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A Spatial Analytical Methods-first Approach to Teaching Core Concepts

Introduction

Teaching geospatial technologies is notoriously difficult regardless of the learning audience. Even students within traditional geographical and geoscience disciplines who are taught *about* GIS (geographic information systems) and *with* GIS take years to master geospatial technologies (Kemp *et al.*, 1992, Audet and Paris, 1997, Sui, 1995). Since the interest in geospatial technologies continues to grow, it is clear that the approach to teaching them must change. I propose a potential alternative or addendum to our original approach to teaching of geospatial technologies. This approach focuses on the characteristics of and analytical methods on spatial entities that are unique to them but shared among them.

Teaching Spatial Characteristics First

What if we started teaching the shared characteristics and analytical methods of spatial entities first? This could entail first teaching about 1) *geometric measures* <u>of</u> lakes, bus stops and elevations and 2) *basic analytical operations* <u>on</u> them <u>rather than</u> how to represent them. Examples would include geometric measures of direction, shape, area, etc. and basic analytical operations such as buffers, overlays, and map algebra. These topics are nested within the analytical methods section of the University Consortium for Geographic Information Science's (UCGIS) GIS&T Body of Knowledge (DiBaise et al., 2006). In other words, perhaps we could start teaching about characteristics of things rather than the things themselves. To elaborate, let's understand what is common across the core content concepts.

The core content concepts are conceptual models of different things in the real world. They are all built on the base concept of location (and perhaps time and theme as well). An object is an identifiable entity that has spatial, temporal and thematic properties. Typical examples include a building, a light post, and a county. A field has a measurement value at every position. Typical examples of fields include elevation, rainfall, and temperature. Networks represent spatial connectivity between objects. A typical example is a network of bus stops that comprise nodes on a bus route. Importantly, all three of these core content concepts share similar spatial properties that are likely familiar to most audiences. For example, objects, fields and networks all have *relations*, such as neighbor relations. Neighbors are other entities that are adjacent and/or deemed close enough to be considered within the neighborhood of an entity of interest. Object neighbors can be determined by topological connections or by a proximity operation (like buffer) that deems other objects to be close enough to be in a neighborhood. Knowing an object's neighbors is useful for many applications such as pattern analysis, and determining how dispersed or clustered a set of objects is. Field values are often influenced by a neighborhood as shown by the *focal* operation (i.e., typically the 3x3 cells surrounding and including a location of interest in a raster model). Neighbors are inherent in a network since each node has a binary relation with each other node directly connected to it via an edge.

Neighbor relations are just one type of relation, and there are plenty of other shared characteristics between the content concepts. For example, the notions of distance, direction, and area are also common. Teaching common characteristics first would likely be easier for students to grasp since they can bring background knowledge of them to the table. Through cognitive maps, wayfinding, orienting, etc. people know about and can communicate about these characteristics. People are more familiar with these characteristics than they are with objects or fields, for example, or the defining characteristics of each, such as an object's identity, or an interpolation used to create a field.

A Comparison to Programming Paradigms

The differences between this alternative and the original proposed teaching approach parallel the differences between teaching object-oriented programming (OOP) and functional programming (FP). OOP leverages objects that contain data and functions that can be applied to the data. It relies on the principles of abstraction, polymorphism, encapsulation, and inheritance. Teaching OOP is similar to teaching the original proposed core content concepts, where each of the concepts are classes that handle data in a particular way and have particular functions that can be applied to them. FP on the other hand relies on the notion that functions are first-class, immutable and pure. One should expect a (well written) function to operate the same way every time it is invoked, and that they can be passed around much like objects are. Teaching FP is similar to teaching characteristics-first, where characteristics like *relations* should have the same result each time invoked.

This comparison is not to say that one method is necessarily better than another, they are just different. The debate between these programming (and corresponding teaching) approaches will likely continue for a while. And while the parallels to core concepts of spatial information are not entirely the same, they depict a difference in teaching paradigms. The original proposed teaching method of the core concepts is an objects-first approach where the content concepts are things that are described, and then their operations are described. Alternatively, a characteristics-first approach describes characteristics much like functions, where *distance, direction, proximity,* etc. will give the same result each time they are invoked. This will show students the similarities between the content concepts, setting them up to then learn about their differences. Afterwards, quality concepts should be introduced as *lenses* on the content concepts as the original position suggests. However, it's important to note that the quality concepts are also like functional programming in that any certain input will result in the same output, even if this is a content concept. Next, I will elaborate on how this approach fits into existing approaches to teaching geospatial technologies.

"Basics First" and "Structured Problem Solving" Approaches

Various other GIS teaching frameworks have been suggested. A non-exhaustive list includes the widely-adopted National Center for Geographic Information and Analysis's (NCGIA) curriculum (Kemp and Goodchild, 1991), Sui's organization of GIS concepts based on Brian J. L. Berry's geographical matrix (1995), and the various country-wide programs outlined in van Manen *et al*. (2009). Additionally, the University Consortium for Geographic Information Science has produced a Body of Knowledge (DiBaise *et al.*, 2006) which is fluid and has undergone several revisions.

