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Accessibility

Enabling Geographic Research across Disciplines: Building an institutional infrastructure for geographic analysis at Harvard University

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Abstract

Founded in 1818, the Harvard Map Collection (HMC) is the oldest map collection in America, holding 400,000 maps, more than 6,000 atlases and thousands of reference books. HMC has a strong commitment to digital resources and manages the Harvard Geospatial Library, a foundation for geospatial data service at Harvard. The Center for Geographic Analysis at Harvard University (CGA) was founded in 2006, independent of the library system, to serve the entire university. This article presents the history, organizational structure, and operational model of CGA and HMC, reviews achievements, lessons learned, suggests future improvements, and reviews GIS-related medical research at Harvard.

Historical Background

Harvard lost its Geography Department in 1948 (Smith, 1987) and the Computer Graphics and Spatial Analysis Lab in 1991(Chrisman, 2006). The support for maps and

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geographic analysis for medicine research and much of the rest of the University fell on the Harvard Map Collection (HMC)[5] alone, with limited resources. By the early 2000s the University recognized that it was missing out on the potential contributions the new geography - the approach to geospatial analysis that combined Geographic Information Systems (GIS) technology with quantitative analysis - could make to disciplines across the university, from medicine to epidemiology to sociology to history to trade policy. The question the University faced was how most effectively, and quickly, to make it possible for students and faculty to bring geospatial to bear on research and teaching (Guan and Bol, 2010). The Center for Geographic Analysis (CGA)[6] was established to do just that (Gehrman, 2006), with a mandate to collaborate closely with the Map Collection and the ongoing digital library project named the Harvard Geospatial Library[7] (HGL; Siegel, et al. 2004).

The History of the Harvard Map Collection

The HMC, a unit under the Harvard College Library, was founded in 1818 with the gift of the Ebeling Collection of 10,000 maps and books, presented to the University by Israel Thorndike (Figure 1). The Collection has grown consistently since that time. With the transfer of maps after the dissolution of Harvard's Institute for Geographic Exploration, the HMC became one of the largest map collections in North America. Visiting the HMC is an opportunity to see some of the cartographic treasures of the world, since the stacks contain not just paper but also digital materials (Figure 2).

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[5] Harvard Map Collection website: http://hcl.harvard.edu/libraries/maps/

[6] Center for Geographic Analysis website: http://cga.harvard.edu/

[7] Harvard Geospatial Library website: http://hgl.harvard.edu

Figure 1 New York State by D.F. Sotzmann, 1799. From the Ebeling Collection, Harvard Map Collection

Figure 2 Harvard Map Collection reading room, photograph by Peter Vanderwarker, courtesy of Harvard College Library

The HMC began its GIS activities in earnest in 1992. More and more cartographic materials were being made available in digital form, but at that time the HMC had only a single PC and it was dedicated to browsing the library catalog. There were data but no methods for library patrons to access them, since the library had no GIS workstations and the staff had minimal GIS experience. There was no support outside of the library on GIS either. The Harvard Graduate School of Design[8] had a strong GIS presence, but support was limited to students in that school. For undergraduates and graduate students in other programs, there were very few options.

At that time, the Association of Research Libraries (ARL)[9] launched the GIS Literacy Project, an effort "to introduce, educate, and equip librarians with skills needed to provide access to spatially referenced data in all formats and to provide effective access to selected electronic information resources in library collections"(Adler 1995). ARL solicited donations and support from the GIS industry to achieve its goals of increased GIS presence in academic libraries. The HMC was in the first wave of libraries to be awarded such support and began to build up the

[8] Harvard GSD website: http://gsd.harvard.edu

[9] ARL website: http://www.arl.org/

infrastructure and staff needed to provide the research community with a place to go for GIS data, software and help.

The first step was to provide access to the materials on the HMC shelves. Computers in the reading room were installed with a variety of GIS and cartographic software programs for general use. Staff were trained in ArcView and started to answer requests from patrons for simple custom map requests. Students and researchers soon saw value of GIS and requests for assistance became more and more complex, to the point where in 1999, a GIS specialist was hired in the HMC to assist with GIS data creation, analysis and programming.

In addition to creating an infrastructure for GIS support in the library, the HMC began, in 1995, to bring GIS to the Internet via the Massachusetts Electronic Atlas (MEA). Hosted by the HMC and created by Harvard, UMass Boston and the Metropolitan Area Planning Council, the MEA allowed users to map over 200 variables for the state, including extensive health data, as well as crime statistics and natural resources information (Cobb, 1995). The site proved to be quite popular and useful, but did not allow for data downloading and also only covered Massachusetts, and therefore did not include data of interest to most students.

