Enabling spaces by GeoComputation

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Abstract

Space, location, coordinates, distance: these interrelated concepts and their practical realisations in data structures, analytical procedures, and visualization techniques are central to what computation is able to achieve in geographical research. We argue the ideals and approaches of GeoComputation have much to contribute to the realisation of a geographical computation that embraces not only the representation and analysis of phenomena in absolute, Euclidean space, but can engage relative and relational spaces as well. Such spaces emerge with process and relation, and they were viewed as central to advancing geographical research during the quantitative revolution. We present results of initial steps taken in this geocomputational research agenda: we formalise, implement, exemplify, and analyse a generalized, empirical projection approach appropriate to translating between the (sometimes complicated and emergent) coordinate systems of relational, relative, and absolute spaces.

Keywords: Absolute space, relational space, geographical coordinate systems, empirical projections.

1. GeoComputation, GIS, and the computational spaces we need

What spaces do we need for what kind of GeoComputation? Space has today receded to the background in many advanced realms of geographical computing, but this question has long remained relevant. By the time the quantitative revolution had transformed geography fifty years ago, it was clear that singular, absolute, Euclidean space (and its spherical counterparts) were inadequate as the sole vessel for geographic research. As David Harvey wrote in that high-water mark of the revolution, *Explanation in Geography* (1969, 210): "Given the philosophy of absolute space, the metric in that space must remain isotropic and constant. To Kant and Humboldt the only metric available was that defined by Euclidean geometry…[and the] direct extension…to the surface of the sphere…. This view is no longer generally acceptable…. The general argument about the nature of distance in geographic research (Olsson, 1965A; Bunge, 1966) has effectively been resolved. There is no independent metric to which all activity can be referred." Instead, as Harvey wrote, "…distance can and must be measured in terms of cost, time, social interaction, and so on, if we are to gain any deep insight into the forces moulding geographic patterns." Similarly, the abstract of Waldo Tobler's 1961 Ph.D. dissertation begins: "Many geographic and economic models of human behavior in a spatial context indicate that the measuring rod of the geodesist or surveyor is less relevant than a scaling of distances in temporal or monetary units…. Different distance relations, however, can be interpreted as different types of geometry." The rest of Tobler's dissertation—and much of his subsequent career—was dedicated to advancing the analytical and visual foundation for this work. Given this history, it is easy to see how researchers in subsequent decades would have created and diffused the computational infrastructure of data structures, analytical methods, and visualization techniques appropriate to this diversity of spaces interwoven by geographical processes and relations.

If so, history rarely goes in a straight line, and many unexpected things happened in the years that were to follow. Geographical computation and much of the associated practical implementation of research methods in quantitative geography became dominated by Geographical Information Systems, which have rapidly developed at the intersections of geography, cognate disciplines, the state, and various commercial interests (Chrisman 2006; Thatcher and Beltz Imaoka 2018). Perhaps surprisingly, with GIS, the spatiality quantitative geography increasingly had available to it was absolute space (Sheppard 1995). This was exactly the spatiality that key quantitative revolutionaries such as Harvey, Tobler, and Bunge had felt was discredited as a singular medium for geographical research. Of course, all would agree that much can be achieved thinking with absolute space, a proposition to which the enthusiastic societal uptake of GIS and prolific research development in GIScience all attest. In GIScience, in particular, basic research has illuminated a great deal about the nature of absolute space and its computational possibilities (see, *inter alia*, Couclelis 1992; Goodchild et al. 2007). The difficulty comes in the overemphasis of one approach to space at the expense of a richness of geographic representation that has long been recognized as important.

Indeed, a geographic spatiality was not the only achievement or aspiration of the quantitative revolution whose development was redirected by the rise of GIS. As Gahegan (1999, 204) argued in a foundational call for GeoComputation, "GIS was, for some, a backwards step because the data models and analysis methods provided were simply not rich enough in geographical concepts and understanding to meet their needs….Consequently, many of the geographical analysis problems that gave rise to the quantitative revolution in the first place could not be addressed in these systems."

