What Curriculum Means, and Could Mean, for CyberGIS

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Keywords: curriculum, polysemy, scale, learning object, MOOC.

The Curriculum Workshop’s goal is to envision guidelines that lead to adoption of CyberGIS teaching and learning in undergraduate and graduate courses. One challenge confronting this task is the fact that “curriculum” is a polysemous concept with multiple related meanings. Here I briefly consider some of those meanings and their implications for efforts to achieve the stated goal.

In general, “curriculum” denotes a designed and guided experience or series of experiences that result in learning. In particular, however, curricula in higher education occur across a spectrum of scales as well as a hierarchy of levels (graduate, undergraduate, professional development, middle college high school, etc.). At the macro-scale, “core” or “general education” curricula span entire institutions. Articulation agreements also make inter-institutional curricula possible. At a micro-scale, discrete educational resources like articles, presentations, demonstrations, exercises, quizzes, and sometimes even games shape learners’ experiences. In between, academic departments offer degree and certificate programs with prescribed sequences of “courses” or “modules” and individual educators or small teams develop and conduct courses/modules made up of sequences of topics and activities.

Macro-scale curricula are longer in duration (sometimes requiring years to complete), have the broadest scope, involve the most stakeholders, and are therefore the most challenging to develop, maintain, and transfer to other settings. Micro-scale curricula, by contrast, are relatively brief experiences that tend to be narrow in scope, reflecting the efforts of fewer authors. They are relatively easy to create and update. And because they can be adopted by others with a minimum of disruption to their own curricula, they tend to be easier to transfer to other settings. If transferability is a key design objective for CyberGIS education, then thinking small may make more sense than thinking big.

If we array the various scales at which curricula occur into a spectrum ranging from most extensive (macro-scale) to most focused (micro-scale), and if we then situate the projects of the CyberGIS Fellows within that spectrum, a concentration of projects at the intermediate scale of courses/modules becomes apparent. The educational experiences engineered at this scale are likely to span weeks or months, involve a small number of individual author/educators, and impact dozens, or at most hundreds of students (cumulatively). The resources are likely to be moderately difficult to develop, maintain, and transfer to other settings (i.e., graduate and undergraduate programs at other institutions). The position I wish to advance is that a broader range of educational resources is likely to increase the chances of achieving the workshop’s goal.

One example of a “micro-scale” resource is Esri’s “GeoInquiries.” GeoInquiries are short, standards-based inquiry activities for teaching map-based concepts found in the most commonly used K-12 textbooks. Each GeoInquiry consists of a one-page (front and back) PDF document that explains the activity and guides the inquiry, and a corresponding ArcGIS Online web map that teachers and students can access freely, without even logging in to the cloud-based GIS. The activities are technology agnostic and can be delivered in a K-12 classroom with as little as a tablet and a projector. They can be mastered in minutes, and can be added to existing curricula for U.S. History, Earth Science, AP Human Geography, and other subjects with little disruption (Baker 2015).
Extending this “micro-scale” approach to CyberGIS, one can imagine a set of learning objects that prompt students’ inquiry into fundamental concepts that make web maps possible. Although the term “learning object” is variously defined, one of the most clearly articulated definitions is “the smallest independent instructional experience that contains an objective, a learning activity, and an assessment” (L’Allier 1997, cited in Polsani 2003). Polsani stresses that learning objects are “…predisposed to reuse in multiple instructional contexts.” Concise learning objects that are narrowly focused on concepts like services architecture, APIs, and cloud computing could be readily added to any number of existing GIS and GIScience courses at many institutions. The approach has proven effective in other disciplines. For example, educators who sought to infuse ethics education in engineering curricula successfully employed a similar approach, which they called “micro-insertions” (Davis 2006). Concept mapping has been used effectively to design and organize reusable learning objects (DiBiase and Gahegan 2009).

At the intermediate scale of courses/modules, massive open online courses (MOOCs) have proven the potential to engage thousands of students in active learning with web maps. MOOCs offered at no charge, and without academic credit, are relatively easy for educators at other institutions to adopt (as extra-credit assignments, for example), and for students to join on their own. The CyberGIS Center’s host institution – the University of Illinois – is an academic partner with Coursera, the leading MOOCs platform. While designing, creating and conducting MOOCs is certainly not without costs, a concise MOOC on CyberGIS principles could expand awareness and generate interest far beyond the higher education institutions currently represented in the CyberGIS community.

“Scale” is a fundamental concept in education as well as geography and GIScience. Here I’ve suggested that more extensive “macro-scale” curricula are harder to transfer between institutions and educators than more focused “micro-scale” curricula. If true, focused educational resources – perhaps fashioned as reusable learning objects – may be best suited for initial adoptions by educators who wish to expose their students to CyberGIS, but are reluctant or unable to disrupt their established curricula. Moreover, a spectrum of curricular resources at a range of scales should help generate and support educators’ broader and deeper adoptions over time.

References:


Alignment of goals, assessment and activities in national GIS&T curriculum and BoK

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Keywords: Body of Knowledge, Advanced Placement, Competency Model, Curriculum.

Over the past two years two related national GIS&T curriculum initiatives have been underway. UCGIS has initiated a substantial revision of their Body of Knowledge document (DiBiase et al. 1996). So far work has concentrated on identifying a model for how a ‘new’ BoK 2.0 can be kept up-to-date through broad and continuous input from the GIS community, and enable direct connection from knowledge areas and units to learning resources. Under a UCGIS steering committee, the work to develop the new BoK 2.0 will be governed by an editorial board to maintain an ongoing peer-review of contributions and updates to the BoK. In this way the new BoK 2.0 will be less of a final printed reference document and more like a constantly developing online resource akin to a wiki and online journal, where new or revised entries will go through peer-review and editorial curation.

Closely related to the BoK work, but as an entirely separate initiative, the Association of American Geographers (AAG), with funding from the Geography Education National Implementation Project (GENIP), are currently developing a course proposal for a new Advanced Placement (AP) course in Geographic Information Science and Technology. AP courses are equivalents of introductory college courses, but given at high schools as a way for students to earn college credit while still in high school. AP courses exist in many subject areas including Human Geography and Computer Science, but so far no AP course exist for GIS&T. A proposal for this new course will need to include a template syllabus, appropriate and viable assessment protocols, professional development for high school teachers, buy-in from university programs to accept AP course credit, and more. In order to generate a template syllabus and appropriate assessment tools, the proposal writing committee has gathered information on introductory level GIS&T courses from 200 sample schools across the U.S. A subset of those courses has been analyzed for content to determine enough commonalities across all of them that could serve as a core set of skills, competencies and knowledge areas for a generic AP course that would be possible to translate into college credits in a large number of 2- and 4-year institutions.

In the work with the AP GIS&T course it has proven to be very useful to use the existing BoK, as well as the Geospatial Technologies Competencies Model, as a reference vocabulary (or ontology if you will) for the comparison of course content across multiple institutions. This identification of skills, competencies and knowledge areas is also critical to identify learning modules and assessment methods that align with course content and goals. Thus, it is clear that a new BoK will have a critical role to play in the further development and specification of learning outcomes and associated curriculum development, not just in the context of the ongoing AP GIS&T course, but for many similar initiatives like the certification of GIS professionals and for GIS program development.

A key concept in all of this work is alignment. Starting with the specification of a knowledge area, divided into units that are broken down into topics like “Buffer” or “Spatialization” allow us to specify units of knowledge that can serve as desired learning outcomes. From those outcomes we then need to identify how some form of assessment can help determine if a student has acquired the knowledge and that in term will help guide instructional designers to identify the necessary pedagogy and activities that can take the student to that point. Unless we have made sure to align learning outcomes (such as BoK
topics) with assessment protocols and learning activities, we cannot say that our instruction is intentional about the desired outcome.

The two initiatives, BoK 2.0 and AP GIS&T projects can potentially provide all needed pieces of this alignment puzzle. BoK can serve as the ontology or vocabulary for expressing and specifying what a core set of knowledges are, and the work with the AP GIS&T course to identify appropriate assessment methods and validated scales for measuring outcomes. By ensuring and supporting alignment of goals, outcomes, assessment, and activities we could provide a rigorous insight sub units that describes what a piece of

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**Educating the next generation in cyberGIS: Challenges & Opportunities**

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Keywords: cybergis, advanced cyberinfrastructure, next generation, education.

**Overview**

Advanced cyberinfrastructure (ACI), including high performance and high throughout computing, offer advantages over traditional computing environments beyond being able to handle large datasets and improved speed of computing. With the explosion of data availability (via personal and environmental sensors and streaming capabilities, social media, etc.) there are tremendous opportunities to explore and develop unprecedented complex models with much higher levels of resolution and accuracy in a reasonable amount of computing time.

