mapping—*shaping* offers other possibilities for visualizing this variability. Mental mapping exercises often begin with a blank page or an outlined geographic entity. The former requires the mapmaker to add geographic features, which then take on spatial relations with each other. This sometimes means that mapmakers draws themselves into corners, as additional geographic features must be awkwardly fit into the map. The latter fixes some of this by setting what amounts to a general basemap. But this also means that space becomes fixed in places, as outlines exert an immutable structuring effect on the overall map.

A mental mapping exercise in *shaping* might begin with a simple line drawing of key geographic features or a loose arrangement of key point features. This drawing may correspond to a projected space, meaning it is spatially 'correct' in a formalist GIS understanding. Or it may begin with points arranged topologically, where general relationships between them are 'correct'. These decisions would be, of course, determined by the research questions that guide the project. The mental mapmaker, without knowing this, could be asked to fix the map to conform to their spatial understanding of place. Using software in this way may lead to different results than those that emerge from hand drawn exercise. It may also offer the researcher more structured ways to analyze the results using the many analytics used in mental mapping research (Gieseking 2013).

Finally, the sculpting function offers the freedom to reshape the space of the map as the cartographer sees fit, whether it be for the expression of spatial concepts, the telling of a story, or for other expressive reasons. For example, sculpting might be a way to express that "space is always under construction," (Massey 2005, 9), shifting with the relations that make it, always in need of reassessment and redrawing. By eschewing the inflexible structures of projected space, other forms of creative geographies and spatial expressions become possible that may well exceed those imagined here.

ALGORITHMIC EXPANSION & CONTRACTION

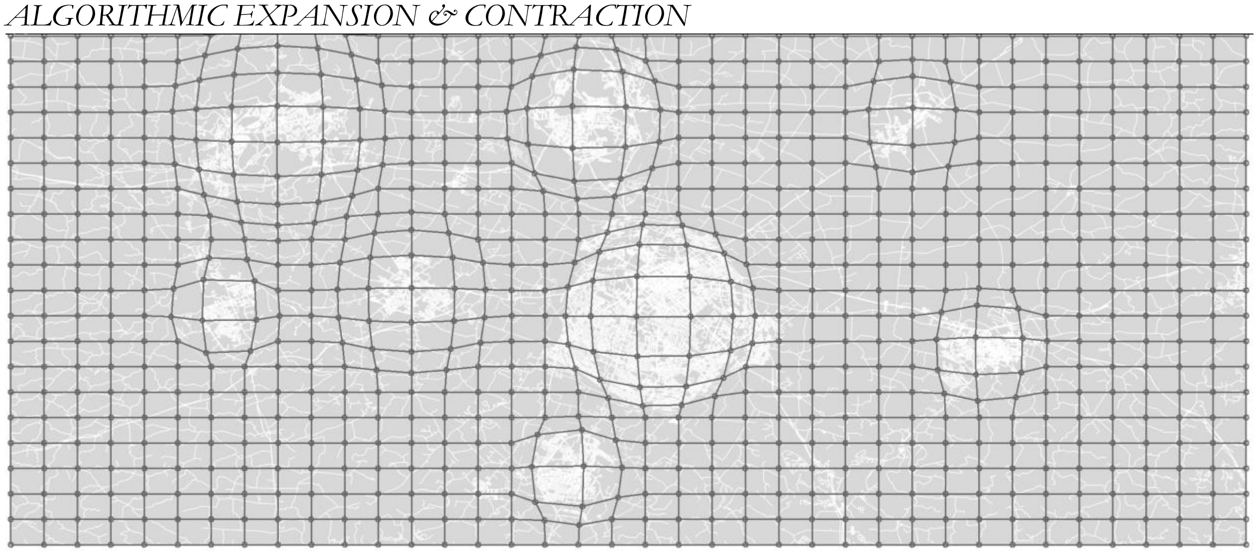

Figure 3: Algorithmic expansions in shaping

In the algorithmic expansion and contraction modes, users can click on a point on the map, causing nearby control points to move away from the clicked point (expansion mode) or towards the clicked point (contraction mode). Both can be used to produce similar results as a cartogram, but by manual means. The cartographer can change the radius of the transformation, which will increase or decrease the distance between the clicked points and those affected by the transformation. They can also change the magnitude of the transformation, which will increase or decrease the amount of displacement. The displacement amount is calculated using a sine wave that extends from 0 to 180 degrees, stretched across the transformation radius, and with an amplitude of the magnitude. This means that at the clicked point and the transformation radius, displacement is 0. The displacement peaks at the midway point between the clicked point and the transformation radius, equaling the transformation magnitude at that point. Figure 3 illustrates a map with several expanded regions. The contraction mode uses the same algorithm, but applies a negative value to the transformation, effectively moving nearby control points towards the click point. Using these functions, the cartographer can make areas of the map more or less prominent with a click of the mouse.