Yet as researchers, we can sometimes choose which pasts become prologue. GeoComputation, as an ideal, encourages us to do this. Again, Gahegan (1999, 204): "GeoComputation represents a conscious attempt to move the research agenda back to geographical analysis and modelling, with or without GIS in tow…. It is about not compromising the geography, nor enforcing the use of unhelpful or simplistic representations…. A true enabling technology for the quantitative geographer…." Insofar as different concepts of spatiality were key to the concepts and practice of the original quantitative revolution—and remain key to the insights of human geography today—many opportunities remain relatively underexamined, theoretically, in the present. Further, computing with relational spaces is difficult to implement, at best, and often forgotten in the margins, at worse (see Harvey 2006 for more on the natures and interrelationships between different types of space). This is somewhat unfortunate given that advances in computation, both scientific and technological, have potentially made the practices of the quantitative revolution that much more feasible to conduct as a matter of course. With further attention to how computing can become more democratic instead of more technocratic (Obermeyer 1995), we may equally be able to engage more research(ers) from human geography, reducing stubborn quantitative/qualitative divides in geographical research within and through computing.

In our presentation, therefore, we examine how GeoComputation can help develop the computational infrastructure to engage in the more diverse approaches to space that both the quantitative revolution and contemporary human geography have envisioned. As we suggest above, we review some of the relevant history and concepts connected to how a more-than-Euclidean geographical computation has and has not developed. We then present research in which we have been engaged to develop the methodological and practical basis for representing, analysing, and visualizing geographic phenomena within coordinate systems appropriate to absolute, relative, and relational spaces. It is to this latter research that we turn in the next section of this extended abstract. We close our presentation by noting paths of basic GeoComputational research suggested by this line of inquiry.

2. Realising the Many Spaces of GeoComputation

Space, location, distance, and coordinates are deeply interrelated concepts. In the case of absolute space, coordinates exist to allow us to index a pre-existing space that serves as a container for phenomena. To the extent that these spaces emerge out of a distance metric, process, and relations, it is physics (classical, or an approximation thereto) that stands prior to geography, analytically. By contrast, if we are to take the early insights of Tobler, Harvey, and many contemporary human geographers seriously, some relevant distance metrics of spaces, and thus coordinate systems, emerge with the dynamics and relations of geographical phenomena. The analysis of such intertwined spaces and phenomena for the purposes of geographical insight was central to Tobler's (2000) analytical cartography. Here, we build on research in Bergmann and O'Sullivan (2017, 2019) aiming to facilitate the use of these non-Euclidean, relational spaces within geographical computation.

In particular, we take Tobler's (1977) concept of the empirical projection as our departure to develop a generalized approach to geographical coordinate systems and the translations between them. The coordinate systems include not only those that we are generally familiar with, those that pursue accuracy in the spatial relations of an absolute space while struggling with our geoidic geometry, but also those relational spaces that can be reconstructed via the approximations of dimensionality reduction techniques (such as multidimensional scaling; Gatrell 1983) applied to complex distance relationships.

In this presentation, we offer a mathematical formalism for the problem of generalized, empirical projections. Such projections are not necessarily one-to-one mappings, and offer an expansive set of representational possibilities. We then offer simple computational implementations of empirical projections, examining their properties and requirements. We do so via the visual and numerical consideration of concrete examples, e.g., approximating a projection such as Briesemeister whose properties are already understood (Figure 1); expressing an areal cartogram as a projection; and considering a reconstruction of the oceans according to distances arising from shipping relationships. How efficiently can our empirical projections be calculated, stored, and applied? How precise are they? What representational limits do they have? In examining such questions, we seek to invite others in the GeoComputation community to join us in further exploring the expansive possibilities for space that have long been latent in our field.