Traditionally, the majority of the GIS community has relied on standalone desktop programs such as ArcGIS and QGIS. Converting existing geospatial algorithms from serial programming for use on a parallel, distributed architecture presents too great a challenge for many researchers who have been trained to think linearly. However, by using existing advanced infrastructure and resources, we can create pathways that can help alleviate this difficulty. The aim of this paper is to outline some of the challenges and opportunities for creating successful pathways to (re)educate the next generation in cyberGIS.

**Challenges: Falling Behind**

GIS is used in many scientific research areas such as climate change and hydrologic modeling that require data-intensive computation. However, in the advanced cyberinfrastructure world, the GIS community is considered a non-traditional user compared to researchers in chemistry, genomics, or physics. Below I explain some of the factors that, in my opinion, are causing GIS to fall behind with regards to other disciplines.

- **Shifting landscape**
  The GIS landscape has evolved and expanded at a rapid rate during the past 10 years. Not only are there now many more applications and disciplines in the GIS arena, especially Humanities and Social Sciences, but the robustness of open source solutions (QGIS, Hadoop) and the recent boom of geo-visualization platforms (CartoDB, Tableau, Google Fusion Tables) are creating a complex, dynamic landscape for GIS.

- **Lack of versatility**
  According to the US National Geospatial Advisory Committee (NGAC), the past eight years have been a time of rapid technological change in the geospatial industry. While the GIS community has adapted well to the use of mobile technologies and cloud platforms, the average analyst is still predominantly a Windows desktop user. Embracing inherently different operating systems, such as Linux, or geospatial programming libraries, such as GDAL, is the exception rather than the norm. This lack of versatility has been an impediment for the use of high performance computing and big data.

- **A bridge too far**
  Another common challenge is the perception that the return on investment in changing architectures is too low. Switching from traditional computing systems into high-performance environments is viewed as too onerous and often, uncertain in its success.
Opportunities: Bridging the two paradigms
There are a number of exciting initiatives, resources, and consortiums that are already in place helping to bridge the two paradigms: traditional desktop and advanced cyberinfrastructure.

- **CyberGIS Center & CyberGIS Fellows**
The CyberGIS Center at the University of Illinois and the CyberGIS Fellows program have been promoting and supporting the development of cyberGIS educational materials and curricula at the national level.

- **ACI-REF Consortium**
ACI-REF is a nationwide alliance of advanced cyberinfrastructure (ACI) educators whose mission is to empower local campus researchers to be more effective users of advanced cyberinfrastructure. One objective of this consortium is to work with the “long tail” of ACI users—those scholars and faculty members who traditionally have not benefited from the power of massively-scaled, cluster computing but who recognize that their research requires access to more computing power than can be provided by their desktop machines.

- **Campus Clusters & National Compute Resources**
Many research institutions have local high performance clusters that are available to researchers of any discipline to meet their computational needs. However, sometimes users might need to manipulate or compute more data than their local system can accommodate and use national compute resources such as the OpenScience Grid, XSEDE, or the new CyberGIS supercomputer: ROGER.

Conclusion
Most of the current efforts on cyberGIS are focused on the development of advanced infrastructure, innovative technologies, open data, and improved models. However, it is my opinion that we are leaving behind many of our traditional GIS researchers and educators that find these new advancements too challenging. High-performance environments provide a remarkable opportunity for the advancement of GIS research and science. We cannot afford to have just a few exceptional researchers diving into this exciting new field and leave the rest of the community behind. How we programmatically design a curriculum that simultaneously integrates and advances Geographic Information Science is challenging, but nevertheless necessary and it should be a proactive and conscious, common effort from all areas of the GIS community. Working with relevant networks and existing resources such as ACI-REF is essential in ensuring the establishment of successful pathways for CyberGIS not only for future generations, but also for the current ones.

References:
Software Carpentry and the Research Bazaar as a solution to the cyber-skills gap

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Keywords: software carpentry, research bazaar, cyberinfrastructure, research computing.

As computationally-enabled approaches to research become more prevalent across all disciplines, the gap between what students and researchers know, and what they need to know to leverage these new approaches, widens. By now it is a huge gulf, with cyberinfrastructures and computer scientists on one side and most of our potential users and collaborators on the other. The gap seems to be at its widest within the humanities and social science communities, where most geographers reside.

Curricula cannot evolve fast enough to close such gaps, and are always hampered by local politics and the equally-important expansion of knowledge in a multitude of other directions within any given research domain. Trying to change the curriculum can also take years, by which time the needs themselves may have changed.

An alternative approach is to up-skill researchers outside of the curriculum, and one advantage of doing so is that the teaching and learning can focus on practical and useful knowledge, skills and practices, without the additional need to meet the rigors of a college syllabus with an academic focus on what is often a very practical need. However, creating an environment where researchers choose to take on additional work that is not for credit is also a huge challenge. How might it be tackled?

At the Centre for eResearch here in Auckland, New Zealand, we have been facing the challenge of equipping researchers to avail themselves of cyber-technologies for several years. Our response has usually been to provide practical help and expert consulting where it is needed, with some regular workshops on specific topics. But this approach is very difficult to scale across a large and demanding research community.

Over the last year we have taken a radically different approach, inspired by the work of the Software Sustainability Institute\(^1\) and specifically Software Carpentry\(^2\) and the Research Bazaar\(^3\) or ResBaz. The aim is to up-skill the community at large, and to empower and encourage individual researchers to form a supportive community to help each other. In short, nothing less than a complete culture change.

In the book *The Cathedral and the Bazaar*, Raymond (1999) contrasts two competing approaches to creating useful software: by a monolithic institution or a loose confederacy of engaged and empowered individuals. The book describes how the highly-successful Linux operating system emerged from the nascent open-source community and the principles that allowed it to do so. In a similar way, there is huge potential for researchers to help other researchers in a way that builds into an effective, sustaining community, over time.

Our new approach took the following form:

1. We began by conducting a research computing (cyber) needs assessment. Two separate focus groups were convened to identify specific and key digital literacy skills for research. The first focus group had 10 attendees representing researchers and research support staff across the university. The second focus group was attended by more than 20 delegates at a national eScience conference, who

\(^1\) [http://www.software.ac.uk/about](http://www.software.ac.uk/about)
\(^2\) [http://software-carpentry.org/scf/](http://software-carpentry.org/scf/)
\(^3\) [https://feb2016.resbaz.com/](https://feb2016.resbaz.com/)
faced similar challenges at their home institutions. High priority needs included: high performance computing, basic scripting and programming, using code repositories, sharing and publishing.

2. With the needs identified and prioritized, it immediately became clear that they aligned well with existing earning materials created by the Software and Data Carpentry\(^4\) movements. The New Zealand eScience Infrastructure (NeSI)\(^5\) arranged a program of Software Carpentry instructor training to help create a national team of engaged, knowledgeable and qualified instructors (all would-be instructors have to pass an evaluation before qualifying).

3. In January, 2016 we ran our first Resbaz event to provide 3 days of intensive training on the use of modern cyber technologies for research with 20 instructors and helpers, and 60 participants—mostly younger faculty and research students. The event was a huge success, you can see the storify highlights reported here: [https://storify.com/cammerschooner/resbazak](https://storify.com/cammerschooner/resbazak) with most participants committing to help out at the next event, which can then be bigger.

4. Each week we host an event called HackyHour\(^6\), run in a public location, currently a cafe, which provides an opportunity for researchers to come along with open ended questions relating to digital literacy, research software or working with data. The participants help each other, with us facilitating and providing more help if needed.

As a direct result of these changes, participation in ongoing events is high, and there is now a growing, researcher-led demand for additional workshops and not-for-credit classes on Python programming. We are now exploring how to train more instructors in time for the next event, enabling researchers to help each other, and to build over time into a sustainable and nurturing community.

During Software Carpentry, participants practice their skills directly as they learn. They post pink or green sticky notes on their computers to show if they are following along or if they need help.

References


\(^4\) [http://www.datacarpentry.org/](http://www.datacarpentry.org/)
\(^5\) [https://www.nesi.org.nz/](https://www.nesi.org.nz/)
\(^6\) [https://uoa-eresearch.github.io/HackyHour/](https://uoa-eresearch.github.io/HackyHour/)
Beyond Widgetology:
CyberGIS as a First Class Citizen in Departments of Geography

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Keywords: GIS education, geography education, computer science and programming, geography and GIS degree design.