A new project was envisioned in 1998, a system that would allow patrons to have access to the rich collection of data in the Harvard libraries at all hours *via* the Internet (Siegel, et al 2004). This system would not only serve data for download but include a robust search engine allowing users to quickly find relevant data without having to browse a file system. By 2001, the Harvard Geospatial Library (HGL) was live and receiving 300 hits per day.

HGL currently holds over 6,000 data layers that are ready for use in geographic information systems (Figure 3). These layers are at a variety of scales - from global (VMAP 1) to local (cadastral data for Boston) - cover many different areas of the world, and range in age from current to 400 year-old historic maps. The catalog is based on detailed Federal Geographic Data Committee[10] Content Standard compliant metadata records that allow for finely tuned searches of the repository. Users can display and download these layers for use in their desktop software.

Figure 3 The Harvard Geospatial Library Entry Page

In addition to current library holdings, HGL is also a distribution mechanism for researcher-created datasets. When GIS projects lead to the creation of new data, those files can be sent to the HMC for inclusion in the repository and catalog. This ability to accept GIS data for distribution led to further collaborations with the CGA since 2006.

The Establishment of the Center for Geographic Analysis

The field of geographic analysis underwent a series of revolutions in the past half a century. The quantitative revolution brought quantitative analysis into geography in the 1950s, which inspired a new generation of students and scholars (Dutton, 2006). The birth of geographic information systems in the 1960s equipped geographic analysis with computers (Niemann and Niemann, 1998). Computer cartography and analysis of remotely sensed images in the 1970s presented new dimensions to the discipline. The integration of geographic analysis with numerical models gained much ground in the 1980s, especially in the field of environmental studies. The information technology (IT) boom in the 1990s gave geographic analysis a swift push into the IT mainstream, complete with relational and object-oriented database management systems (RDBMS and ODBMS), programming platforms, client server architectures, and web-

[10] FGDC website: http://www.fgdc.gov

based implementations. The completion of the Global Positioning System (GPS) and the ever increasing earth surveillance satellites resulted in an exponential increase of spatial data in native digital format, feeding content to, and at the same time putting pressure on, the geographic information systems. By the middle of 2000s, Google released Google Maps and Google Earth, which generated a heightened public interest in geographical issues and expanded awareness of geography in other disciplines. The geo-technological revolution is still ongoing as of today, pushing geographic analysis up to computing clouds and down to mobile devices, into the hands of all walks of life. Its continued growth has expanded job market for geographers, increased enrollment in geography departments, and brought improvement in geography education at all levels (Murphy, 2007).

In 2003, a faculty committee on spatial analysis was formed at Harvard University, led by Professor Peter Bol, a prominent historian and a pioneer in applying GIS to the study of history. The committee was set to find a solution to address the increasing concerns from faculty and students on improving access to spatial data, support for research employing geospatial analysis, and curriculum development. Two years of investigation and discussion led to the decision by the University President and Provost to establish the Center for Geographic Analysis (CGA). The inauguration of the Center was held in May 5, 2006 (Gehrman, 2006), some called the day “a new dawn for geography at Harvard” (Waters, 2006).

From day one, the CGA has been focused on research and education in the field of spatial analysis and geographic information. Building on the foundation established by the HMC and HGL, the CGA was expected to create a more substantial infrastructure to support a wide range of scholarly research projects that wish to apply, improve, or study geospatial analysis techniques. One of the largest and most advanced user groups is Harvard's medical and public health research community.

Multifaceted Medical Research at Harvard University

Medical research is conducted at a number of institutions at Harvard University, including the Harvard School of Public Health, Harvard Medical School (Figure 4), and affiliated hospitals, the Harvard Humanitarian Initiative, the Harvard Initiative for Global Health, and the Faculty of Arts and Sciences. The following section will describe the application of geographic analysis and GIS to medical research being conducted at Harvard University.

Figure 4 The Harvard Medical Campus

Application of Geographic Analysis to Medical and Public Health Research

The early applications of geographic analysis to medical research can be traced to a small Soho district in London in 1854. John Snow, a British physician, identified the Broad Street water pump as the source for one of the most severe cholera epidemics in history, by using observational data and a series of maps. Based on this work, he is considered the father of modern epidemiology, one of the cornerstones of public health (Singer and de Castro 2001). John Snow's study was a transformative event in the history of medical geography and public health. The handle of the Broad Street pump has become a symbol, marking the integration of medicine, geographic analysis, and public health research.

Over 150 years since John Snow's cholera outbreak investigation, geographic analysis remains intricately linked to medical research. The application of spatial analytic techniques to understand the distribution of disease and determinants of health is at the core of medical and public health research. During the past two decades, advances in technologies have made it possible to examine spatial and temporal trends in large-scale epidemiological data with enhanced precision and speed.

