Observations on the Gaps and Opportunities for Geocomputation

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ABSTRACT

Traditional geographical approaches to acquiring new knowledge and understanding problems varies significantly from the primary *modus operandi* of computational thinking that is practiced by computer scientists. These differences have contributed to a persistent absence of geocomputational courses within academic geography departments and an underdeveloped and limited understanding of spatial thinking by computationally-minded scholars.

KEYWORDS

Geographical thinking, geocomputation, enumerations, coordinates, spatial thinking, spatial relationships

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1 Early Geographical Thinking about Computation

Computational thinking involves logical and necessary sequences and workflows, systematic and procedural steps, and solution-oriented processes. Extending this to *geo-computational* thinking means that geographic and/or location-based elements become relevant components in one way or another, such as natural patterns or processes being modeled, or location data are being considered. The issue or problem under consideration need not be completely or entirely "geo" focused, but once geographic components are included, factors such as scale and spatial dependencies become necessarily relevant.

Thinking in linear, systematic, or sequenced approaches is not part of the disciplinary history or traditional practices of Geography or geographers. The "-graphy" (description) part of geography was traditionally most often accomplished by writing, sketching, drawing, note taking, or otherwise graphically making representations, often following a period of direct observations (e.g., field work). That quintessential geographic question of "Why is it like this, here" has long been pursued via explorations and surveys that were both initially much more qualitative than quantitative in nature. Eminent geographer Carl Sauer placed the highest priority on the experiences, methods, and approaches of individualistic approaches. As he noted in his 1956 treatise on *Education of a Geographer*,

> *"What* (italics his) geography is, is determined by what geographers have worked at everywhere and at all times. Method is means; the choice is with the workman for his particular task; the critic may object to incompetence but not to what the author has sought. Let us ask "what is geography'' by looking for and appreciating whatever has been done well and with new insight." (Sauer, 1956, 297).

He was particularly skeptical about approaches that allowed aggregation or synthesis to preempt an interpretation of the individual or singular experience.

> "The 'unit area' scheme of mapping may be a useful cataloguing device like the decimal systems of librarians, though I doubt it, but as a means of research I should place it below almost any other expenditure of energy.
>
> These misgivings about mapping programs and their techniques rest on a growing conviction that we must not strain to make geography quantitative. Quantification is the dominant trend in our social sciences, which are imitating the more exact and experimental sciences; it happens to be fostered at the moment by the liking of those who dispense funds for long-term programs and institutional organizations. I think we may leave most enumerations to census takers and others whose business it is to assemble numerical series. To my mind we are concerned with processes that are largely non-recurrent and involve time spans mainly beyond the short runs available to enumeration." (Sauer, 1956, 298).

Sauer's ideas were strongly influential on generations of geographers and academic geography departments, in part because they represented an (overly) idealized view of geographical research and inquiry that was nostalgically remembered following the disciplinary-disruptive quantitative revolution of the late 1950s and 1960s. By the mid-1980s when computers and computational thinking were increasingly integrated into scholarly lines of inquiry, the late geographer Peter Gould described the tension that he observed.

> "Of the problems that geography faces, along with all of the other human sciences, is that its mathematics is borrowed, and much of it was originally generated by the need to describe a physical world of *mechanism*. This means that if geographers borrow what is essentially a mathematics of mechanism to describe certain aspects of the human world, and that mathematics comes straight out of mechanics – levers, forces, attracting masses, atoms like billiard balls and so on – then the human world expressed in this borrowed 'language' *cannot look like anything except a big machine*. And since language shapes thinking, geographers employing such mathematical 'languages' are going to have their thinking channeled and directed towards mechanistic models. So in a sense, within this pre-chosen but unthought-about mechanistic framework, the thinking of geographers may already be trapped, pre-structured and disposed towards a mechanical view of human society." (Gould, 1985, 42).

With these ideas Gould admits that he is deliberately highlighting the negatives in order to get to his main point: his prescient sense of machines dominating human thought that directly forebodes expressed fears of artificial intelligence today.

> "For mechanics, quite properly and legitimately, is a science of knowing and manipulating physical things, and there is no question that our modern word could not exist without our capacity to manipulate by devising technical solutions to some problems. The difficulties come when thinking about technical solutions shifts sideways into the parallel human world where the 'things' are not things at all, but you and me, human beings with consciousness, with the capacity for self-reflection, and the ability to judge and make choices on moral, ethical, aesthetic, religious and many other grounds – including those of love and concern." (Gould, 1985, 43).

2 Vive la Difference

These words of Sauer and Gould hint at the gaps that have long persisted between the practices of geographical and computational thinking. Traditionally, geographers pursued lines of research that were characteristically idiosyncratic. Over the decades a handful of theories and models did develop and emerge, usually involving the variable of distance (e.g., gravity models) and its role in the formation and recognition of patterns (e.g., Central Place theory, spatial autocorrelation).

However, the primacy that spatial heterogeneity is not only an observation but an expectation continued to be dominant. "The essence of geography is variation; a fundamental assumption of geography is that there is not one single environment," noted Golledge (1996, 475). Thus much geographic research has been pursued that was by definition *not* aligned with tenets of computational thinking. The methods and approaches have *not* been formulaic, systematic, procedural, or solutions-oriented, those defining aspects of computational thinking. One particular outcome of this has been that much geographic research would score very poorly on marks for scientific replicability or reproducibility.