The ability to write computer code, i.e., the ability program, is moving closer and closer to the required section of job advertisements in the GIS field. What were previously nice-to-haves, or “desired” skills – “2-plus years programming experience”, “fluency with Python”, “ability to create web maps with JavaScript” – are now becoming required skills necessary to perform the stated duties of many entry-, mid- and senior-level GIS Analyst, GIS Technician, and other positions across a number of fields including but not limited to Oil & Gas, Local & Regional Government & Planning, Retail, Real Estate, Construction, and Environmental Services. The required knowledge, skills, and abilities of a GIS student with an undergraduate degree seeking a job in 2016 are markedly different than those of a decade ago. The subject material included and emphasized in the degrees we offer our students in two and four year colleges and universities needs to change to keep pace with what employers are expecting of our graduates.

An initial analysis of a year-long survey of GIS hiring performed by the authors which captured the full text of 22,000+ GIS job postings in the US has revealed some astounding facts about the state of GIS hiring in the US. Most astonishingly, a full one third of all job posting for entry level positions – GIS Technician (I), or GIS Analyst (I) – posted during this timeframe (Feb 2015 – Feb 2016) explicitly either require or desire CyberGIS knowledge, skills, and abilities spanning the full spectrum of the CyberGIS knowledgebase. These include but are not limited to: knowledge and extensive experience in one or more programming languages like Python or JavaScript; knowledge and extensive experience in web-based GIS and server platforms like Windows Server or ArcServer; and knowledge and extensive experience in managing spatial data in one or more databases management systems like PostgreSQL, MySQL, or SQL Server.

These are not the topics covered in many Departments of Geography in the US, currently. To many in Departments of Geography nationwide, these topics are seen as something that should be “outsourced” and “should be covered in the [XYZ] Department”, where X, Y, and Z are often Computer Science, Management Information Systems, or Information Technology. These (not intentionally disparaging) sentiments by colleagues across the country may have their roots in the same confusion that many have traditionally found between GIS as “Geographic Information Systems” or “GIScience.” Students seeking degrees in GIS in many Departments have in many cases been seen in the light of the former, as “Buttonologists” – technicians (i.e., worker bees) trained in how to click buttons to solve a problem that someone else hands to them. With the growth of Geographers undertaking CyberGIS research careeres and the responsibilities it entails – engineering systems; developing code; managing servers, creating interactive apps and web-based visualization – the Buttonologist is giving way to the equally irreverent term “Widgetologist”, referring to those Geographers whose research outputs consist primarily of software code and engineered systems which solve novel problems, at larger scales, faster, on innovative platforms, with new sensors or previously undiscovered interfaces or functionality.
Our ongoing survey of the needs of GIS workforce, from the perspective of those hiring in the field as demonstrated by the job ads for people they seek to hire, has revealed clearly for us that the time has come to raise the profile of CyberGIS education in Departments of Geography in the US. A recent survey completed by the authors of the degree requirements for Geography and GIS undergraduate degrees (210 different degree options) in the top 55 Departments of Geography in the US (as ranked by National Research Council Rankings and Academic Analytics) revealed that only 22 degree tracks (10% out of 220 degree tracks investigated) require any form of programming course for degree completion. We contend that when one third of all jobs in our discipline require a skill of our graduates, and only 10% of the degrees offered in the US require this skill as a foundation for graduation, nationwide, we are failing in our job as educators.

We acknowledge fully that CyberGIS and the trend toward the GIScientist-as-programmer is an emerging phenomenon that has been unfolding before our eyes in just the recent few years thanks to the high profile efforts of a number in the GIScience community. However, Android devices and platforms which offer turnkey samples for creating mobileGIS applications, web services and relevant API’s for building interactive JavaScript application, and software development kits (SDK’s) for extending desktop GIS (e.g., Esri) have been in existence for, in many cases, decades. The technological basis for CyberGIS education has been around for quite some time, and we have no excuse for not teaching it other than inertia. Designing a new course takes effort; getting a special topics course approved by Departmental, College, and University curricular committees takes time; purchasing hardware, servers, and licenses to enable student development takes money; inserting a new course into an already packed undergraduate degree plan takes approval from colleagues and often means that something else must go by the wayside.

Many of these challenges cannot be overcome by a single faculty (research group, or cluster) alone. Such changes take full departmental buyin for a vision for the future of Geography and GIScience where a Computational foundation is just as fundamental as a Human, Cultural, or Physical Geography foundation is in many Departments now. The leaders in our field, our Departments, our Colleges, and our Universities must be convinced that just as Big Data is permeating through all aspects of the Academy, Cyber is permeating through GIS and Geography as a whole. Our society needs Geographers highly trained and skilled in developing and utilizing CyberGIS to solve hard, large, impactful problems with broad-reaching consequences. Without the fully-developed educational frameworks of curricular materials, shared and accessible learning environments, and realistic problem sets and collaborative spaces that a coordinated CyberGIS education agenda at the national scale can afford, students in the US will continue to graduate from our departments unprepared to join the US STEM workforce or lead the world in the innovation that CyberGIS can be used to foster.

However, all is not doom and gloom. Initiatives such as the CyberGIS Fellows Program and strong investments by the National Science Foundation are seeding the core for a burgeoning future of CyberGIS educators and researchers at US institutions. The AAG CyberInfrastructure Specialty Group will likely sponsor 70+ sessions at this year’s AAG. Our job, as members of the CyberGIS community, is to continue to demonstrate that software development, systems engineering & design, and all of the other aspects that encompass CyberGIS remain as the drivers of science which solve important problems. And, most importantly, we translate these accomplishments into exciting learning materials that can be used and shared in the classroom to inspire more and more of our students to demand more and more CyberGIS-related courses be included in their degree plans.

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**Fundamentals of Big Data for CyberGIS**

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Keywords: Big Data, new media, data quality, conflation, volunteered geographic information

Massive data volume is one of the three frequently mentioned Vs, the defining characteristics of Big Data, and thus Big Data is often cited as a driver for CyberGIS. It is important, however, that students recognize the other characteristics, notably velocity and variety, and understand their implications for computation. Moreover Big Data is also often associated with highly variable and sometimes questionable quality, and thus with a fourth V, either validity or veracity. Big Data is also raising numerous issues of a fundamental nature, and stimulating much discussion about changes in the nature of science. If we believe that Big Data is intimately associated with CyberGIS, then I believe it follows that a CyberGIS curriculum must include the topics discussed in detail in what follows.

*The defining characteristics of Big Data*

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**Volume:** What techniques have been used in the past to work around the problems caused by massive data volume, for example in remote sensing?

**Velocity:** What new opportunities are afforded by data that are available in close-to-real time, and what does this imply about the changing nature of science? What new methods of analysis are needed?

**Variety:** In the world of Big Data there are almost always many sources of the same information, with different properties including quality. How can traditional methods of analysis be generalized to handle multiple sources?

**Data quality**

How can geospatial data quality be characterized? What metrics are available, and how can they be used to address the propagation of uncertainty through analysis? How can uncertainty be simulated?

**Conflation**

How can multiple sources of geospatial data be combined to produce a synthesis that is more reliable than the individual sources? Topics include fusion of raster data, conflation of vector data, and conflation of both vector and raster data. What new methods of conflation and synthesis are needed?

**Volunteered geographic information**

VGI, and crowdsourcing more generally, is an important source of Big Data. How can its quality be assessed and modeled?

**New media**

The topics discussed above are all important in applying CyberGIS to Big Data. But they do not address the long-term implications of doing so, and rather focus on the ways in which Big Data can be brought into traditional approaches. In my view the more fundamental impacts of Big Data and CyberGIS are if anything more important in a curriculum than the technical ones, especially if what is learned through the curriculum is to be useful to students in the longer term, and is to prepare them for a lifelong career.

First, Big Data is challenging the traditional role of theory, and writers about data-driven science have even suggested that theory is dead, that we should “let the data speak for themselves.” Second, the traditional limits that have been placed on publication in order that discoveries fit within the norms of journal articles or books no longer apply, and Web-based dissemination provides a very different model
in which it is possible to publish everything relevant to a topic, not just carefully distilled and synthesized results. Similarly, a project no longer ends with publication, since it is easy to edit and modify publications as new research emerges.

I think it is very important that students of CyberGIS and Big Data understand the distinct differences between geospatial data and other types of data that may well have figured in the classic articles about Big Data and data-driven science. We know that no geospatial data are perfect, that all are to some degree subject to uncertainty. This means that if we “let the data speak for themselves” we make discoveries about the data, but not necessarily about the real geographic world that the data are trying to represent. We need to be aware that our discoveries may be due to artifacts of the data, such as sampling interval or raster orientation, rather than of the real world.