GIS techniques are ideally suited for public health surveillance and infectious disease control, as transmission of infectious diseases is closely related to geographic proximity. This includes case location, identification of clustering, mapping of epidemic dynamics, and mapping disease burden and response. More recently, geographic analytic methods have been applied to the fields of environmental health and chronic disease epidemiology, to link proximity to exposures to incidence of non-communicable diseases. Application of GIS methods and collaborative data sharing has also contributed to the emerging fields of crisis mapping, response to natural disasters, and infectious disease outbreaks, to inform timely targeted emergency responses, resource allocation, and health care delivery strategies.

Understanding spatial and temporal distribution of disease is central to targeting health problems. Using GIS facilitates exploration of a broad range of determinants - such as demographic, socioeconomic, geographic, and environmental factors - from a diverse array of disciplines that influence disease transmission patterns in a single environment.

Geographic analysis provides a unique interface between health data and a map - to effectively present information to key decision-makers. GIS methods enable summation and presentation of large amounts of data for disease surveillance and health reporting, and identify new cases, map at-risk populations, stratify risk factors, and quantify distribution of risk and transmission patterns. Optimal summary and visual presentation of complex medical and scientific health data can be used to communicate abstract quantitative data, and inform health care policy, program planning, and health resource allocation. Geographic analysis also informs evidence-based policy and program planning, such as the design, implementation, and monitoring of targeted interventions, and examining patterns of disease burden and health care delivery. Selected examples of applying geographic analysis to medical research at Harvard University are presented in Table 1.

Table 1 Selected Medical Research Projects at Harvard University

Examples of Geographic Information Systems in Medical Research at Harvard

Geographic analysis and examining medical research questions spatially have helped to integrate medical and public health research across disciplines and departments at Harvard University. For example, the Exposure, Epidemiology and Risk Program (EER) at the Harvard School of Public Health brings together the departments of Environmental Health and Epidemiology to explore environmental and occupational determinants of health and disease, and inform evidence-based policy.

Researchers have applied novel GIS techniques and cutting-edge statistical methods to longitudinal epidemiological studies, to answer unanticipated research questions not envisioned at the study onset. The Nurses Health Study, founded in 1976 in the Department of Nutrition, is among the largest and longest running investigations of factors that influence women's health. Started in 1976, this study of over 238,000 nurses has led to many new insights on health and disease. Researchers in the Exposure, Epidemiology and Risk Program, Department of Environmental Health, and the Departments of Nutrition and Epidemiology have applied GIS techniques to analyze data from the Nurses' Health Study, and use semi-empirical models to predict spatially and temporally resolved long-term average outdoor concentrations of particulate matter (PM) (Yanosky, Paciorek et al. 2008) and successfully predict chronic fine and coarse particulate exposures using spatio-temporal models for the Northeastern and Midwestern United

States (Yanosky, Paciorek et al. 2009). Spatial methods are also being incorporated into new research designs for longitudinal studies; in fact, the third Nurses Health Study is currently underway over three decades later, to examine environmental and lifestyle exposures of women.

Similarly, researchers have applied GIS methods to examine long-term ambient multi-pollutant exposures (PM10, PM2.5, nitrogen dioxide, and sulfur dioxide) in 53,814 men in the US trucking industry, and found that residential ambient air pollution exposures were associated with significantly increased mortality (Hart, Garshick et al. 2010). GIS methods have also been applied to the Harvard Six Cities Study, one of the most influential, innovative and longest-running studies addressing the health effects of air pollution in America; this landmark study has led to the regulation of airborne particulate matter and the development of the Clean Air Act.

Geographic analysis has also been used in medical research to target advocacy and social justice in resource-limited settings. In an example of geographic analysis bringing together the university with the community, researchers examined the influence of traffic on air quality in an urban neighborhood (Buonocore, Lee et al. 2009). In this project in the Mission Hill neighborhood of Boston, Massachusetts, GIS methods were used to examine spatial and temporal patterns of traffic-related air pollutants to determine factors contributing to elevated concentrations and inform environmental justice concerns. In another project in Malawi, Africa, investigators used GIS methods and data from the Malawi Health Facility Inventory and the Malawi Demographic and Health Survey to identify disparities in access to modern reproductive health services (Heard, Larsen et al. 2004).

Geographic analysis has been transformative in international medical research at Harvard University. GIS technologies have allowed researchers to send portable GPS units to remote field settings to monitor conflict zones, urban slums, and remote villages, and provide precise health data in areas with limited infrastructure. GIS and remote sensing technologies have also been used to identify host habitats and identify clusters of cases, to examine infectious disease transmission patterns, and inform targeted interventions. For example, researchers in the Department of Nutrition at the Harvard School of Public Health used GIS methods to examine ecological determinants of parasitic infections in school children in rural KwaZulu-Natal, South Africa, including *Ascaris lumbricoides* (Saathoff, Olsen et al. 2005) and hookworm (Saathoff, Olsen et al. 2005). Researchers in the department of Global Health and Population also obtained complete coverage of larval control to suppress malaria vector mosquitoes through comprehensive spatial coverage with community-derived sketch maps in Dar es Salaam, Tanzania (Dongus, Nyika et al. 2007). Researchers also used spatial and temporal analysis of malaria risk to inform policies for disease control in the Amazon region in Brazil (Singer and de Castro 2001).