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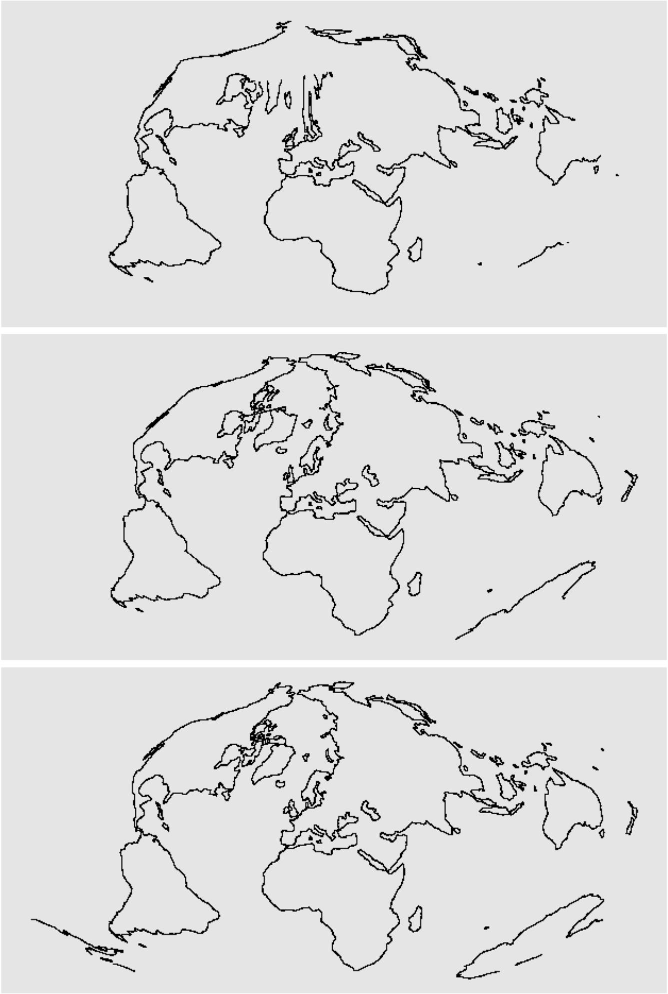

empirical
projection:
32 points

empirical
projection:
128 points

mathematical
projection

Figure 1: A computational implementation of an empirical projection. For reference, the bottom panel shows the closed-form mathematical Briesemeister projection. By comparison, the top and middle panels show empirical projections. These empirical projections differ in the numbers of points on which their transformations are defined. The empirical projection method here, discussed in the presentation, is related to the linear interpolations of triangulated irregular networks (TIN).

4. References

Bergmann, L. and O'Sullivan, D. (2017) 'Computing with many spaces: Generalizing projections for the digital geohumanities and GIScience'. *Proceedings of GeoHumanities'17: 1st ACM SIGSPATIAL Workshop on Geospatial Humanities*, Los Angeles Area, CA, USA, November 7–10, 2017.

Bergmann, L. and O'Sullivan, D. (2019) 'Geographical space expressive of geography: a transformational view'. In preparation.

Chrisman, N. (2006) *Charting the Unknown: How Computer Mapping at Harvard Became GIS*. Redlands, CA, USA: ESRI Press.

Couclelis, H. (1992) 'People manipulate objects (but cultivate fields): beyond the raster-vector debate in GIS' in Frank, A.U., Campari, I., and Formentini, U. (eds.) *Theories and Methods of Spatio-temporal Reasoning in Geographic Space*, Lecture Notes in Computer Science. Springer-Verlag. pp.65-77.

Gatrell, A.G. (1983) *Distance and Space: A Geographical Perspective*. Oxford University Press.

Gahegan, M. (1999) 'What is Geocomputation?' *Transactions in GIS*, 3(3), pp.203-206.

Goodchild, M.G., Cova, T., and Yuan, M. (2007) 'Towards a general theory of geographic representation in GIS', *International Journal of Geographical Information Science*, 21(3), pp.239-260.

Harvey, D. (1969) *Explanation in Geography*. London: Edward Arnold.

Harvey, D. (2006) 'Space as a Key Word'. *Spaces of Global Capitalism: Towards a Theory of Uneven Geographical Development.* London: Verso, pp.117–148.

Obermeyer, N. (1995) 'The Hidden GIS Technocracy'. *Cartography and Geographic Information Systems*, 22(1), pp.78-83.

Sheppard, E. (1995) 'GIS and Society: Towards a Research Agenda', *Cartography and Geographic Information Systems*, 22(1), pp.5-16.

Thatcher, J.E. and Beltz Imaoka, L. (2018) 'The poverty of GIS theory: Continuing the debates around the political economy of GISystems'. *The Canadian Geographer / Le Géographe Canadien*, 62(1), pp.27-34.

Tobler, W.R. (1961) *Map Transformations of Geographic Space*. PhD Dissertation. University of Washington, Seattle, WA, USA.

Tobler, W.R. (1977) 'Numerical approaches to map projections' *Beitrage zur theoretischen Kartographie Festschrift für Erik Amberger*. Vienna. pp.51-64.

Tobler, W.R. (2000) 'The development of analytical cartography: a personal note'. *Cartography and Geographic Information Science.* 27(3), pp.189-194.