Much of the literature on Big Data is concerned with successful prediction, but prediction has always occupied a somewhat contested place in science. A traditionalist would argue that successful prediction does not necessarily imply the acquisition of new, useful knowledge, and that one prediction may well not generalize to other predictions. But to take a positive view, we need to decide what is meant by prediction in a geospatial context. I would argue that geospatial prediction is concerned with predicting where something will happen, and possibly when. Thus far the literature in GIScience is very thin on prediction.
Advancing CyberGIS pedagogy for urban planning practice and research: existing gaps and future potentials

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Since its inception as a spatial decision making tool, Geographic Information Systems (GIS) have been widely applied in urban and regional analysis (Bardon, Elliott, & Stothers, 1984; Campbell, 1994; Han & Kim, 1989). The integration of multiple decision criteria and collaborative decision making processes have remade the discipline of urban planning, opening new avenues for the use of GIS (Nedović-Budić, 1998). GIS has become an indispensable component of planning support systems with various applications that cut across the different stages, levels, sectors, and functions of urban planning (Yeh, 1999). Besides serving as an effective medium for public participation (Carver, 2003; Talen, 2000), GIS is commonly used for database management, visualization, spatial analysis, and spatial modeling in urban planning (Levine & Landis, 1989; Marble & Amundson, 1988; Webster, 1994). However, the application of GIS and related technologies by urban planning practitioners has not kept pace with the advancement of GIS science. Despite developments in the late 1960s, the prohibitive cost of hardware and limited capabilities of the software limited the ability of planning agencies to widely leverage this technology until early 1980s (Yeh, 1999). Also, currently the conventional GIS software, primarily based on closed and monolithic architectures have limited capability for managing very large spatial data and for sophisticated spatial analysis/modeling (SAM) and visualization (Shaowen Wang et al., 2013).

CyberGIS, as a cyberinfrastructure (CI)-based GIS has emerged as a fundamentally new GIS modality, leading to widespread scientific breakthroughs, wider scope for utilizing big data, and broad societal impacts (S. Wang, Wilkins-Diehr, & Nyerges, 2012; Shaowen Wang et al., 2013; Wright & Wang, 2011). It represents a holistic approach to combining data-intensive and computational sciences for geographic problem solving (Shaowen Wang, 2010; Shaowen Wang et al., 2013), which can significantly improve urban planning decision making processes. But consistent with the earlier trends, CyberGIS has yet to be extensively adopted by planning practitioners and researchers. While the earlier slow adoption of GIS in urban planning is understandable considering cost, data availability, and software capability, it is unfortunate that the rapid growth in cyberinfrastructure and pervasive access to the internet have not translated into more widespread adoption of CyberGIS in urban planning. The inadequacy of education materials on urban planning applications of CyberGIS and a lack of planning professionals trained in CyberGIS are two of the main contributors to this disconnect. Through the CyberGIS Fellows program we initiated the process to fill this gap and already have developed some learning modules targeted towards urban planning professionals and researchers. This position paper relates our experiences and identifies the potentials for further pedagogical advancement to facilitate the adoption of CyberGIS capabilities in urban planning practice and research.

Through the CyberGIS Fellows program we developed education materials on CyberGIS to augment existing GIS curricula of the Department of Geography and Geographic Information Science and the Department of Urban and Regional Planning at the University of Illinois at Urbana-Champaign. We delivered the lecture and lab materials to three GIS courses, GEOG 379: Intro to GIS, UP 418: GIS for Planners, and UP 519: Advanced Applications of GIS. The first
two courses is primarily intended for new GIS users and introduces basic concepts and techniques of GIS widely used in multiple disciplines. The third course (UP 519) primarily focuses on advanced applications of GIS for research and policy analysis in urban planning. Previously these courses relied upon stand-alone GIS software (ArcGIS, GeoDa, and R) that did not provide an opportunity to expose students to CyberGIS capabilities, so our participation in the CyberGIS Fellow program was centered around developing lecture and lab materials for these GIS courses. Given the aims and audiences of these three courses we developed education materials separately that focus on CyberGIS application in spatial analysis and data visualization (GEOG 379 and UP 418), and advanced GIS application using cyberinfrastructure in urban planning (UP 519).

We identified several key barriers while delivering our learning modules and have articulated some recommendations for advancement in the CyberGIS curriculum that can further facilitate CyberGIS application in urban planning practice and research. Broadly, they can be situated under three groupings: accessibility, data availability/acquisition, and demonstration (case study).

Accessibility: Despite significant progress in the research arena, CyberGIS tools are yet to have easily accessible Graphical User Interfaces (GUIs) which can be quickly grasped by those with little or no prior GIS experience. We used the CyberGIS Gateway developed by NSF CyberGIS project for our introductory GIS classes and found the students easily navigated this interface. For advanced GIS applications however, which are usually performed by planning practitioners and researchers, this kind of CyberGIS environment needs to incorporate more GIS tools with better data integration capabilities.

Data availability/acquisition: Although the big data deluge is now widely acknowledged and has entered popular discourse, there are very few tools or techniques that can enable a new GIS user to quickly acquire big data for urban and regional analysis. There is a need to develop more learning materials that outline the process of data acquisition and data curation/cleaning targeted towards the GIS users without much of a programming background. This will also help to accelerate the adoption of CyberGIS tools by planning practitioners.

Demonstration (case study): In order to expand the use of CyberGIS capabilities to a wider community of planning practitioners and researchers we need to develop some problem-specific case studies demonstrating how this cutting edge technology can be applied for more efficient decision making and planning support. Ideally, these resources will also help practitioners to see how they can adopt and deploy these tools and techniques in their particular work context.

CyberGIS is opening new frontiers of technological capabilities for efficient and collaborative decision making processes that fit well with the work of urban planning practitioners and researchers. The CyberGIS community needs to be more aware of the needs of this substantial pool of GIS users and work on developing more learning tools that may help us better connect with the broader planning community.

Acknowledgement

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References:


CyberGIS Curriculum at the University of Kansas

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Keywords: cloud computing, geospatial big data, spatial programming.

Our involvement in developing a CyberGIS curriculum began when we co-taught the course Mapping and Analysis in the Cloud as CyberGIS Fellows in the fall of 2014. In the course, we were able to introduce students to html, JavaScript, and the use of the Google Maps API to create a range of web mapping applications. The textbook that we used for the course, Mapping in the Cloud (Peterson, 2014), provided a good overview of basic cartographic and GIS principles and also provided numerous example code for developing various web mapping applications. This course also took advantage of our separate skills, Professor Slocum’s in cartography and visualization, and Professor Li’s in spatial analysis and programming. It also gave us a chance to be involved in team-teaching, something that we had not done together before.

Our biggest challenge in teaching the course was the limited programming capability of the students as several of the students enrolled in the class had little or no programming background. Although we had stressed that some programming background was essential prior to offering the class, we could not afford to have too many students drop the class. As a result, we had to move slower through the material than we originally had anticipated and could not cover as much material as we had hoped. We were particularly disappointed that we could not conduct analysis in the cloud. We were only able to briefly introduce Google Earth Engine (GEE), which has strong cloud analysis capabilities, and we didn’t have time for students to complete an associated exercise. Another challenge that we faced was trying to fit our conception of what should be covered with Peterson’s textbook. Peterson’s book alternates chapters of cartography/GIS material with chapters of coding approaches. At an introductory level, we expect that this approach could be quite effective, but many of our students already had considerable background in cartography and GIS; as such, our students would have benefitted by more of a programming emphasis in the book. Another difficulty in using the textbook is that it does not emphasize mapping and analysis of big data.

Realizing the lack of programming skills for most geography and earth sciences students, in the fall of 2015 Professor Li offered the introductory programming course, Computer Programming for Mapping and Spatial Analysis – this course assumes no previous programming experience and teaches programming and computational thinking using spatial data and analysis as applications. The course had been offered previously using the Python programming language, and dealt with only desktop spatial datasets and analysis. In the fall of 2015, Professor Li made a significant change by integrating the emerging areas of cloud computing and CyberGIS. Instead of Python, the course used the JavaScript programming language and taught students to develop web mapping applications and perform cloud-based spatial data analysis using GEE. In one assignment, students were asked to explore land cover/use change at their favorite place on the Earth’s surface using images at two different times from the Landsat 5 image archive (between 1984 and 2012) available in GEE to show significant land cover/use change caused by natural events or human activities. With the few lines of JavaScript code they learned from the class, students were able to see the shrinking Aral Sea, the impact of hurricane Katrina on New Orleans, and the extent of the 2011 Missouri River flood. In another assignment, students were able to visualize, explore, and analyze a quasi-global trend using the CHIRPS precipitation time series data between 1981 and 2015 (Funk et al. 2014). Both
assignments would be nearly impossible to complete in a single assignment if the data, visualization, and analysis capabilities were not available in the Cloud.