Geographic analysis has also emerged with increasingly important humanitarian projects. In the aftermath of natural disasters, such as the 2010 earthquake in Haiti, GIS technologies have played a critical role in rapid and efficient response to crises, and in conducting public health research to develop and monitor evidence-based programs. GIS also plays an important role in crisis mapping initiatives and developing early warning systems to mitigate the effects of natural disasters, avert mass atrocities, strengthen international aid coordination, inform resource allocation, and develop evidence-based humanitarian interventions.

The Harvard Humanitarian Initiative (HHI) is a university-wide center involving multiple entities within the Harvard community that provide expertise in public health, medicine, social science, management, and other disciplines to respond to humanitarian complex emergencies. In the Humanitarian Crisis Mapping and Early Warning project, GIS methods and mapping technologies are used to promote evidence-based approaches to humanitarian assistance, and advancing the science and practice of humanitarian response worldwide. For example, in the Incubator Implementation project in Indonesia, GPS devices were used to map remote areas where incubators were placed. Within the HHI and the Harvard medical community at large, researchers understand the utility of GIS technology in their research and use it for a diverse range of projects.

Collaborations Between CGA and HMC

In order to effectively support the diverse needs for geographic analysis from the Harvard medical community as well as the rest of the university at large, CGA established a governing structure which includes faculty members from the medical school and the school of public health in its faculty steering committee, and key GIS professionals from the library and the medical campus in its technical advisory committee. The faculty committee meets once per semester to guide the center in its strategic development, while the technical advisory committee meets three times per semester to advise the center in its technical operation, such as service level and distribution, technology adaptation, outreach event coordination, and feedback from the user community. Staff of HMC and HGL serves on the CGA technical committee, while CGA staff serves on the HGL Standing Committee. This cross-organizational structure provides a forum for regular checks and balance of the shared responsibilities between the CGA and the HMC in optimizing user support.

Data Acquisition, Development, and Sharing

Data is usually the first thing a user asks for when considering geographic analysis. Utilizing each organization’s strength, the HMC focuses on systematically acquiring geospatial data, making them available, and helping users find the appropriate data precisely and quickly from the Harvard library holdings. The CGA often refers users to the HMC for data-related questions, such as data availability, source, cost, and format. Patrons interested in historical data are often forced to create that data on their own by digitizing paper maps, and HMC has a larger format scanner that can be used to create an image of any material in the collection. Those images can be georeferenced with assistance from either CGA or HMC and the relevant information can be digitized. When the user receives their data, they may return to CGA for help in analyzing and visualizing the data. If the patron requires less complex analysis or straightforward cartography, they can get that help at HMC.

Many research projects require unique data that are not acquired by the library yet and are not available from well known public data sources, such as international data, high resolution images, or custom-created data by a researcher or a research institution. CGA facilitates the identification of such data sources, helps define and clarify the data properties and quality, serves as the liaison between Harvard data users and some data companies and institutions, manages data development service and cross-institutional data sharing contracts, and assists the users in submitting their unique data to the HGL with proper permission. The HMC takes on the responsibility of geospatial data stewardship alone, freeing the CGA to focus on analysis services.

Whether data is acquired by CGA or HMC, the goal is to hold onto it and make it available to future researchers. While licensing restrictions sometimes prohibit data sharing, whenever possible, new data are deposited into the HGL. For that the data are delivered to HMC and translated into the HGL accepted format (ArcSDE layers). Metadata that is compliant with the FGDC standard is created by the Harvard College Library geospatial resources cataloger, and the data is published via HGL. Many layers are restricted to Harvard affiliates only, but all metadata is publically searchable so that non-Harvard researchers can at least discover that a data set exists and get information on how to obtain the layer for themselves. Every effort is made to license data for use by the entire Harvard Community. However sometimes that is just not possible, and only a single user is allowed access at any time. In those cases, metadata is still created and placed in the HGL catalog, with information on where to access the data set on campus. By collaborating in this way, CGA and HMC have increased the size and value of the HGL collections as well as the usefulness of the system to patrons.

Software Licenses and Labs

The CGA manages all University-wide geospatial software license contracts, and equips computer labs across the University with updated versions of GIS, image processing, spatial data conversion, visualization and geostatistical analysis software packages from multiple companies, as well as some freeware and open source GIS tools. Most of these software licenses are managed through a centralized license server, with one or two backup servers to maintain uninterrupted availability. The HMC maintains a small lab of PCs equipped with GIS software distributed by CGA, as well as powerful desktop publishing applications that can be used to create professional quality illustrations.