Several of these studies have explored the effectiveness of teaching concepts first, an approach that has been proven to be an effective means for the long-term retention of information. This is likely why many departments (including some geography departments) teach with a decontextualized “basics first”[1] approach where students learn the fundamentals and core concepts of a discipline or topic before being exposed to more complex material or techniques (Campos, 2002). This approach can be seen in UCSB’s biochemistry course sequencing, where first year students take general chemistry, general chemistry lab, general biology and calculus before taking vector calculus and general biochemistry. However, as Campos (2002) found, many GIS students also perform very well on exams and follow-up exams under the “structured problem solving” approach where students are additionally assigned practice questions and can control supporting video tutorials. This approach differs from “basics first” because it adds some context and gives students a problem-solving goal to work towards.

Kemp *et al.* (1992) define similar parallel approaches where “fundamental principles must be presented first so that the more complex ones can build on knowledge, while [an] alternative begins with a superficial introduction to the complex whole in order to motivate interest in the various component parts.” This alternative is in some ways similar to the “structured problem solving” approach. Students are handed a relatively large amount of information and try to make sense of it themselves through activities rather than just building knowledge from the bottom. Kemp *et al.* (1992) continue on to suggest that the best approach is a “short superficial introduction, followed by a progression from simple to complex fundamental principles.” This is the approach that I most agree with and will argue for. As a result, the sequence of an introductory GIS course should start with an immersive activity followed by an introduction to the core characteristics of spatial information, and then the core content concepts.

Organization of an introductory course outline

For sake of brevity, I have organized this approach to teaching into bullet points.

- What to teach in an introductory GIS course
  - *Prerequisite of 1+ cartography, 1+ human geography, 1+ statistics courses*
  - *Take in conjunction with 1+ spatial cognition courses (recommended)*
    - *Should cover some GIS cognitive and social foundations (as specified in GIS&T Body of Knowledge (DiBaise et al. (2006))*
  - Core characteristics
    - *What is unique about spatial data and what you can do with it*
  - Core content concepts (conceptual models)
    - *How things in the real world are is modeled conceptually as spatial data*
- Sequencing
  - 1) Short immersive introduction
    - *1-2 weeks: hands-on interaction with spatial data*
  - 2) Introduction of core characteristics
    - *2-3 weeks: exploring core characteristics and analytical methods*
  - 3) Introduce of core content concepts (building complexity)

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[1] This approach relies on Jean Piaget’s cognitive theory statement schemas are building blocks of knowledge.

- *2 -3 weeks: Objects & Fields*
- *2-3 weeks: Quality Concepts*

To summarize, I’ve outlined what content should be taught in one introductory GIS course, as well as its prerequisites. I’ve also described a sequence of three sections for the course, which begins with an immersive introduction followed by an introduction to the core characteristics of spatial information, and then introduce the core content concepts.

I posit that teaching geospatial technologies should start with students directly handling and exploring native spatial data in a GIS. This would be a structured problem-solving activity. With some instructional guidance, learners should visually explore simple familiar real-world data, like point representations of restaurant locations. This would expose them to pure *where* questions, like *where is my favorite restaurant*, and *where should restaurants be?* This should naturally guide learners to more complex questions like *what is the distribution of restaurants?* The UCSB data science club takes this approach to web mapping where they first naively explore what data and tools are available. Having students “get their hands dirty” with data will allow them to see the value in the tools they have to answer their questions. Otherwise, they may approach a concept-first or characteristic-first approach by saying, “I don’t get why this matters,” “how is it applicable,” or worse, “why can’t I just Google it”. Finding something worth doing is critical to a GIS introduction (Audet and Paris, 1997).

After a few weeks, core characteristics of spatial information should be introduced. This list would include practically all geometric measures and basic analytical operations unique to spatial data discussed in GIS&T’s analytical methods section such as geometric distance and direction, shape, regions and areas, neighbors and proximity, connectivity and adjacency, as well as supporting operations such as buffer, overlay, neighborhood and map algebra. Some of these ideas should be familiar from background knowledge and prerequisite content (e.g., Hotelling, von Thunen and factory allocation models, and cartographic principles discussed in Nyerges and Chrisman (1989)). After students have several weeks to explore what they can do with their data, focus should be shifted to core content concepts.

Conclusion

As an addendum to our original position, teaching geospatial technologies could start with a hand-on problem solving activity followed by an introduction to the core characteristics of spatial information before then jumping to core content concepts. To test this and the original approach, I suggest surveying GIS students and faculty (Audet and Paris (1997) and Rickles *et al.* (2017)) to ask about the perceived importance and clarity of the core content concepts, and the sequencing of what is taught. Additionally, I suggest comprehension testing (as conducted in Campos (2002)) of the original position as a “basics first” approach, and compare this to the alternative “short superficial introduction” / “structured problem solving” approach.

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