Building on the experience of the above courses, Professor Li also is offering the course *GIS Application Programming* in the spring of 2016. The emphasis of this course is to teach students to develop spatial and temporal data analysis tools and applications on desktop computers and in the Cloud. Students are developing desktop solar radiation models for horizontal, inclined planes, and on DEM where the shading effect from surrounding terrain is considered using desktop GIS. Students then scale the models to the Cloud with global DEM using GEE. Another planned topic and related assignments are to develop the Mann-Kendal non-parametric trend analysis tool on GEE and use it to analyze the trend of annual snow cover frequency with 15 years of MODIS daily snow cover data, and eventually to serve the analysis on the Google App Engine cloud platform as shown by the Trendy Snow cloud application (https://litrendylights.appspot.com/).

In summary, our teaching experience with CyberGIS, and especially GEE, has opened up and demonstrated the potential and capabilities of cloud computing to students with examples from spatial and temporal data analysis. Ultimately, future CyberGIS might provide a standard GUI that would be transparent to the user, and thus hide the difference between local and cloud data and analysis. Current users and future power users, who need to develop custom computing tools, of geospatial cloud computing platforms, however, still need to access cloud computing programmingly. There are still gaps in teaching spatial programming with current transition from traditional programming concepts and constructs to the programing paradigm for CyberGIS and cloud computing. We need to identify and introduce new programming concepts, such as asynchronous programming, the map reduce programming mode, and programming patterns for spatial and temporal analysis, for the era of big geospatial data analytics.

**Acknowledgements**

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**References:**


For those of us immersed in CyberGIS teaching and practice, the era of big data is an exciting time. Data that was previously thought unattainable is readily available in great troves and at little or no cost. The promise and potential of this new data, new platforms, and spatial analysis to create a better world positions CyberGIS and digital map-makers at the cusp of an important transformation. Yet, these data and their analyses are not without controversy. The new data and new platforms available for CyberGIS require intentional and reflexive choices of data-sources, methods, and technical platforms. I argue that three interrelated and often overlooked components of curriculum play central roles in defining the future uses, users, and clients of CyberGIS. First, users of new repositories of geospatial data are divorced from the political struggles or asymmetric power relationships employed in the collection of data. This post-political turn has the potential to lead to partial or incomplete conclusions that reinforce existing asymmetrical power relationships. Second, an increasing number of platforms are available for building maps, distributing map, and analyzing geospatial data, but are built with or lead to technological lock-in and come with high “switching costs” to new software or platforms – often supporting limited interoperability and reproducibility. The ever changing nature of the firms which create these platforms serve as a fruitful example, particularly the technical dependencies and pricing structure associated with Mapbox. Lastly, the data wrangling, complex cartography, and detailed spatial analysis necessary for CyberGIS suggest the skillsets of computer scientists, not those of geographers or spatially-oriented interdisciplinary scholars. Addressing these shortcomings in the CyberGIS curriculum presents a necessary opportunity to re/focus education and practice intentionally and reflexively – two qualities necessary for the betterment of spatial understandings.

The groundbreaking work of JB Harley (1989) argued that map-making is not an objective enterprise, but instead one that is constructed through social forces as a metaphorical and rhetorical tool for the expression of power. His Derridian-fueled deconstruction of the map called for geographers to “…search for the social forces that have structured cartography and to locate the presence of power — and its effects — in all map knowledge” (Harley, 1989, p. 2 emphasis own). Of course, Harley is mostly addressing physical maps in the late 1980s and is lamenting the rapid proliferation of a technical rationality within cartography (namely GIS) and map-making that is devoid of politics. Harley is specifically lamenting the hasty technical rationality that Noble feared was proceeding sans oversight, purpose, or social intervention (1986). From Harley’s written work, it is hard to imagine that he could have fathomed the instant access, vast amounts of data, and interactivity of digital maps. Yet, digital maps are still maps – and thus are still constructed by social forces and are still expressions of power.

Map-making, digital or otherwise, has always relied on both geospatial data and cartographic tools. However, new data sources and the complexity of the tools used for digital mapping require intentional decision-making and reflexivity-in-practice by map-makers and cartographers. That is, digital mapping requires that map-makers understand the social forces and representations of power that undergird their practice. Not only is the geospatial data, especially social media data, collected under asymmetrical and exploitative power relationships (Thatcher, O’Sullivan, & Mahmoudi, 2016), but the
act of quantification masks are discards the social (Sheppard, 2001). And the new sources of quantified data are but only part of the digital map. Different technical platforms afford and abet different map features, representations, and, importantly, interactivity. These features can shape or transform certain aspects of the data in the same way that one can “lie” with maps. The takeaways for CyberGIS curriculum extend Harley’s deconstruction of reading maps, but require a coordinated effort for implementation. That is, digital map-makers must deconstruct their data and tools to make decisions that suite their map’s purpose – again for the improved spatial understandings and cartographic expression.

Separate from the map itself, digital map-makers must also question who benefits from their decisions on which data and tools to use. For example, the rise of GeoJSON as a file format appears to challenge the dominance of organizations like Google and ESRI. While the adoption of FOSS software and formats in the corporate world in the 1990s was heralded as a success, the profit-motive requires that these sponsoring organization adopt profit-motives for their longevity. We see that FOSS software and formats are not contingent, but necessary, to the rise of new corporate FOSS organizations that generate wealth in the same manner as their competitors, but rely on their FOSS branding or freemium model to create a technological lock-in which makes it increasingly difficult and expensive to switch to alternate platforms. Many of the original open-source developers of GeoJSON now work at Mapbox – and Mapbox now owns the development branch of open-source leaflet, yet leverage this to build their own competing package which is not only proprietary, but requires Mapbox’s Enterprise for many previously open-source features. CyberGIS curriculum should intentionally adopt and cultivate organizations and technologies which strive for interoperability and reproducibility.

Lastly, the skills required for CyberGIS are increasingly technical. Access to data may require leveraging APIs or manipulating very large datasets, and mapping software packages often require coding or programming numerous languages. CyberGIS curriculum would benefit from lessons in computer science: to teach the theory so that practitioners can learn any language or access any API rather than learning to access a single API or single technology stack. And while these technical skills are important, it is equally important that they go hand-in-hand with the discussions of social forces and the political economy to avoid the trap of feeding a geospatial technical rationality.

A coordinated effort is needed to shape CyberGIS so that future uses, users and clients of digital maps are not trapped into using data and technologies that run the threat of entrenching existing power structures and relationships. As practitioners and educators we must understand the social forces from which our data and tools arise, and balance the necessary technical skills with social understandings.

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References:

What is the Role of CyberGIS in Teaching Students to Think Spatially?

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Keywords: spatial visualization, geological sciences, undergraduate STEM education

My interest in this workshop arises from my research program, focusing on the development of spatial thinking skills in the undergraduate geoscience student population, and my work on faculty professional development, with an emphasis on bringing research-based practices into undergraduate STEM teaching.

For the past several years, I have collaborated with a team of cognitive scientists and geoscience faculty in a multi-faceted program of research focusing on characterizing, assessing, and developing the spatial thinking skills of students in undergraduate Geology courses. Spatial thinking is fundamental to the geosciences, for tasks as diverse as map-reading and navigation; understanding atmospheric and oceanic circulation patterns; visualizing groundwater flow, the Earth’s magnetic field, crystallography, and structural cross-sections; and interpreting seismic reflection profiles. Furthermore, spatial thinking is not a single skill. The tasks listed above require a variety of spatial skills, including understanding scaled representations; visualization of 3D objects, patterns and motions; penetrative thinking (imagining the interior of an object); and disembedding (seeing relevant data in a noisy pattern). Unfortunately, there is no formal teaching of spatial thinking skills in the K-12 curriculum. As a result, students arrive in undergraduate geoscience classrooms with a wide range of abilities in this area (e.g., Murphy et al., 2011). A number of studies, in geoscience education and in cognitive science, have shown that spatial skills do improve with practice (e.g. Titus and Horsman, 2009; Ormand et al. 2014). However, average gains over a single semester tend to be quite modest. It is therefore cogent to consider how we can facilitate the development of spatial thinking skills in our geoscience courses.

Students arrive in undergraduate geoscience classrooms – whether introductory general education courses or upper-level courses for majors – with a wide range of spatial skills. For example, on instruments measuring skills including mental rotation, penetrative thinking, and disembedding, some students demonstrate proficiency on every measure, while others clearly struggle with every task. Moreover, some students are proficient at some kinds of spatial tasks but not at others (Figure 1). To the extent that these skills are necessary to understand geoscience concepts and solve geoscience problems, weak skills can be a significant barrier to student learning.