The Harvard medical community has unique license requirements because of its geographically distributed nature. Many Harvard Medical School and HSPH faculty members also work in the various hospitals in Boston. The CGA provides special assistance to them, making sure that their research and teaching needs are supported by the university floating licenses, while these licenses are not mistakenly used in the hospitals' operation, which would be a violation of the university site license agreement.

Training Programs

Before the establishment of the CGA, the HMC GIS staff offered hands-on training in both GIS and remote sensing, which were converted into online tutorials. These tutorial materials continued to be available online through the HMC website. In addition, the CGA offers a multi-faceted GIS training program both on the main campus and on the Longwood medical campus. This includes a number of credit courses at the introduction level, the senior thesis level, and the graduate student level, tailored to meet different needs from students in different disciplines, such as social sciences, environmental sciences, engineering, and public health. It also includes non-credit courses, and a series of hands-on training seminars of geographic analysis tools and methodologies open to all Harvard affiliates every Friday during the academic year. Since 2009, the CGA has added a 10-day intensive training program called the Harvard GIS Institute, for faculty and graduate students who wish to learn GIS during the winter or summer breaks. The program is so popular that some applicants have to wait for a year to obtain a seat in it. Software specific self-learning tutorials are easily accessible from the CGA website as well.

These training programs and the CGA's technical consultation services feed and backup each other, and combined with the HMC's data service form a balanced support network to users with different needs. Some researchers come to CGA for technical consultation first, but as their projects develop, they realize that it would be more efficient if they themselves can do some hands-on GIS work, thus they sign up for the training, and gradually become more independent in designing and conducting their geographic analysis. On the contrary, some researchers have unrealistic goals in their geographic analysis project at first. After taking the training courses, they realize that GIS is not as simple as just learning to use a piece of software. Their time is better spent on focusing on their disciplinary topics, leaving the geographic analysis work to the CGA staff. Thus they became more frequent users of the CGA analytical services after the training.

Many students who took these courses or training programs went on to apply geographic analysis in their thesis or dissertation work. In the past five years, one of the authors who served on the review committee for the Howard T Fisher Prize in GIS[11] witnessed significant improvement in the complexity and quality of GIS work among the award applicants. This observation is shared by all members of the review committee.

Consultation and Help Desks

The CGA has designated office hours when users can walk in and ask for help (Figure 5). Questions addressed at the CGA help desks include where to find certain data, how to do certain analysis, which software tool is most appropriate for certain projects, how much to budget for geographic analysis in certain grant proposals, which GPS model meets certain field work needs, how to design the database or web service for certain projects, how to quickly learn certain GIS skills, and many more. The CGA help desks on the main campus and the medical campus, together with the virtual help desk (24 hour response time by email and/or phone) served over 100 inquires per month on average. Users range from faculty members, research associates, post-

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[11] The Howard T Fisher Prize in GIS website:
http://gis.harvard.edu/icb/icb.do?keyword=k235&pageid=icb.page190018

doctoral fellows, graduate and undergraduate students, and staff, to visiting scholars. Among them, graduate students are the most numerous help desk users.

Figure 5 The CGA Front Office and Help Desk

The HMC reference desk gets GIS and digital data requests daily, and the questions tend to be from patrons who may not even know what GIS is or how it can help them. There are no set hours for GIS-related questions, since patrons are just as likely to be looking for a road atlas as for GIS help. Patrons with time consuming requests are often asked to schedule an appointment, and complex projects are referred back to CGA. Most GIS interactions are with undergraduates, but there are also many graduate students who are introduced to GIS for the first time at the HMC reference desk.

Analytical Services

In some cases, a help desk visit could lead to a follow up consultation session, which could lead to a more dedicated service project. At this capacity, the CGA operates like an internal consulting firm, working with the users to define project scope, specify deliverables, estimate risks and uncertainties, plan alternatives, set schedules and milestones, and calculate service costs. Most of such service projects are completed internally by CGA staff, but a portion of them involves outsources services too. For those cases, the CGA staff would identify appropriate external service providers, negotiate service contracts, communicate technical requirements, perform quality assessment and quality control on their deliverables, and manage the external contracts for the end users. Work requiring external services are usually labor intensive (such as digitizing features from historical maps), or highly specialized (such as developing a software module to plug into certain CGA systems). Another type of CGA service supports teaching directly, where the CGA staff would develop and deliver a customized GIS training module for a non-GIS class or research team. Such training is usually followed up by more hand-holding when the students or researchers start to use what they have learned to apply geographic analysis in their course work or research project. The authors will discuss more specific geographic analysis service cases in support of medical research at Harvard in the next issue of this publication.

Technology Monitoring

With the rapid evolution of the geospatial technology, many faculty and students find that even after investing significant amount of time learning the GIS tools, it is still very hard to keep their skills and knowledge up to date with the changes. They could be proficient with one version of a popular software, or one model of a popular equipment, but a couple of years later, they are at a loss again when facing the new versions, new models, new data formats, and new visualization trends. The CGA staff serves as the geospatial technology steward for the Harvard GIS user community, monitoring, evaluating, reporting, selectively acquiring new technology products, and introducing new methodologies, standards, architectural platforms, and technology services. They attend the major geospatial conferences periodically, subscribe to the popular technical newsletters and journals, and remain active in the geospatial professionals' circle. In return, they publish a monthly newsletter to over 1000 readers, and maintain the CGA website which averages over 1000 hits daily.

The CGA also hosts annual conferences, providing a forum for the Harvard users to exchange ideas and experiences with invited scholars on geospatial technology and its application in designated fields. Conference themes range from GIS, remote sensing, geocoding/georeferencing, spatial-temporal modeling, technology applications in the study of religion, global temporal gazetteer development, and web mapping. Another technology forum is co-sponsored by the CGA and the Harvard grass-root technology group called ABCD-GIS[12]. The monthly brownbag seminars bring out speakers from the Harvard GIS professionals community and other universities, companies or government agencies. It is open to the GIS community at Harvard and beyond.

Web Map Services

Anyone who has kept an eye on the geospatial technology trend in recent years would not have missed the wave of web services. In addition to the HGL discussed earlier, the CGA has developed and continues to enhance a number of web mapping applications, engaging in a variety of technology platforms from ArcGIS Server (ESRI, 2008), to GoogleMap API, to complete open source systems built on OpenLayers, MapServer and PostgreSQL (Lewis and Guan, 2010). Among them are several applications in support of medical research, such as the Surgical Safety Web Map and the Emergency Department Web Map. These applications will be discussed in detail in the next issue of this publication.

The WorldMap is an example of collaboration between the CGA and the HMC at the system development and collections levels. It was built to assist academic research and teaching as well as the general public with an open source system that allows for discovery, investigation, analysis, visualization, communication and archival of multi-disciplinary, multi-source and multi-format data, organized spatially and temporally. The first instance of WorldMap was

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[12] The ABCD-GIS group website: http://www.abcd.harvard.edu/harvard/groups/abcd-gis/

focused on the continent of Africa, called AfricaMap (Lewis and Guan, 2010)[13]. Since its beta release in November of 2008, the framework has been implemented in several different locations with different research focuses, including metro Boston, East Asia, Vermont geological sites, Harvard Forest and the city of Paris. These web mapping applications are used in courses as well as by individual researchers. Figure 6 shows the Malaria seasonal variation overlaid on population density in AfricaMap.

Figure 6 Malaria Seasonal Variation Overlaid on Population Density in AfricaMap

Some data layers presented in the WorldMap systems are contributed by the HMC, and some data layers acquired by these systems are in turn submitted to the HMC for long term archiving. Moreover, critical data layers in these systems are included in HGL, and the download function calls an HGL download service directly. This cross-system integration avoids the duplication of data storage and system development, offering the users a seamless experience utilizing both systems behind the scenes. Further integration is under development which will allow for cross-serving of data layers between the two systems as web map services (WMS) and web feature services (WFS).

Conclusion

The HMC, with a history of nearly two centuries, and the CGA, with merely 5 years of existence, form the core components of the infrastructure in support of geographic analysis at Harvard University today. Their success relies on collaboration, not only between each other, but also with various research support organizations in the schools and departments throughout the

[13] AfricaMap website: http://africamap.harvard.edu

University (Figure 7). The CGA's Technical Advisory Committee includes members from not only the libraries, but also the Harvard-MIT Data Center, the Institute for Quantitative Social Sciences, the Instructional Computing Group of the Faculty of Arts and Sciences, the Computer Resources Group of the Graduate School of Design, the Harvard School of Public Health, the Harvard Planning & Allston Initiative, FAS Department of Earth and Planetary Science, and the School of Engineering and Applies Sciences. Each of these organizations provides infrastructure support to their department, school, or the University at large, and covers different technology domains, such as statistical analysis, database management, web design and development, computer aided design, three-dimensional visualization, and system engineering. Geospatial technology intertwines with these technology domains, and the CGA receives support from these organizations while providing support to them at the same time. The CGA staff could be an end user of their service in one project, a collaborative partner in another project, and a subject matter expert offering consultation service to them in yet another project. For example, the CGA is an end user of the Dataverse Network (DVN) for data archiving and dissemination; the CGA staff and the DVN development team are working together to explore methodologies for mapping the study cased in the DVN; and the CGA built a geographic location finder tool for the DVN users to populate the latitude and longitude fields in the metadata when they submit data to the DVN.