ALGORITHMIC EXPANSION & CONTRACTION USES

Algorithmic expansion methods have been used to increase the legibility of map regions by allowing the map reader to zoom into selected regions while maintaining the surrounding context of the map. Building on fisheye methods of zooming, scholars have developed the focus+glue+context method, where the overall map and zoomed in areas are not distorted, held together by a distorted 'glue' section (Takahashi 2008; Yamamoto, Ozeki, and Takahashi 2009). The algorithm used in *shaping* offers a smooth ramp of distortion, avoiding the high distortion areas of a glue method in order to make a more cohesive overall map. But other algorithms could easily be implemented, allowing the cartographer to experiment with various types of transformations.

In addition to selectively increasing the legibility of map regions, expansion and contraction functions may also prove useful for the creative visualization of geographical concepts. Jack Gieseking (2020) theorizes the queer production of space as constellations. Places that hold meaning to his research participants are conceptualized as stars of "varying brightness" that "convey the magnitude of import that my participants exhibited while describing their limited number of lesbian queer place" (p. 946). Instead of simply being represented by points, places like these could be expanded using *shaping*, showing how certain places take on larger-than-life significance within a person's situated experiences of life in a city. Gieseking also writes of the fleeting nature of these stars, as significant sites come and go. Here, the contraction function might be deployed in conjunction with the expansion function in order to show these changes. The results could even be translated into 3D rendering programs in order to animate these flickering constellations—a technique I have written about elsewhere (Lally and Bergmann 2019).

CUTTING

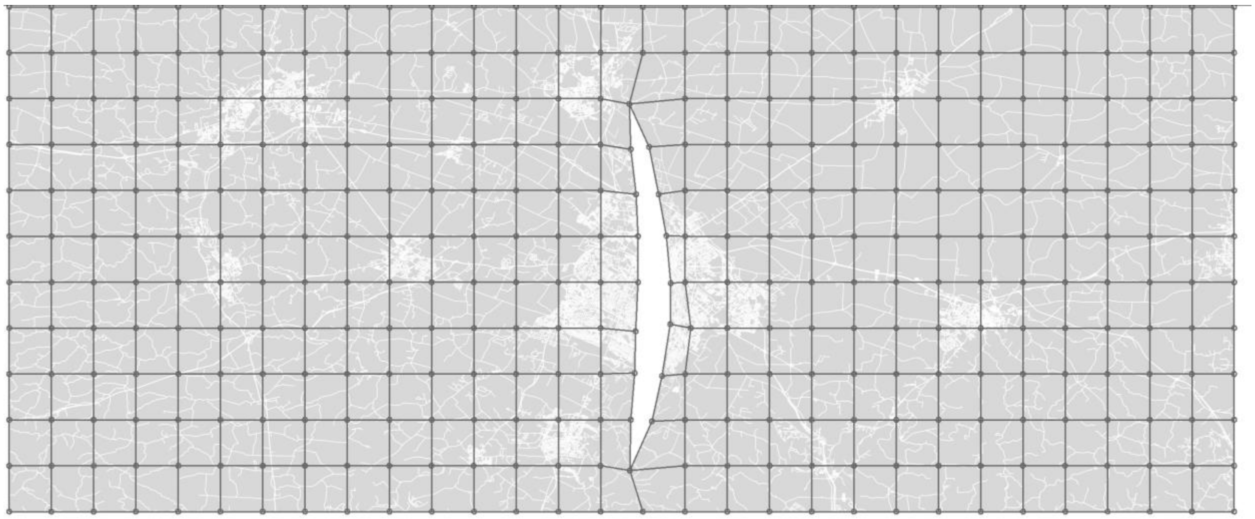

Figure 4: A cut rendered in shaping

Users can make a cut in a map by clicking on a control point while in one of the two cutting modes. Cutting works by taking a control point, splitting it into two control points, and offsetting them from the original location by a small amount in opposite directions. Users can choose from two cut modes—one offsets the two generated control points vertically, the other horizontally. To make a vertical cut in the map, as illustrated in figure 4, the cartographer would select the horizontal cut mode. They would then click on a number of vertically-aligned control to effectively open a cut. By going to the sculpt mode, the cartographer can then shift each control point to the exact location of their choosing.

CUTTING USES

Geographic proximity can be deceptive, especially if we uncritically embrace the so-called first law of geography, which states "everything is related to everything else, but near things are more related to distant things" (Tobler 1970, 236). Tobler himself, who famously coined the law, pointed to the ambiguity of what constituted "near" throughout his career, which he addressed explicitly in a 2004 paper, writing: "Some speak of social distances, time-varying network distances, topological distances, genetic distances, ordinal distances (far, farther, farthest), and soon. Often these distances are not symmetric. We refer to the friction of distance. Thus, *proximity and near can take on many meanings in different situations*."" (Tobler 2004, 306, emphasis added). Barriers of various sorts often impose serious distance between locations that are proximate in Euclidean terms. Cutting the map is one way that such distances can be expressed cartographically.

National borders, for example, can be extremely variable across time and space in addition to being experienced differently according to how subjects are interpellated by state actors. Meghan Kelly (2019) created cartographic grammars for symbolizing this variability in terms of the porosity of borders and how they are experienced by individual research subjects. The cut offered by *shaping* adds to this grammar by showing how impassable borders serve to increase the distance across otherwise adjacent geographies. The distance offered by the cut might symbolize the physical impassibility of a border, or it might symbolize the emotional distance experienced by a person in response to that border.