Figure 1. Student test scores on the Purdue Visualization of Rotations Test (a test of mental rotation) vs. their scores on the ETS planes of reference test (a test of penetrative thinking).
While the skills are strongly correlated, many students excel at one but not the other.
Cognitive science and STEM education research suggest many kinds of “interventions” that may be effective in improving students’ spatial skills. Several are tried and true geoscience teaching methodologies, like taking students into the field or using 3D physical models in laboratory exercises. Others, however, are less familiar. In several studies, Susan Goldin-Meadow and colleagues have found that students who are required to gesture are more likely to use correct problem-solving strategies than those who are prevented from gesturing (e.g. Broaders et al., 2007). It seems intuitively obvious to many geoscience educators I’ve talked to that students who have strong mental models of 3D objects gesture when they describe those objects; what also appears to be true is that having students gesture about spatial relations may help them to build mental models. This is, of course, just one example. Our team has developed a set of two dozen teaching activities, using principles derived from cognitive science research, designed to strengthen the spatial thinking skills of students in upper-level Geology courses. These can be found on our project website: http://serc.carleton.edu/spatialworkbook/index.html.

I am excited about the opportunity to think collaboratively about the potential for using CyberGIS as a platform for developing undergraduate students’ spatial thinking skills, and to work with other attendees to develop a roadmap leading to curriculum guidelines and recommendations for adoption in a broad range of courses. In particular, I think that CyberGIS has the potential to help “spatialize the curriculum” a recommendation arising from a National Research Council 2006 report.

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References:


Learning Big Data Analytics with Digital Storytelling

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Keywords: big data, big data analytics, big data mining, digital storytelling, learning module, iSchool.

This paper aims at introducing a part of our NSF research project on big data education, “Building a Big Data Analytics Workforce in iSchools¹.” There is increasing demand for skilled personnel in big data industries, but existing big data curricula at the university level focus primarily on students with a strong computational background, ignoring a large segment of students who might otherwise pursue education and training in this vital area, but who will be faced with big data issues in the workplace. Therefore, our project’s primary goals are to address the national demand for professionals with knowledge in big data and to broaden the pool for a big data analytics workforce. Part of this effort will involve research as to whether the newly developed learning modules are more effective at increasing students' big data competencies, e.g., knowledge, skills, and analysis.

The objective of this project is to develop three innovative learning modules. These modules will be designed to: (i) utilize both group-based and contextualized learning methods and (ii) be applicable and accessible to students majoring in disciplines outside, but related to mainstream computer science (e.g., iSchools). The first module will involve digital storytelling exercises where students will be asked to develop their own narratives about the relevance and significance of big data in solving real-life problems and will be expected to become knowledgeable of, and proficient with, big data concepts and applications. The second module will be more technical in nature and will allow students to discover the efficacy of big data concepts in solving practical problems in information security. Finally, the third module will introduce more advanced topics in big data mining, such as examining a large amount of complex data to unearth important patterns and knowledge, and introducing how to interpret the results to arrive at appropriate decisions in a specific context.

Module 1 Details

As of this writing, we are finalizing the first phase of our project and completing our first module. The goal of the first module is to use “storytelling” to build awareness about big data, big data analytics techniques, and big data-related career opportunities. Since a majority of iSchool students whom module-1 targets may not have obtained basic computational competencies (i.e., concepts of algorithms, data structures, or programming), in the first module, our intention is to first introduce students to basic concepts on big data and encourage them to explore the materials in the format familiar to them (instead of programming). Digital storytelling is the modern expression of the ancient art of storytelling (Barrett, 2005), and has gotten increasingly popular in recent years, as shown well in the examples of YouTube, podcasting, or Second Life. Today’s young generation is very familiar with diverse platforms and tools (e.g., Second Life, OpenSim, Xtranormal, Garry’s Mod, or Microsoft Kinect) with which interactive

¹ http://sites.psu.edu/bigdata/
videos can be easily made, played, and shared. Three examples are shown in Figure 1. We have an experience in using Second Life and OpenSim to develop security educational materials, as shown in Figure 1(c) below (i.e., NSF DUE-0817376 TUES phase 2 project--An Immersive Security Education Environment Using Second Life).

![Second Life](a) Second Life  ![Xtranormal](b) Xtranormal  ![PIs’ I-SEE Project](c) PIs’ I-SEE Project

Figure 1. Example Virtual Platforms for Digital Storytelling

In this project, we attempt to answer the following research questions: How to develop innovative teaching materials in the big data analytics context to effectively train undergraduate students with insufficient computing competencies? To determine whether our new learning modules are more effective to increase students’ awareness, knowledge, and skills about big data analytics as well as computational competencies, compared to conventional teaching methods. Toward this end, we will employ quasi-experimental designs that use pre-posttests either with or without control groups depending on the availability of control groups. Specifically, we will use a group comparison design with pretests and posttests for students at University Park and Altoona. That is, we create a treatment (i.e., a course taught by the new teaching modules) vs. a control setting (i.e., a course taught by traditional teaching methods).

Our research will have a direct impact on increasing the number and diversity of undergraduate students with computational competencies and big data skills. Initially, our project will positively contribute to training undergraduate students in 4-year iSchools and 2-year community colleges. Eventually, the pedagogical findings and developed teaching materials will have a positive influence on general computing education with the focus on big data analytics in broader scientific and engineering communities throughout the nation. The developed big data analytics materials through this project will be freely available from our project web site (e.g., http://sites.psu.edu/bigdata/).

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References:


A practical approach to overcoming barriers to teaching CyberGIS-related science and skillsets in undergraduate and graduate curricula

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Keywords: teaching, online learning

Introduction

I have been a faculty member of the Spatial Sciences Institute University of Southern California since its inception, and I have been teaching online graduate classes for many years in Web GIS and desktop GIS programming which includes basic programming skills in HTML, JavaScript, J query, CSS, and Python in the latter (Swift et al. 2015). We also offer a Mobile GIS graduate class which covers Java programming (Swift and Pultar, 2014). I do not have a formal education nor other training experience in big data science, cyberinfrastructure, and high-performance computing. Nevertheless, I am enthusiastic about learning about these domains myself, and, in turn, devising creative ways to teach these topics to undergraduates and graduates. In this position paper, I suggest straightforward, practical mechanics for delivering teaching materials to students and learning materials to faculty to support CyberGIS-related studies in our undergraduate and graduate curricula.

If a target audience for the current phase of curriculum development in the CyberGIS-related domains include faculty like myself, and perhaps those with even less background in teaching similar scientific and technical skills, then I believe it is critical to both educate faculty as well as develop teaching materials. Basic teaching materials must be readily accessible from sources that are widely acknowledged as high in quality, consistency and currency. Nonetheless, the following suggests a practical approach to introducing CyberGIS concepts and research across disciplines and is not intended as a replacement for traditional computer science curricula augmented with big data science, cyberinfrastructure, and high-performance computing learning opportunities.

A practical approach to overcoming current barriers to teaching and learning

One of the biggest barriers to teaching these advanced sciences and skill sets lies in the lack of accessibility to resources for faculty to learn about these topics as well as to teach them. Although excellent opportunities are provided such as workshops at conferences and recorded online seminars, these are one-offs and only available to those who have the means to travel to the workshops and attend live seminars. Attending live seminars depends on time zones and schedules, and there is often a delay in access to recordings not always archived or maintained for significant links of time.

Today, there are many virtual or online venues including software vendors, university-based organizations and consortiums, open source collaboratives and commercial online learning platforms that provide extensive resources for teachers and students in numerous disciplines, including a myriad of programming and computing skills. As a practical approach to bridging this gap, I suggest considering two commercial online learning resources as examples of pathways to the development and delivery high-quality cyberinfrastructure and high-performance computing instructional materials that would be readily available to instructors and students. The targets are interdisciplinary academic programs and (as a complement to) traditional computer science curricula that already have trained faculty in place.
Delivering Instructional materials to faculty and students

One example of a well-recognized online teaching materials which many universities currently subscribe to is Lynda.com (http://www.lynda.com). This resource offers suites of courses geared towards academia, providing thousands of video courses (including transcripts and downloadable exercise data) in multiple domains, seemingly updated annually. Lynda.com has become a popular resource for higher education instructors for introductory to advanced learning materials in programming languages, Web design, 3-animation, mobile application development, cloud computing, and computer operating system development, etc. I propose that beginner, intermediate and advanced level courses related to CyberGIS be developed and deployed using Lynda.com or a similar readily accessible online learning platform. These courses could be geared toward undergraduate and graduate-level work. For example, there is an existing framework called “Foundations of IT security”, which includes many courses in cyber security, and six “Cloud” courses covering Google cloud computing. At present, there are no CyberGIS-related offerings in Lynda.com or other similar systems, to the best of my knowledge.