Figure 7 The institutional relationship among CGA, HMC and other organizations

These multi-dimensional collaborations form a support web, providing many places and methods for patrons to start their projects with the proper technology support, and to be guided to geographic analysis if their projects call for it. This support web also ensures that the people in each place work together, each according to their own strengths, to get the patron the help he needs. It avoids redundant capacity building, which is critically important in the current financial hardship. For example, the CGA does not invest in long term data repository. All geospatial data that are worth archiving are handed over to the HMC to be properly cataloged, loaded into HGL for user download, and archived in the Harvard Digital Repository Service (DRS).

Such a collaborative infrastructure is not without challenges. Harvard University has the tradition of being a distributed system, with each organization operating under autonomous terms, described as “every tub has its own bottom.” Many excellent support teams are focused on supporting their own department or school only, with no mandate or capacity to provide support across the administrative boundaries. The CGA’s operational model broke this tradition. It was established to serve the entire University from the beginning. But five years into its operation, the CGA has yet to reach out to all potential users. The demand on CGA’s service is still growing exponentially, almost doubling every year (Figure 8). Outreach and coordination continues to be major tasks for CGA, competing for limited resources with technical projects.

Figure 8 CGA help desk number of tickets (2006-2010)

Moreover, for users who are familiar and satisfied with CGA services, CGA became their “one-stop shop” for technology support. It is often hard for the end user to clearly define their project’s need for the different technical domains. Often times, one project needs data acquisition, database design, web development, geographic analysis, and statistical modeling. The researcher may not be familiar with all the specialty support teams for each of these components. They may rely on CGA, or whichever team that they are most familiar with, to help them define their project scope, identify technology needs, and establish initial contact with the other specialty teams.

The CGA's operational model not only bridged among the technical support teams, but also made cross-disciplinary and cross-school connections. People from all parts of the university come to CGA for assistance in finding data, making maps, selecting analytical tools or receiving training. The broad user contacts put CGA staff in a unique position to help make cross disciplinary connections for scholars. An epidemiologist from the Harvard School of Public Health might be looking for the same census data as a political scientist from the Harvard Kennedy School of Government studying violence; and an entomologist from the Harvard Museum of Comparative Zoology may be interested in building the same digital elevation model and hydrologic network as a historian or archaeologist studying ancient trade routes. Through the CGA, some of them became aware of other's work in the same region of the world, made contacts to each other, shared base data and local data sources, coordinated equipment usage (such as GPS), and some even found other's work inspiring to their own research (Guan and Bol, 2009).

The CGA started with a humble beginning of 3 FTEs and a 2-room office. By the fifth year, it has doubled its annual budget, tripled its staff, and quadrupled its office space. The core funding from the Provost Office allowed for the CGA to offer basic services free of charge to anyone with a Harvard ID, including help desk, non-credit training, and initial consultation service. An educational endowment supports the GIS Institute, and income from service projects, grants and gifts make up the rest of the operational budget. By focusing on serving everybody else across the University, the CGA gradually advanced its own status, despite the financial hardship in the past year.

The HMC and the CGA share the same mission of enabling geographic research across disciplines. The quest to building an institutional infrastructure for geographic analysis at

Harvard University has just begun. As the geospatial technology evolves, and people's awareness and expectation increase, both the HMC and the CGA will continue to adapt and adjust in order to improve efficiency and effectiveness, to better serve research and teaching at Harvard University.

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References

Adler, Prudence S. 1995. A Special Issue of Geographic Information Systems and Academic Libraries: And Introduction. *Journal of Academic Librarianship* 21(4):233-235

Buonocore, J. J., H. J. Lee, et al. (2009). "The influence of traffic on air quality in an urban neighborhood: a community-university partnership." Am J Public Health 99 Suppl 3: S629-635.

Chrisman, Nick. 2006. Charting the Unknown: How Computer Mapping at Harvard Became GIS. ESRI Press

Cobb, David A. 1995. Developing GIS Relationships. *Journal of Academic Librarianship* 21(4):275-277

Cobb David A. and Arlene Olivero. 1997. Online GIS Service, *Journal of Academic Librarianship* 23(6):484-497

Dongus, S., D. Nyika, et al. (2007). "Participatory mapping of target areas to enable operational larval source management to suppress malaria vector mosquitoes in Dar es Salaam, Tanzania." Int J Health Geogr 6: 37.

Dutton, Geoffrey. 2006. Everything is where it is having moved there. A memoir on the occasion of the dedication of the Harvard Center for Geographic Analysis. http://isites.harvard.edu/fs/docs/icb.topic39008.files/Dutton_Memoir.pdf

ESRI. 2008. China Earthquake Geospatial Research Portal Launched by Harvard University. ArcNews Online, Fall 2008. http://www.esri.com/news/arcnews/fall08articles/china-earthquake.html

Gehrman, Elizabeth. 2006. Geography center launched - Center for Geographical Analysis to explore 'vast intellectual territory'. Harvard Gazette. May 11, 2006. http://www.news.harvard.edu/gazette/2006/05.11/05-geography.html.

Guan, Weihe (Wendy) and Peter Bol, 2010. Embracing Geographic Analysis beyond Geography – Harvard's Center for Geographic Analysis enters its 5th year. *International Journal of Applied Geospatial Research* (in press)

Guan, Weihe (Wendy) and Peter Bol. 2009. Harvard Revisited: Geography's Return as GIS. In *The Geography Teacher* 6(2), published by Taylor & Francis.

Guan, Weihe (Wendy) and Guoping Huang. 2009. Bringing Operational GIS into University Classrooms. *Geomatica - Special Issue on Higher Education in Geomatics* 63(2)

Gudrais, Elizabeth. 2010. Harvard Center's Maps Help Haiti Effort. Harvard Magazine, January 19, 2010. http://harvardmagazine.com/breaking-news/harvard-center-hosts-haiti-map-portal

Hart, J. E., E. Garshick, et al. (2010). "Long-term Ambient Multi-pollutant Exposures and Mortality." Am J Respir Crit Care Med.

Heard, N. J., U. Larsen, et al. (2004). "Investigating access to reproductive health services using GIS: proximity to services and the use of modern contraceptives in Malawi." Afr J Reprod Health 8(2): 164-179.

Kaplan, Robert M. 2006. Medical Geography–Who Gets the Goods? More May Not Be Better. In Optimizing Health: Improving the Value of Healthcare Delivery. Edited by Franz Porzsolt and Robert M. Kaplan. Published by Springer US.

Lewis, Benjamin and Weihe (Wendy) Guan. Jump Starting the Next Level of Online Geospatial Collaboration: Lessons from AfricaMap. In Advances in Web-based GIS, Mapping Services and Applications. Songnian Li, Suzana Dragicevic and Bert Veenendaal, eds. (in press)

Murphy, Alexander B. 2007. Geography's Place in Higher Education in the United States. *Journal of Geography in Higher Education* 31(1): 121 – 141

Niemann, Bernard J. Jr. and Sondra (Sue) Niemann. 1998. GIS Innovator - Allan H. Schmidt: GIS Journeyman. *GeoInfoSystems*, May and October, 1998

Reed, Christopher. 2006. Hello, Geotech - “Modeling our world,” geography returns to Harvard. Harvard Magazine, November-December 2006. http://harvardmagazine.com/2006/11/hello-geotech.html

Saathoff, E., A. Olsen, et al. (2005). "Ecological covariates of Ascaris lumbricoides infection in schoolchildren from rural KwaZulu-Natal, South Africa." Trop Med Int Health 10(5): 412-422.

Saathoff, E., A. Olsen, et al. (2005). "Ecologic covariates of hookworm infection and reinfection in rural Kwazulu-natal/south Africa: a geographic information system-based study." Am J Trop Med Hyg 72(4): 384-391.

Siegel, David, Bonnie Burns and Tim Strawn. 2004. HGL: A Web-Enabled Geospatial Digital Library. ESRI International Conference Proceedings, 2004. http://proceedings.esri.com/library/userconf/proc04/docs/pap1024.pdf

Singer, B. H. and M. C. de Castro (2001). "Agricultural colonization and malaria on the Amazon frontier." Ann N Y Acad Sci 954: 184-222.

Smith, Neil. 1987. Academic War Over the Field of Geography: The Elimination of Geogrpahy at Harvard, 1947-1951. *Annals of the Association of American Geographers*, 77(2):155-172.

Sui, Daniel Z. Sui. 2007. Geographic Information Systems and Medical Geography: Toward a New Synergy. *Geography Compass* 1(3): 556 - 582

Waters, Nigel. 2006. Harvard, Geography and GIS: A Race to the Top, M2MEDIA360. http://www.geoplace.com/uploads/FeatureArticle/0609_EDGENODES.asp

Yanosky, J. D., C. J. Paciorek, et al. (2008). "Spatio-temporal modeling of chronic PM10 exposure for the Nurses' Health Study." Atmos Environ 42(18): 4047-4062.

Yanosky, J. D., C. J. Paciorek, et al. (2009). "Predicting chronic fine and coarse particulate exposures using spatiotemporal models for the Northeastern and Midwestern United States." Environ Health Perspect 117(4): 522-529.

Youngblood, Dawn. 2009. A Case Study in Proactive Development: David Cobb, Harvard University's Curator of Maps. *Journal of Map and Geography Libraries* 5(2):187-197

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