Geographers regularly encounter cuts in the landscape that could benefit from other forms of visual expression. So-called 'urban renewal' programs of the mid-twentieth century, for example, often included the construction of highways that cut through predominately poor and Black neighborhoods, severing those communities from each other and the rest of the city (Derickson 2017). Similarly, in the siting of prisons, Ruth Wilson Gilmore (2007) writes of the massive distance between a prison and the community that surrounds it. We might conceive of the prison borders as cuts and the prison as an island, topologically connected to private corporations and the state much more than the community members standing on the other side of its fortified walls. A cliff is another sort of cut, where a matter of inches in the horizontal direction can mean hundreds of feet in the vertical direction. Traversing those inches might require an alternate route of many miles in the horizontal direction, not to mention changes in elevation.

Cuts are one possible grammar for expressing the scenarios above, which might also have implications for spatial analyses. While the increased distances represented by a cut might be rather subjective in their implementation, those distances might better represent various types of barriers when performing distance-based spatial analyses. In this scenario, a humanistic mode of interpretive mapping meets the quantitative certainty of GIS that depends on a narrow understanding of projected space. While this possibility may be generative, the cut currently cannot be translated into a GIS, which is described in more detail below.

IV. WORKFLOWS

With the exception of cuts, the transformations performed on a map image in *shaping* can be exported as data files and applied to geographic information in QGIS. Separate export options are available for raster and vector layers, due to their conceptual separation in GIS. To export the transformations, first a user is required to input the coordinates of the four corners of the map image, assuming the original map has been rendered using a cylindrical projection. By using a cylindrical projection, intermediate points may be easily interpolated across the map image. Future versions that build on this prototype may choose to ingest and interpret images containing geographic information, like GeoTIFFs, which would allow for different coordinate analyses. While the software requires the initial cylindrical projection, this can be modified later once the transformations are translated into a GIS.

After a user enters the geographic coordinates of the map's corners, they can then output transformation data in one of two file formats. The first outputs all transformed control points as linestring pairs representing the starting and ending points of each transformation. The GeoJSON file that is generated can be imported into QGIS. Using the VectorBender plugin (Dalang, n.d.), the transformations can be applied to any vector layer in QGIS. Applying transformations to vector layers means that lines widths remain constant and labels move to match the new locations of map features. Manipulated vector layers do not appear distorted, rather, they are transformed in ways akin to a projection. Maps can thus assume the 'authoritative' look that visualized geographic information often evokes, even while showing geographies otherwise. The second output option renders all control points to a ground control point (GCP) file. This file associates each control point with both geographic and pixel coordinates. In QGIS, the GCP can be used to georeference a raster image, making it reflect the transformations performed in *shaping*.

Methods to translate cuts into QGIS do not currently exist, but innovative approaches to projections may one day allow for those translations. Bergmann and O'Sullivan (2017), for example, have proposed a projection system that they term 'hyperproj'. This proposed generalized projection format would allow for interruptions, or cuts in the map, in addition to the transformations offered by the sculpting and expansion/contraction functions within *shaping*. Expanding the purview of projections to include a range of spatial transformations would be a boon to the types of expressive cartographies suggested in this article.

In addition to GIS workflows, *shaping* can be used as a standalone tool to transform existing maps by users who are not versed in the technical operations of GIS. Existing maps can be run through the software and outputted directly as image files. Users can then use the output to visualize geographic concepts, incorporate into art-informed geography projections, incorporate into mental mapping research, or use in ways not foreseen here. My hope in building tools is not to predetermine what they may be used for, but to open mapping to other geographical imaginations and creative explorations that can express the complexities of space and place otherwise.

IV. CONCLUSION

shaping is presented here as a prototype, showing what becomes possible with an expanded functional grammar of GIS. Grounded in existing modes of geographic inquiry and cartographic expressions, *shaping* offers users sculpting, cutting, and algorithmic expansion/contraction functions. By enabling direct and real-time manipulations of cartographic space, *shaping* acts as an expressive tool that engages geographic information. It is also an example of how accessible tools can be built that are interoperable with existing GIS while still being useful as standalone tools. While academic incentive structures often result in the creation of ad hoc and inaccessible tools, there is much to be gained from a flourishing of accessible and expansive ways to engage with space as a matter of concern within mapmaking (Boeing 2020; Gahegan 2018).

Additionally, further attention to interoperability could expand the possibilities for toolkits built on the model presented here. *enfolding*, another web-based tool that I built with Luke Bergmann, could be integrated with *shaping* through the use of a common data format like graphML. Additionally, both are hosted on github.com, which allows users to change the code, request features, and report bugs, engaging them at different levels of software production. While *shaping* is currently integrated rather haphazardly with QGIS, using tools available at hand, more robust open-source connectors would enable better integration of *shaping* and similar tools. Data standards or new projection formats that make the widespread interoperability of geographic information might serve as a model for making such connections and expanding the possibilities for GIS and cartographic visualizations of space.

You can explore the code repository here: https://github.com/nicklally/shaping

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