Learning Opportunities for Faculty

At universities with curricula that already offer or would like to develop new courses to support the integration of these new topics for undergraduates as well as graduates, faculty may represent a variety of disciplines not including a computer science background. An example of widely recognized online learning platform which could be used to bridge this gap is the Online Learning Consortium (OLC), an organization focused on professional development in a variety of fields. Faculty can voluntarily take workshops that provide instruction aimed at improving the quality and breadth of teaching experience. Such professional development activity is strongly encouraged in many universities and counts towards promotion, in particular in teaching tracks. I propose that a series of workshops be proposed as a “Mastery Series” in CyberGIS. For example, just a few years ago OLC launched the “Mobile Learning Mastery Series” which focuses on “…research, teaching and assessment of mobile learning environment” (http://onlinelearningconsortium.org). Perhaps it is only a matter of time before such a Mastery Series in CyberGIS is developed for the OLC, given the popularity of this research. Or, i.e., OLC could simply be used as an example of a way to deliver comprehensive learning materials to interdisciplinary faculty.

Generating new career tracks for students and faculty concentrations

Although commercialization of instruction may be be-unappealing, if access to learning and instructional materials in CyberGIS opens up, universities, as well as individual curricula across disciplines, may become more familiar with the importance of these topics. I believe that making basic supporting instructional materials suggested herein available via visible, accessible learning resources will facilitate the development of these as career tracks in higher education at both the undergraduate and graduate levels. Demands for students trained in the sciences of big data science, cyberinfrastructure, and high-performance computing will increase regardless, which is already leading to opportunities for new types of faculty appointments that include these focuses.

References:


CyberGIS in the Classroom: Reflections and Projections

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Keywords: cyberGIS, spatial thinking, computational thinking

This position paper is a personal reflection based on my experiences teaching a course entitled 'CyberGIS' and my thoughts looking toward the future for cyberGIS curriculum development. These thoughts include personal biases with a tendency toward practical considerations for CyberGIS in the classroom rather than broader curriculum challenges. My experiences are drawn from teaching two CyberGIS courses, participating in the CyberGIS Fellows program, and leading the development of a new programming language for cyberGIS that was used in my CyberGIS course.

Perhaps surprisingly, I eliminated prerequisites from my CyberGIS course and instead relied on student discretion for enrollment, which was challenging and rewarding. Removing prerequisites encouraged non-Geography students to take the course and as a result 3 graduate students from Business enrolled with interests in supply chain management and business information systems. These students were especially interested in the social media analytics portion of my course. While these students had no GIS training, they appreciated the value of GIS and cyberGIS, had a strong grasp of statistics, and often brought a different perspective to the discussion. There is often a desire to create deep prerequisite pipelines so students enter our courses with expert-level skills and knowledge. However, these deep pipelines can be 'leaky' and we may lose great students, especially those outside of Geography. Flattening a cyberGIS curriculum provides multiple entry points for students interested in the various aspects of cyberGIS including GIS, parallel computing, data science, or its applications. By drawing students from business, forestry, planning, or computer science, a robust cyberGIS curriculum can create interdisciplinary classes providing not only an engaging learning environment, but also preparing students for a future where collaboration across fields or business units is commonplace.

The course was redesigned after the first offering. In the first iteration the course was divided into four sections: Introduction to CyberGIS (3 weeks), Services and Databases (5 weeks), Cyberinfrastructure and Web-enabled Technologies (4 weeks), and Group Research Project (4 weeks). The course looked broadly at the use, design, and development of cyberGIS and related technologies including geo-enabled social media, spatial databases, and spatial data infrastructures. The CyberGIS Fellows program enabled me to redesign the course to include parallel and high-performance computing (HPC). The Parallel Cartographic Modeling Language (PCML) is an open source programming language that is designed to be easy to use and automatically parallelize spatial data processing (https://github.com/hpcgislab/pcml). The course was divided into three sections in the second iteration: Introduction to CyberGIS (6 weeks), Spatial Data Processing and Services (6 weeks), and Web Portals (4 weeks). The second iteration de-emphasized spatial databases, emphasized programming fundamentals, and introduced HPC concepts such as speedup and Amdahl's Law. Both iterations culminated in a final project in which students designed and developed a component of cyberGIS. The challenge of designing a CyberGIS course, like many GIS courses, is selecting from the countless concepts and technologies to cover. An equally valuable course would be one that looked outward toward the various applications of cyberGIS rather than inward at the 'guts' of cyberGIS. Naturally this would be a very different course and likely would attract a different student population that would nevertheless be engaging to all. I thoroughly enjoyed teaching both courses and student feedback was very positive.
I experienced several practical challenges that are worth noting. Eliminating prerequisites to encourage an interdisciplinary class required a clear description regarding expectations and quick ramp-up period in the beginning of each course to get all students up to speed (i.e., expectations for students were high). The order of topics was important due to varying skills and abilities, and both courses benefited by being adapted slightly to the students that enrolled. Interestingly, I found some students who may have benefited from the course were intimidated and opted not to enroll (based on personal conversations) while other students were drawn because they recognized the changing landscape of GIS and wanted to learn more about 'cyber' and 'big data.' In-class exercises and peer-based learning was vital to ensure each student had sufficient experience to excel in the class. These courses also require constant adaptation to keep pace with changes in technology (e.g., changes in APIs, web-technologies, packages and tools). They also demand a knowledgeable instructor and computational infrastructure for experimentation, which may be challenging for some institutions.

There are also opportunities for educators and students alike. CyberGIS as a system (Wang, et al. 2012) provides new tools to explore topics typically not covered in a traditional Geography/GIS curriculum such as geo-enabled social media data analytics (unstructured geospatial data), volunteered geographic information and crowd sourcing, and science gateways. CyberGIS as a science provides new avenues for Geography/GIS students to gain a deeper understanding of the concepts and theories, or explore the depths of spatial databases and computational methods. Perhaps more importantly it exposes these students to computational thinking. As a cyberGIS curriculum emerges I see tremendous promise in merging computational and spatial thinking. There is an untapped synergy between these two ways of thinking that once unleashed could lead to transformative learning and research opportunities.

Drawing on my experiences and looking toward the future, I think it is vital to reduce barriers for teaching and learning cyberGIS. Not all learners will be expert programmers with a combined interest in GIS and HPC and have a natural aptitude for database design. Similarly not all instructors will be knowledgeable in all areas of cyberGIS. There is an opportunity for making cyberGIS approachable in a well-structured curriculum. For example, I refined my materials to introduce cyberGIS to non-technical audiences. I find these materials help ease the intimidation and makes an often formidable looking "cyberGIS" more approachable. I also began experimenting with interactive online tools and multimedia for cyberGIS. I piloted several interactive mini-modules in my cyberGIS course in which students were shown simple non-technical stories that illustrated a key concept such as parallel computing. In this way, students explore and experiment with straightforward examples to gain conceptual understanding before getting bogged down in technical details. These online and digital platforms are also promising avenues for broadening outreach to more types of learners including self-learners, GIS practitioners, or learners at institutions that do not offer cyberGIS courses. Creating an effective online curriculum opens the educational door for these learners thus broadening the impact of cyberGIS.

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References:

An Online Introductory CyberGIS Course for Masters Degree Professionals

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Keywords: cybercommunity, cyberGIS, online education

The broad range of studies and projects that can benefit from geographic information systems (GIS) technology attract students of varied backgrounds and skills. A challenge in cyberGIS education and curriculum is that students have different forms of fundamental skills or the computer science background that is required for service-based technology. Often, student experience is limited to individual workstations used privately or in academic laboratories. The challenge for the JHU cyberGIS course, called Big Data Analytics: Tools and Techniques, is to provide professional training to students of diverse backgrounds in a focused way that enables or facilitates any number or type of cyberGIS activities.

Students participating in the Big Data Analytics course are typically already GIS professionals with limited interest in advancing to research doctoral programs. Thus, the central objective is to provide professional preparation for students to initiate and develop cyberGIS solutions for projects within and outside of the graduate program environment. To do so, the curriculum being developed integrates skills required for relevant approaches, analysis of best practices, and planning for time and work constraints. Non-expert users are expected to demonstrate a level of technical proficiency in one fourteen-week semester. Non-programmers are required to understand aspects of coding so programs can be edited, but no programming is required for the course.