3 Problematic Areas: Measurements and Aggregations

Our societal resistance to settle on a global standard of longitude (to aid in navigation and time-telling) until the late 19th century is analogous to the effect of computers on our ability and need to measure location with varying degrees of precision. In 1956, Sauer (the then President of the American Association of Geographers) noted that the "Time-consuming precision of location, limit, and area is rarely needed; sketch maps of type situations, cartograms at reduced scales serve most of our purposes. Field time is your most precious time - how precious you will know only when its days are past." (1956, 298).

Latitude and longitude are the poster children for geo-computation novices. Naïve users latch on to these coordinates like a fly to honey because they make sense to them: 1) they can be easily construed as X, Y values; 2) a computer will readily report these back to the 12th decimal place (because more must be better); and therefore, 3) spatial analysis of any item or phenomena can be pursued because that item's location has been machine-read and understood.

Latitude and longitude are also the poster children for geo-computation experts who are resigned to correcting the misunderstandings and their incorrect usage, and anxious about the ways that the false knowledge permeates applications and instructional exercises.

Census enumerations were dismissed by Sauer as being irrelevant for their time scale and quantitative nature, but in the digital decades since his writings, Census data have become essential components of geographical analysis and geo-computation. In the United States, the data cover all geographies comprehensively and offer the best available proxies for recent and current social and economic patterns. And their formats are tantalizingly machine-readable for geo-computation.

That said, computers are better at space than place. Census data are readily and frequently misunderstood and misused due to factors such as sampling, changes to the questions and coding over time, the modifiable areal unit problem/dilemma, ecological fallacies, and related issues of scale and zoning. These are opaque issues that most people are unlikely to know or care about, but they do affect analyses, results, and interpretations.

4 Classroom Thoughts

Interestingly, Gould noted in 1985 that "Courses in computer programming – the actual writing of the instructions to tell a computer what to do – are standard parts of geographic curricula today, and most students go on to take more specialized work necessary for courses in analytical methods, remote sensing and computer cartography" (Gould 1985, 48). What evidence Gould had to make the claim about computer programming is unknown, but nevertheless, it is not like that today (Bowlick et al. 2017). Computers and computing power are ubiquitous components of geography programs today, especially in the geospatial and mapping sciences of GIS and remote sensing, but it is uncommon for a geography instructor or student to demonstrate or develop programming skills. That lack of confidence and competence by instructors and faculty at modeling computational thinking practices for their students is a persistent barrier to advancing the practice at the curricular level. Students are sent to other departments to acquire skills with programming and other computational capacities and are then additionally challenged to link, integrate, and transfer their new knowledge to their home base learning.

One approach in higher education that has demonstrated success is to recognize that acquiring the capacity for computational thinking is beyond the outcomes of one single university course. At DePaul University, almost 20 different courses were "re-worked" to have computational thinking be an explicit component and method of instruction (Perkovic, et al. 2010). Multiple and diverse contexts proved to be more robust and effective than solitary insertions. In another situation, thoughtful design of a single course that was unambiguously problem-driven, relied on simple code that can be written rapidly, and had a significant visualization element was the right combination to encourage further computational-study (Harmbrusch et al. 2009).

Geospatial technologies serve as an effective platform to engage both geography and non-geography students with practices of computational thinking because of the nature of the digital tools and the diverse range of applications, problems, and contexts (Knobelsdorf, Otto, and Sprenger 2017). In particular, emphasis of the computational components of *information science* itself rather than GIS software was a notable outcome. Muller and Kidd (2014) found that the R platform provided the right blend and level of computational thinking and programming for exploration of geographical problems and issues. Shook and his colleagues (2016) approach the geo-computation connection by mitigating the more technologically complex dimensions via incremental, brief (one-hour), and non-threatening tutorials. I find that the systematic and regular use of tools such as Esri's ModelBuilder are efficient and effective at supporting the types of sequential and iterative workflows that computational mindsets expect. Moreover, being able to see the big picture view of an analytical process is the type of "thinking with space" that benefits all mindful activity.

5 Spatial Thinking and Spatial Relationships

In their 2016 article on Defining Computational Thinking for Mathematics and Science Classrooms, Weintrop et al. designed a taxonomy of computational thinking that bridged across four STEM dimensions: 1) data practices, 2) modeling & simulation practices, 3) computational problem solving practices, and 4) systems thinking practices. By thoughtfully breaking down the whole of computational thinking in this way, and explicitly listing tasks and behaviors that a computational-thinking practices within each of these, a holistic vision of the practices is easy to appreciate. One can appreciate how the simple practice of "collecting data" eventually builds to "defining systems and managing complexity."

Being able to articulate the practices of a savvy and seasoned geo-computational thinker in this way is an elusive but desirable goal. In this way one could specify how and where one moves beyond a rudimentary understanding of latitude & longitude to more interesting and nuanced topics. How the practices of spatial thinking constantly and consistently span methods and applications is unfamiliar to most everyone (Sinton 2016). Notably significant in its absence is the idea of spatial relationships. Understanding how objects, phenomena, ideas, entities, and other things are related– physically, conceptually, intellectually, socially, culturally – and at varying scales – is extremely rich fodder for understanding how the world works. There is key knowledge here that is typically goes unnoticed by computer scientists aiming to become more geo-enabled.

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