AC 2008-751: MODELS FOR EVALUATING VISUALIZATION CENTER EFFECTIVENESS

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Models for Evaluating Visualization Center Effectiveness: Selected Case Studies

Abstract

Seven visualization centers at institutions of higher learning in the Unites States were visited where directors or senior staff/faculty of visualization centers or laboratories were interviewed using a standard survey instrument. These centers represented science, medicine, engineering, art, and social science disciplines. Of particular interest were original and continuing funding models, the organizational structure of each facility, the profiles of participating faculty, and the relationship of the centers' research activities with undergraduate and graduate academic programs. This paper develops three models based on the sampled centers, describes the topology of visualization activities, and draws preliminary conclusions from the survey data.

Introduction

Data visualization has become an important tool in technical education and practice as witnessed in technology, the sciences, medicine, engineering, and social science. Technologies for interacting with complex multi-dimensional data have become economically feasible and functionally practicable as witnessed by the establishment of "Visualization Centers" at a number of university locations. Visualization technologies include, but are not limited to: immersive and non-immersive virtual reality experiences, active and passive stereo displays, multiple displays using data walls, animations, and simulations.

To better understand the current state of visualization activities, seven such centers were sampled for a survey conducted by the researcher. A chronological listing of the centers that were visited is found in Appendix A.

Indeed, visualization technologies have become sufficiently mature that most, if not all, technical problems in delivering visualization functionality have been solved. Still, many questions concerning implementation, especially as part of degree programs, persist.

There have been initiatives by technology providers—notably EON Reality of Irvine, California and Fakespace of Marshalltown, Iowa—to focus visualization tools on academic activities. Through their sponsored Interactive Digital Centers (IDC), EON Reality provides a model for evaluating visualization technologies as well as their integration into technical curricula. Fakespace Cave and PowerWall systems are widely used in institutions of higher education in this country and abroad.

A number of funding models exist for these visualization centers, both for initial startup and continuing support. These models reflect unique local legislative, economic, and educational factors: state appropriations, internal institutional funds, one-time economic development funds, sponsorships by technology providers, partnerships (industry, military, and government), and ongoing funding through research grants (NSF, NASA, DOD).

Visualization techniques such as modeling, simulation, video imaging, and virtual reality allow students who otherwise would find it difficult or impossible to understand complex visual relationships the opportunity to directly interact with numerical, graphical, and conceptual data. Graduates of the technical professions previously mentioned— technology, science, and engineering— with the addition of medicine, law, and the social sciences, make use of data visualization to an increasing extent.

In fact, use of these tools change not only the way problems are solved, but alter the manner in which problems are identified, prioritized, and eventually explained to a broad spectrum of the population.

Profile of Visualization Centers

Although a number of universities have recognized the potential of these data visualization tools in understanding problems based on complex data, there has been a perceived disconnect between establishing a facility that demonstrates the viability of visualization technologies and the actual integration of visualization technologies within curricula. This is not a unique situation in the history of digital technology maturation. Almost every digital technology has gone through stages culminating in an “island” or “silo” of technology. What has happened after that point has determined, in large part, how imbedded that technology has become in professions, education, and society in general. The question is: Are visualization technologies embedded in curricula and if so, how; if visualization technologies are not embedded in curricula, why not.

Currently, visualization technologies are at a critical crossroad. Will data visualization remain the provenance of an elite few or will structures and approaches arise to distribute its functionality to those who can best make use of its potential? It is the modern equivalent of the 1990's centralized versus decentralized computing conflict. As with most digital technologies, it is not a question of *if* current visualization activities are introduced into the day-to-day activities of technical curricula, only the matter of *when* and *how*.

It has been a general practice to implement visualization technologies in a centralized and dedicated "center," a facility separated physically, intellectually, and pedagogically from academic enterprises that might use it best. The centers sampled in this study ran the gamut of potential physical and organizational locations—from small, dedicated, discipline-specific laboratories, sequestered behind locked doors to public, open, and readily accessible facilities in the heart of a campus.

Visualization centers are heterogeneous along almost every imaginable parameter. Although they have grown out of a myriad of academic and organizational structures and funding sources, centers may still be described as adhering to one of three basic models:

The visualization tool-demonstrator model. This is the lowest level of visualization center. Essentially, visualization tools are brought into a "demonstration center" where canned presentations are given to interested parties. This model is characterized by corporate-style theaters. This is done to increase the interest in the technologies and to attract additional funding. This type of center has minimal impact on academic programs other than as a passive technology introduction.

The visualization tool-user model. This model stresses using visualization tools to solve discipline-specific problems. In this case, the technology needs to be relatively transparent, meaning that a significant technical staff is required to insulate faculty and students from the nuances and vagaries of the tools. This model is characterized by faculty and staff using visualization tools in research, projects, and classroom activities and can have a significant impact on curricula and programs. A by-product of the tool-user model is that the same facilities can be used for visualization demonstrations.

The visualization tool-maker model. This model creates visualization tools that the other two models use. The tool-maker model eschews turnkey applications by solutions providers. There are positive curricular benefits for technical students making the tools (engineering, technology, computer science) but because much of the development takes months or years, and the facilities are in such a constant state of flux, tool-demonstrators and tool-users generally are excluded. Tool-demonstrators can promote the technology during development, but the facilities have the look of a scientist's laboratory, and not a corporate theater

Questions Addressed

This study focused on identifying where and how visualization technologies have been effectively integrated into technical curricula. Preliminary findings to interview questions included:

• *Were representatives from interested academic programs involved in the original planning of visualization facilities and if so, how?*

In general this question was answered by how the center was originally funded. If the visualization activity was originally funded by internal, institutional funds, there was a high likelihood that academic programs that might use the technologies were involved in its planning. If the technology was the result of a grant (especially an NSF Instrumentation Grant) then academic faculty was unlikely to have been involved in planning its acquisition or implementation.

• *If interested representatives were not involved in the planning of visualization facilities, what have been the ramifications?*

The generalization can be made that the less a broad representation of interested academic programs were involved in the planning, the more isolated and less embedded the technologies.

• *If organized as a center, is there an established mission statement? Are there identified outcomes and methods established to assess them?*

Several centers had established mission statements. However, outcomes assessment was unheard of among visualization personnel. All centers were required to participate in some sort of critical short- and long-range institutional planning and review, though no centers had active advisory committees and none had knowledge of directly contributing to accreditation efforts—

either at program or institutional levels. These are fair indicators that these centers operate out of the academic mainstream.

• *What funding models exist for the continuation of visualization technologies, especially in curricular integration?*

In general there are three funding models: totally funded internally from legislative appropriations, totally funded externally from research grants and development projects, and a hybrid where some recurring support comes from the institution in the form of operating funds and staff/faculty salary lines but where the majority of funding comes from external sources.

• *If not organized as a center, how can the organization be characterized and how is its effectiveness evaluated?*

At some institutions, a "center" is a specific organizational structure, requiring governing board action for its creation. As such, this controls its administrative structure, budgeting lines, and review procedures. At other institutions, a center is formed by a department, as needed. Effectiveness is generally measured by the amount of funding generated by associated faculty (in the case of a "soft" funded center) or by the number and distribution of "credits" charged against academic programs for the use of the facility (in the case of a center funded mostly or entirely from internal funds).

• *What mechanisms exist to promote the capabilities of the available visualization technologies?*

All centers host extensive Web sites that promote their activities. These Web sites feature current projects, publications, and capsule biographies of the faculty and students. Some centers produce annual reports, research bulletins, and printed promotional literature. Centers that are located in high-traffic areas of the central campus enjoy a natural visibility among the general student populations. Other promotional activities include student competitions, shows, and public thesis and dissertation defenses.

• *What mechanisms, if any, exist to assure that undergraduate students have access to the functionality of visualization tools?*

It is of note that there was a consensus that visualization (at least as practiced by those centers visited) is predominantly a graduate-level activity. In fact, opinion was voiced that undergraduates were not desired because there were too many of them and they required a level of instruction in the technologies that was a cross-purposes to the mission (even if it was not expressly established) of the facility.

An interesting additional point: none of the centers engaged in determining the spatial visualization abilities of either their faculty or students, or in measuring change in such ability brought on by engaging the visualization technologies. In fact, only one director was aware of this field of inquiry and the role high visualization plays in technical program success and completion. This may be partially due to many of the centers considering visualization technologies as simply a tool to get at the science and not something to be studied itself.

• *What would be done differently if embarking on a new effort to integrate visualization techniques on your campus?*

Almost unanimously, center personnel lamented that they would like their efforts to be better known on campus. There was a high anecdotal correlation between the remoteness of the center (either physically or academically) and this feeling of isolation. Most centers would like to involve a broader range of disciplines but were frustrated in getting faculty to plan for visualization activities in their grants.

Scripps Institute of Oceanography (SIO)
SIO Visualization Center
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Focus of Visualization Activities

Scripp's visualization activities center on modeling and displaying oceanographic data from its Institute for Geophysics and Planetary Physics. Its mantra is to make visualization tools available on the desktop as a means of explaining science. The SIO is decidedly application-driven and not particularly involved in visualization tool development. A new visualization demonstration center is currently being constructed.

Funding Model

Center's base operations are supported by recurring university funding. This funding supports a director (60%) and an administrative assistant (25%). Visualization services are charged back to the individual departments and are usually paid for by external funding sources. Service activity to local business and industry (renting the center's facilities) was attempted but abandoned as a "loss leader." Graduate students are supported from internal (institutional) grants.

Curricular Integration

There appeared to be no integration of the center's visualization activities with academic programs within SIO. No courses in visualization techniques are offered; no individuals are permanently assigned as teaching faculty; the center does not knowingly contribute to accreditation activities. There are student award programs that highlight visualization accomplishments. Visualization is seen as a research activity best directed toward faculty and graduate students.

Identified Trends in Visualization

Visualization has become sufficiently ubiquitous that it is perceived and not being that difficult—either in terms of resources or skills/knowledge. The cost of hardware and software remains a problem. Three-dimensional data will be fully integrated into applications and stereo will be more common as data becomes more complex.

Conclusions

The visualization activities at SIO are an island of activity essentially removed from and remote to academic programs. It receives a sufficient reoccurring budget to remain active but not at the level to either achieve integration within the institution or to generate significant external funding. It represents a low-level effort that benefits a small number of faculty and students, and makes a minimal impact on the institution's visualization landscape.

University of California-San Diego (UCSD)
California Institute for Telecommunications and Information Technology (CalIT$^{2)}$
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Focus of Visualization Activities

Visualization activities at UCSD are housed within engineering but involve faculty from more than two dozen departments within the university. Many of its activities focus on developing vision-quality displays and experiences. UCSD takes on a decided research and "tool development" focus, attempting to do visualization that commercial enterprises do not want to do. There is little or no relationship with turnkey visualization providers. Housed in a central facility, several sophisticated visualization "theaters" are used to test hardware and software solutions. Laboratory space is highly flexible and can be reconfigured as needed to support research activities.

Funding Model

Original funding came from the state of California's CalIT^2 information technology initiative, and some legacy funding continues. The current funding model includes institutional sources (for base staffing, facilities, overhead), government funding through competitive grants, and private development monies. Unrestricted gift funds play an important role in securing technology. The majority of the staff is on "soft" money.

Curricular Integration

Faculty enjoys a formal association with CalIT^2 through academic appointments. CalIT^2 staff teaches courses and workshops within the facility and many of the labs and theaters are used for various academic enterprises. Because new technologies are being developed, intellectual property agreements with supporting agencies stifles curricular integration.

Identified Trends in Visualization

Visualization activities are being developed that require a minimum of intervention on the part of the participant. The expectation for near-real experiences is becoming prevalent. Visualization experiences can be used to build virtual communities and expand the impact of information technologies.

Conclusions

UCSD represents one end of the visualization spectrum—where the boundaries of visualization technology are constantly being stretched. Rather than applying visualization to better understand various scientific and social phenomenon, CalIT^2 focuses on the nuts and bolts of making visualization tools work. Visualization at UCSD is well-publicized, well-funded, and adds to the overall visualization landscape of the community.

University of Minnesota
Super Computing Institute for Digital Simulation and Advanced Computation (DSAC)
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Focus of Visualization Activities

This center's visualization activities grew out of UM's supercomputing efforts in the early 1990's. Graphical visualization was a natural offshoot from processing significant amounts of medical data but now extends to five laboratories dedicated to processing data for visualization. Commercial applications are used as extensively as possible to support activities across the sizable campus. Activities are promoted by an institute research bulletin, annual report, and publications archive.

Funding Model

Funding for the institute comes from legislative line item appropriations. Institute's functions can be engaged through external grants or through a system of visualization "credits" that academic departments can expend for time in the labs and staff expertise. The DSAC is viewed more as an institutional resource than a specialized lab, available only to a few. Students pay a general IT fee, some of which comes back to the institute. There is a recurring capital budget for equipment purchases and upgrade. Researchers are able to recover some indirect costs through internal, institutional grants.

Curricular Integration

This institute achieves integration through several means. First, it is located in the center of campus, in the library just off a central mall. Its theaters, displays, and promotional materials are seen by tens of thousands of students each day, achieving a high level of visibility. The use of visualization "credits" promotes visualization activities at the program level. Each functional laboratory has a faculty advisory committee and the DSAC has a review board to guide its overall activities.

Identified Trends in Visualization

There is a trend to develop virtual as opposed to physical laboratories. Relationships with business and industry will be focused on the computing with the visualization distributed on site. There will be a greater focus on supporting the strategic research areas of medical device simulation and remote visualization; more open access to turn-key visualization; some application for immersive technologies; push visualization tools down as far as possible to the desktop.

Conclusions

This institute has addressed several fundamental visualization issues. It's funding is secure and supplemented by a variety of sources. It has spread visualization functions broadly across the institution by providing central high-powered computing and distributed visualization. It makes visualization technologies available at the program level with a system of "credits" that can be used alone or bundled with other funds. The central location of the institute contributes greatly to its visibility on campus.

University of Illinois Chicago
Electronic Visualization Laboratory (EVL)
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Focus of Visualization Activities

This long-running visualization effort focuses on the integration of art and science. A major thrust of the EVL is to make the most advanced tools available to artists for making their art. Many of the visualization technologies now in place throughout industry and the academe were developed in conjunction with the EVL. A major thrust is to build the applications for the technology. The EVL enjoys a close relationship with the NCSA at the University of Illinois/Urbana. Interdisciplinary teams are assembled to address research and public service projects. There is no demonstration theater. The EVL is a working laboratory.

Funding Model

The EVL, including its staff, is largely supported though soft money. Some support comes through information technology technicians. All capital equipment is secured through external grants. This equipment is distributed to programs as it is upgraded and replaced.

Curricular Integration

Four computer science and two art professors are attached to the EVL and their activities in project-oriented laboratory exercises support programs and courses. The laboratory is structurally tied to the Computer Science, Art, and Medical Informatics departments. A staff research scientist provides technical assistance to the faculty. Academic programs and their students and faculty build application technologies through the EVL. Their relationship with industry avoids intellectual property issues by the EVL providing training where “nobody keeps anything.”

Identified Trends in Visualization

The future of visualization is in new “match ups,” putting data together in novel ways. To do this, there will be a greater emphasis on concurrent hardware/software/application development. Those involved with visualization should be careful in promoting the technologies—the problem of being too popular. The matriculation of visualization to the desktop has exploded the “big house” model for computer graphics and puts visualization tools in the hands of artists, scientists, and developers.

Conclusions

The EVL does not have the impact on visualization it once had probably because of its own success. It is an example of the “big house” trend mentioned above. The fact that little or no institutional funds are invested places a serious limitation on potential integration within the university. Laboratory’s activities are distributed among several academic departments though not integrated within program course offerings.

Purdue University
Envision Center for Data Perceptualization (Envision)
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Focus of Visualization Activities

The Envision Center is structured to be a central resource for visualization on Purdue's West Lafayette campus. Technology is predominantly turn-key solutions from visualization vendors. The center includes a demonstration theater for showcasing the technology. A close administrative and fiscal relation exists between Envision and ITaP (Information Technology at Purdue). The vision of the center is to enable the development and practical application of collaborative perceptualization science and to focus is on the research, development, integration, and evaluation of high-end technologies and systems that extend and complement commercially available tools.

Funding Model

Original funding was through an NSF instrumentation grant and a corporate donation. There is a recurring capital budget from ITaP and tuition premium funding went into the strategic plan for the center. Staffing is supported by 100% hard line funding; there is recurring funding to buy-out portions of "faculty fellow" contracts. Departments are charged back for visualization services unless supported by grants. There is some institutional funding for graduate students not specifically tied to grants.

Curricular Integration

Non-credit courses are offered through the center, open to anyone in the university. Credit courses are offered through the Computer Graphics Technology department by their faculty and center staff. There is a Master of Science in technology specialization in Visualization. The center has an advisory committee, although it is not particularly active. It employs an "Envision Leadership Team" from different academic disciplines to direct the center's activities. The center maintains a 10GB switch out to projects run within individual departments such as a haptics project in the Electrical and Computer Engineering Technology department.

Identified Trends in Visualization

There is the potential for visualization and graphics to aid in understanding large data sets. For visualization centers to survive they will probably have to be attached to academic programs. There is a need to determine where the interest lies in visualization activities and to go there first.

Conclusions

The Envision center represents a mixture of demonstration, academic and research activities. It enjoys a funding model based on both hard-line and internal and external grant sources, possibly making it less susceptible to funding fluctuations. Its central location in the Purdue Union Building gives it exposure to the general student population. Its association with ITaP and the College of Technology has the potential to embed many of its activities into academic programs.

Pennsylvania State University
The GeoVISTA Center (GeoVISTA)
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Focus of Visualization Activities

GeoVISTA utilizes remote sensing data to build visualizations beyond automated cartography and is a research center within Geography housed in the College of Earth and Mineral Sciences. With an initial focus on visualization, the center now is recognized for is leadership in interdisciplinary cooperation in geographic and information science. Activities focus on geographic representation, geovisual analytics, knowledge management, spatial cognition and human factors, and risk assessment and spatial decision making.

Funding Model

The GeoVISTA center was originally funded by capturing salary lines from retiring faculty. Base staffing is accomplished by granting several hard-line positions partial release. The GeoVISTA center receives funding through The North-East Visualization and Analytics Center (NEVAC). The bulk of GeoVISTA's budget comes from competitively secured grants.

Curricular Integration

The center generally supports the needs of research projects though its facilities are integrated into tow master's degrees—The MS in Geography, and the MS in Geographic Systems. This second option is a project-based online degree. Projects often come from the Department of Defense and its National GeoSpatial Intelligence Agency and the CIA. This keeps much of the center's activities from being universally available to the general student population.

Identified Trends in Visualization

Center staff felt that visualization functions should be pushed right into the browser and that students have a more expansive view of visualization than most faculties.

Conclusions

The GeoVISTA center represents a focused, dedicated facility than minimally impacts undergraduate curricula and only impacts graduate curricula of those students involved in funded projects. The stated goal of becoming an "institute" within the university would broaden its impact on the university community.

The Ohio State University
Advanced Computing Center for the Arts and Design (ACCAD)
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Focus of Visualization Activities

ACCAD can trace its roots to 1969 with the formation of the Computer Graphics Research Group (CGRG). This center brought together faculty and students from art, industrial design, photography and cinema, computer and information science, and mathematics. This activity was reconstituted as ACCAD where partnerships are formed between artists, designers, art historians and critics, computer scientists, engineers, and architects. The center's focus is on expanding the influence of computer graphics across disciplines. The fact that ACCAD shares a facility with Ohio State's super computer center promotes natural connections between visualization and computer science.

Funding Model

A National Science Foundation grant in 1969 began the CGRG. Currently, a base staff is institutionally funded. Center associates (faculty) may share joint lines with their academic departments and ACCAD or use release time from grants to engage in the center's activities. The center offers a number of academic courses (see below) and tuition dollars follow the students. The center enjoys a recurring capital budget from the university.

Curricular Integration

The center offers a number of credit and non-credit courses (14 listed) that can be used for graduate credit in a variety of colleges. Student work is highlighted at a center open house and MFA theses are publicly exhibited. A summer program for 7^{th} and 8^{th} grade females is offered to encourage interest in visual careers.

Identified Trends in Visualization

The director anticipates more interactive visualization over the Web, where the eventual user of the imagery is able to construct their own information. The technology has become sufficiently robust to support real-time animation and story telling. There remains a dichotomy between computer imagery and that created by traditional analog methods.

Conclusions

ACCAD represents a successful synthesis of research, demonstration, and academic enterprises. However, its remote location (~3 miles from the central campus) limits its eventual impact on the university as a whole.

Conclusions

Although three additional visualization centers will be visited in the spring of 2008, a number of conclusions can be drawn preliminarily. The first conclusion is that even though visualization technologies are widely available they remain expensive. Institutions often feel that visualization centers are a frill and if implemented, must be through external funds. This sets up a circle of narrow implementation and low potential effectiveness. It goes like this: The institution refuses to support the activity so outside funds are secured which removes the center from the mainstream of academic programs which in turn reinforces the idea that visualization is not a university resource and shouldn't be supported through appropriations.

Visualization is also generally considered a tool for graduate-level investigation. There may be several reasons for this. First, because the equipment is expensive and dedicated to one or a few users, mass undergraduate experiences with visualization technologies is perceived to be unfeasible. Even running several hundred freshmen through a demonstration center may be out of the question.

Tool-users often feel that the user's discipline must be well in hand in order to understand the data in visual form. In other words, in order to visualize biological information you must first understand biology. (Interestingly, few centers entertain the idea that visualization tools can be used by the uninitiated to understand fundamental relationships.)

Tool-makers believe that the underlying technologies (computer science, information design, modeling, animation, and simulation) must be in hand before developing visualization applications. (Again, few centers entertain that developing visualization technologies can be an effective way to learn computer science, information design, modeling, animation, or simulation.)

Finally, and to their credit, even discipline-specific centers recognize that visualization activities, at their core, are both multi-disciplinary and inter-disciplinary. To be successful, they must draw from computer scientists, engineers, artists, technologists, and discipline subject matter experts. This ends up being both strength and weakness. Strength lies in how teams can be assembled to solve a myriad of technical problems. Weakness lies in the manner in which promotion and tenure processes generally penalize inter-disciplinary work, placing faculty involved in visualization-based research at a disadvantage.

Future analysis of the data gathered in this study will concentrate on the institutional ramifications of accepting visualization as a university-wide resource.

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