The course design rests on a logical narrative of problems and approaches in sequential lecture and reading assignments that are reinforced through exercises and tests. Topics include: forms of distributed architecture; distributed databases, processing, and services; open source software environments such as Hadoop and derivative commercial products such as MapReduce; and case studies of projects described in various relevant literature, including online sources. Emphasis is placed on software algorithms, data models, and translators in current practice. Access to infrastructure is contracted with Amazon Web Services, though exercises and projects are based on a range of available tools.

Secondary presentations and tutorials offering reviews of fundamental skills involved in more complex projects are designed by the instructor to complement the central focus of the lectures and exercises. These include NoSQL, web services, Linux, Python, and other tools. Other sources of background information or that explain basic skills are identified and made available over the Internet with provided links. Students are free to use them or not; these materials are not required for tests. The focus remains on cyberGIS concepts. Foundational concepts will be evaluated not as stand-alone topics, but as they interrelate with a focused geographic information (GI) process. Sometimes the most enlightening material is the vast wealth of GI science literature that has been published in the last thirty or forty years that build the logical application of a geospatial perspective.

Curriculum materials are designed with online education principles in mind. For example, research findings recommend smaller, frequent lessons provide greater effectiveness of instruction. A variety of online resources are made available, but without causing confusion for students, and peer communication and information sharing is supported. Optional approaches are demonstrated and
instructions for completion of the work are clearly explained. Such an environment requires testing for comprehension of concepts, not memorization of materials.

An important aspect of the course is to integrate with other classes the students take in their masters degree GIS program. The Big Data Analytics course may touch upon semantic graphs and reasoning, commercial GIS products, volunteered geographic information, alternative media such as sound, and other areas that are ubiquitous in the information environment.

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Bridging the Gap between Geography and Marketing: Opportunities for CyberGIS

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Keywords: location, geospatial thinking, curricula, spatial analytics, marketing strategy, consumer behavior

There are three things that matter in property: location, location, location. —Lord Harold Samuel

The above-mentioned quote, coined by a 1950s British real estate tycoon and dating back to the 1920s or earlier based on a real estate classified ad in the Chicago Tribune, highlights the superiority of location in the property market. This notion cannot be more familiar to geographers, because they have accentuated space, place and spatial thinking for centuries. Grounded in the concept that geography and business share common overarching epistemology and ontology, this position paper first uses marketing (as a sub-discipline of business) to identify continuous scholarly efforts documenting business value of space and spatial thinking. Secondly, it compares and contrasts the curricula of one leading geography program and marketing program in the U.S. and highlights gaps in pedagogical strategies. Thirdly, it outlines ways that CyberGIS can contribute to bridging the gap between geography and marketing in this Information Age.

The Fact

There is only one valid definition of business purpose: to create a customer.... It is the customer who determines what the business is.... Because it is its purpose to create a customer, any business enterprise has two-and only these two-basic functions: marketing and innovation. —Peter F Drucker

As Peter F Drucker—the founder of modern management—stresses the importance of marketing and customer, we use marketing as a proxy for the general business discipline to illustrate the shared epistemology and ontology between geography and business as antecedents for the proposed synergy (Drucker, 1954). First, geography and marketing share a unified theoretical framework. The U.S. National Science Foundation (NSF) ascribes the Geography and Spatial Sciences Program to the Division of Behavioral and Cognitive Sciences, emphasizing the behavioral and cognitive traditions of geography. One school of Marketing is called consumer behavior, which blends theories from psychology, sociology, anthropology and economics to understand consumption behaviors amongst individuals or organizations and the impacts that those behaviors pose to the society. Second, geography and marketing anchor the same human-environment relations tradition. Geography aims to tackles the relationships between men and nature, while marketing cares for the societal impact of individual and firm behaviors. Essentially, both disciplines are about relations. Third, geography stresses the importance of scale (e.g., the modifiable areal unit problem, MAUP), as does marketing. Another school of marketing thought is named marketing strategy, which addresses how the hierarchical structures of marketing units attribute to different levels of firm strategies.

Empirically, spatial thinking and spatial modeling approaches have been expressed in leading marketing literatures since the recent decade (Mittal, Kamakura, & Govind, 2004; Bradlow et al., 2005; Jank & Kannan, 2005; Gauri, Sudhir, & Talukdar, 2008; Choi, Hui, & Bell, 2010). More recently, Wharton Professor David Bell published a book entitled Location is (Still) Everything: The Surprising Influence of the Real World on How We Search, Shop, and Sell in the Virtual One, where he analyzed thousands of U.S. zipcodes and millions of transactions from consumers and explained location-based conditions shape human behaviors and the physical and virtual environments intersect.

The Gap

Despite the common ground in epistemology and ontology, there are significant gaps in curricular design of both geography and marketing. Here, we use the current undergraduate programs in Geography

1 Source: http://www.nytimes.com/2009/06/28/magazine/28FOB-onlanguage-t.html?_r=0
and Marketing at the University of Georgia (UGA) as an example to argue this notion. Chartered in 1785, UGA was the first state-chartered public university in the U.S.; the Geography Program is ranked in the top 20 programs in North America and the Terry College of Business is ranked among the top 30 programs in the U.S.  

For undergraduates majoring in geography, the only required business related course is Principles of Macroeconomics/Microeconomics. Although the upper-division curriculum structure includes Introduction to Economic Geography, Location Analysis, and Advanced Economic Geography, they are offered through the human geography track only, and lack the inclusion of techniques or concepts of geographic information science (GIScience). Meanwhile, the undergraduate GIScience track in geography fails to include business-oriented courses. For undergraduates majoring in marketing, the notion of geography is entirely blank, with only weak ties to courses such as Digital Marketing Analytics. Although the Geography Department will launch a certificate in Urbanization and Metropolitan Planning in Fall 2016, partnering with multiple departments including the Terry College of Business, this is not enough to address the disconnect in geography and marketing curricula. This gap offers ample opportunities for CyberGIS to remedy this divide.

The Light

The gaps in both intra-geography disciplines and the geography-marketing interface can be mapped by CyberGIS. Essentially, CyberGIS bridges the digital divide through the synergy of high-performance computing (HPC), geolocational Big Data analytics and geovisualization. First, HPC is required to handle massive amounts of both geographical and business data. Second, given visualization has been centralized in marketing analytics and business intelligence, while cartography and geovisualization are emphasized in GIScience, CyberGIS can play a significant role in both disciplines. Third, the prevalence of Big Data, user-generated contents and crowdsourcing enables CyberGIS a unique opportunity to handle critical concerns of behavior and human-environment interactions in both fields.

In a nutshell, we have illustrated geography and business/marketing share overarching epistemology and ontology, as a foundation for a synergistic view. We then identified the gaps in curricula within undergraduate programs in Geography and Marketing in a leading U.S. university. Finally yet most significantly, we shed light on pathways that CyberGIS can contribute to bridging such gaps. We aim to ripple more discussion amongst GIScience experts towards expanding CyberGIS to meet growing needs of the Information Age.

References


Integrating Big Data Analysis and CyberGIS into Education

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Keywords: Big Data Analysis, CyberGIS, Data Science, Geographic Data Mining and Knowledge Discovery.

CyberGIS represents new-generation GIS based on advanced cyber infrastructure for resolving geospatial big data challenges [1], which require new tools and technologies to store, manage, and analyze massive geospatial data sets. CyberGIS is a promising young discipline. There is an urgent need to bridge the curriculum gaps in teaching foundational knowledge and skills in big data science, cyberinfrastructure, and high-performance computing for various CyberGIS-related scientific domains. This position paper focuses on improving an existing graduate level course (Data Science and Big Data Analysis) by incorporating new geographic information science and systems based on advanced cyberinfrastructure. This course aims to train students’ essential spatial thinking and computational thinking skills. Course materials including slides, hands-on activities, programming assignments, and projects will be designed to create an effective learning experience for students. This course is offered regularly at Lamar University. It covers a broad range of topics related to massive geospatial data analysis, visualization, and CyberGIS software. This course is organized into five main sections:

- State-of-the-art reviews of Geographic Data Mining and Knowledge Discovery.
- Techniques for storing and managing massive geographic datasets.
- Advanced algorithms and analytics techniques for massive geographic datasets based on advanced cyberinfrastructure.
- The emerging area of spatiotemporal data mining techniques, e.g. spatial temporal clustering algorithms and their applications to GIS.
- New trends and advanced technologies used for geographical information science research.

Overall, this course focuses on introduction the state-of-the-art studies and achievements in algorithms, analytics, and applications of Big Data and CyberGIS. It provides students with the basis for further efforts in this challenging CyberGIS field that will play a leading role in next-generation Geographic Data Mining and Knowledge Discovery. This course can serve as a foundation for numerous advanced CyberGIS-based courses.

References: