VAIRoma: A Time Based Visual Analytics Interface for Art and Architecture in Rome

Digital Humanities Start-Up Grant Proposal, Level II

Enhancing the Humanities Through Innovation

Throughout the humanities, emerging digital technologies have begun to offer researchers powerful new tools with which to assemble and analyze archival materials. At UNC Charlotte, the Digital Arts Center in the College of Arts + Architecture, and the Charlotte Visualization Center in the College of Computing and Informatics propose to create a working prototype of a time based visual analytics tool, VAIRoma, (**V**isual **A**nalytic **I**nterface for **Roma**) that will focus upon the study of historical data in the city of Rome. Specifically, this prototype will focus on both art and architecture, disciplines that require extensive geospatial and temporal information. We have selected Rome because of its intricately interconnected histories and depth of resources.

Visual Analytics is the emerging field of analytical reasoning facilitated by interactive visual interfaces. Its important features include the ability to deal with high-dimensional data sets, to present information visually, and to allow researchers to interact with this information. Visual analytics' fundamental premise is that analysis is better undertaken as a symbiosis of the computational power of computers with the pattern and sense-making capacity of human users. It is this understanding that will guide the development of the VIARoma project.

How, then, can visual analytics enhance archival research among the humanities? We will discuss the potential of the VIARoma tool using the context of two on-going scholarly projects by the co-directors of this project (Professor Balmer and Professor Frakes) within UNCC's College of Arts+Architecture.

Professor Balmer's research focuses on the interior iconography of Bernini's Sant'Andrea al Quirinale church in Rome. There are ample primary source materials available on this building. Balmer began his research by examining Bernini's entire oeuvre, attempting to place Sant'Andrea in that context, or others: Roman churches undertaken in the 1650s; those constructed in the Quirinal district during the 17th century; or perhaps churches dedicated to Saint Andrew, or those commissioned by the Jesuit Order – all within narrow parameters of time and place, to allow for an exhaustive examination of all relevant archival materials.

Such parameters are normative for traditional archival scholarship. There are, however, broader contexts of interest. Sant'Andrea al Quirinale might be studied in the context of a history of the Jesuit Order, the Roman Baroque, or the liturgical and aesthetic priorities of both patrons and designers with onset of the Counter-Reformation. Wider yet, the church might be placed within broader histories of painting, sculpture, architecture or urban design. Traditionally, as the frame of reference grows wider, so too does the scope of work: exhaustive command of a subject is demanded of scholarship. Understandably, such efforts remain the province of those rare individuals with either super-human stamina or a rare access to the support (financial and temporal) required of such work. Even then, such works are surveys that adopt a measure of superficiality as a necessary premise. The pitfalls of such attempts are well documented: a scholar may establish conclusions based on their necessary reliance on secondary sources, which runs the risk of being biased, flawed, or merely incomplete.

The capacities of the proposed VAIRoma tool could track not just a specific history of a single building, but of entire districts in Rome, while preserving Balmer's direct access to primary sources. For example, the Quirinal district witnessed widespread construction throughout the 17th century, driven by the expansion of institutions affiliated with the Church in the wake of the Counter Reformation. The VAIRoma tool would not only provide Balmer the means to track construction records for Sant'Andrea, but *when* and *where* else specific contractors, plasterers, gilders, or mosaicists were active on other projects. Such minutiae, presently isolated into discrete packets of archival particulars, could, like the tesserae of a mosaic, be arranged and re-arranged at will through the capacities that the VAIRoma tool would provide researchers.

Professor Frakes's research addresses the imagery issued on coins by the Roman Imperial mint under a particular emporer's reign and its implications of what might be termed the 'propaganda architecture' of the regime. His research begins with the coins themselves: researching within the non-digitized official *Roman Imperial Coinage* (RIC) collection and the open sourced online database, *Coins of the Roman*

Empire in the British Museum (CBM). Frakes would use both the *RIC* and the *CBM*, and with each new research attempt, must wade through disparate information in order to understand the state of the field.

Furthermore, there is a proliferation of non-connected databases on Roman coins. Vendors and appraisers have been much more active in digitizing *images* of coins than museums or scholars. Consequently, many non-commercial websites, such as *aeqvitas.com,* are subject to the market drives behind existing digital data. Also, there is a whole class of coinage from the Empire that was *not* issued by the imperial mint, but by civic mints throughout the eastern half of the empire and is published unevenly as *Roman Provincial Coinage.* Digital studies in the field of Roman numismatics require sifting through independent websites, which results in an inefficient and many times inconclusive survey of information.

All of the resources mentioned thus far give a picture of Roman coinage as it appears *by type*. If Frakes searches for *distribution,* he must comb through an unmanageably complex array of niche periodicals and scattered archaeological reports even to suggest a probable geographic range. Alternately, interest in *relative scale of manufacture* would lead to another set of scholarly articles and track reports on coin hoard finds. Because few consistent practices exist among either numismatists or archaeologists, the management of these important questions remains unkempt.

The visual analytics approach of the VAIRoma tool would allow for a comprehensive survey of existing digital resources, allowing Frakes to quickly sort out sources formed by commercial interests from those that are peer-reviewed. A comparative visualization of the incommensurable data sets would not only eliminate months (or years) of archival footwork, but would quickly present the scholar with a picture of how many questions have been answered in part, how many are possible to pursue, and even where unanswered questions exist.

This grant proposal approaches historic Roman architecture and art in a new way. Through the development of the VIARoma tool, researchers, students, and others will be provided with a new way to access and understand visual and textual information on Rome through an interactive visual analytics interface. The innovation of this project is its unique approach to sophisticated computational and visualization tools, real-time interactivity, and the unique capability of the human user to understand connections.

Environmental Scan

Visual analytics is a relatively new field, especially its application in the humanities. As mass amounts of data held in analog archives are becoming digitized, alternative approaches and tools are emerging to reveal new understandings within the humanities.

A seminal example of analysis through quantitative methods is Franco Moretti's *Graphs, Maps, and Trees*. Moretti rejects the study of exceptional literary occurrences and focuses attention on literary production as a whole. In one study, he maps the total number of novels using simple line graphs over time in several countries. Next, he uses diagrams to examine the dynamics of a novel, and then uses trees as a structure to show the evolution of the form and techniques within a novel. Each of these operations is a strategy to destabilize conventional readings of 'great' literature. The statistical objectivity of his models are meant to provoke tension with more orthodox forms of literary studies.

Lev Manovich's *Style* studies artistic production, employing simple scatter-plot diagrams to plot the distribution of paintings according to various visual criteria. He begins with two sample sets of Van Gogh paintings, one executed in Paris and the other in Arles. Using software to obtain a median value for saturation and brightness in each painting, he then plots the results for possible interpretations of patterns of grouping, evenness of distribution and cross comparison of the sets of images. This project also uses graphs to analyze reverse skew value, plotting tonal values in the paintings against standard historic art categories, projecting trend lines against sets of data points and graphing the tonal elements in each painting over time. Manovich makes no claim as to the comprehensiveness of such analyses, instead seeing them as a tool to reveal otherwise hidden patterns.

A new understanding of the realignment of static documents may be exhibited in the development of navigable digital models. The *Rome Reborn* Project is an ongoing 3D modeling project of the city of Rome. The goal of the project is to produce an accurate model of Rome that represents the city over the duration of its existence. The model is navigable by both temporal and geospatial position. In addition,

the project provides the archeological sources and rationale behind the reconstructions, along with pertinent hyperlinks. This reconstruction can be used to visualize alignments, orientations, and other architectural queries, but while they provide the underlying information for the reconstructions, they do not analyze it.

The *Hypercities* project is navigable by both temporal and geospatial position, but involves a cartographic view rather than a 3D environment. It interfaces with Google Earth, providing a range of media (maps, genealogies, documents, 3D models) that is searchable via a navigable (zoom and pan) map of the city and a sliding timeline. As the user defines the geographic and temporal range of their query, a list of associated collections and media appear. This program provides a means of searching for media related to a place and time, but does not provide analyses of this data.

The *QueryArch3D* tool, developed by The MayaArch3D Project, is similar to the Hypercities project, but in addition to an interactive geographic and temporal interface, this tool is queriable via items in a navigable virtual reality environment. The tool combines the functions of a database and a hyperlinked map, but its innovation is the capability to perform distance-dependent object searches within the environment, meaning that a change in scale of the view results in different kinds of information received.

Such navigable and queryable 3D virtual environments and graphic representations of humanities-based collections reveal several shortcomings: There is little or no coordination among the various visualizations; we are forced to infer the relationships between them. More importantly and practically, there is no opportunity for user interaction with the analysis of the data. Both of these features are fundamental to the visual analytic approach that we propose below. To facilitate the analysis of enlarged surveys of data, the necessity of time-based analysis, and a common geospatial frame of reference, we propose to use a specific set of techniques from visual analytics as a tool to allow for searching and formulating questions within the humanities.

History and Duration of Project

The UNCC Visualization Center has a national and international reputation for innovative research on a wide variety of visualization techniques and is the home of the Southeast Regional Visualization and Analytics Center, one of 5 regional centers funded by the federal government. The range of projects engaged by the Vis Center has ranged from bank data to urban visualization to terrain visualization to infrastructure visualization. William Ribarsky and Zach Wartell are experts in the use of visualization, visual analytics and interaction, and have published dozens of papers on the subject in computer science.

Before beginning a detailed description of our work, we should be clear about three characteristics of visual analytics. *First*, visual analytics involves visualization not as a representation of something we already know, but as Stu Card of Stanford has noted, "using vision to think". This recognizes the unique ability of human to identify and understand patterns, and the unique symbiosis that this affords with computers. *Second*, visual analytics involves the use of sophisticated analytic techniques from statistics and mathematics, but gives them no final authority. They are presented to the user not as fact, but as possibilities; the researcher is in a unique position to evaluate their meanings. This is why visualizations are always invariably presented in multiple views, implying that no single view will tell the whole story. And *third*, interaction with the data is a vital part of this approach. It allows researchers to test ideas, follow hunches, and explore in ways that can uncover relationships that might hide from the first visualization. This is the tangible fulfillment of the symbiosis implied by humans and computers complementing each other in solving complex problems.

Applying a visual analytic approach to Rome would bring these techniques to art and architectural history. The technologies comprising a temporal visual analytics approach would create what we call an *intertwined* history of Rome. Such a history would begin with an overarching temporal narrative of the entire historical digital corpus of important events. Here we define 'event' as a meaningful occurrence at a particular place and time. A meaningful event in weather history could be a great storm, while one in religious history could be the building of a church. An intertwined history would place events from various histories into the same time structure.

Events can be arranged and displayed in multiple ways simultaneously. A complex history of a large-scale event can be automatically arrayed as a series of sub-events that provide a compact signature for the

whole story. Alternatively, interactive event timelines can display news events that have been extracted automatically from CNN over an entire month. Each event-bubble shows all the news stories for a particular main event, with the thickness of the bubble proportional to the number of related and concurrent news stories. Selecting a bubble at a particular point produces a video of the main news story.

Although automated techniques can provide accurate event identification, their significance is assigned entirely by human expertise. In these cases, a user determines meaningful labels or categories to the events. Since singular, 'higher-level' events are much compact and less numerous than the mass of information they describe, this should be feasible for the researcher.

Once we have the collection of events and sub-events over time, they may also be arranged into hierarchical tree structures. The next step is to combine such tree structures with the spatial structure of GIS. The incorporation is first spatial. A standard GIS Spatial Analysis in Macro-ecology is used to divide and subdivide the surface of the virtual world into spatial cells, and the locations of the events, city boundaries, buildings, social activities, etc. (for an urban history) are placed in their respective cells. To this combination, we add the time hierarchy over the events for this spatial region. The appropriate level for Rome might be a spatial cell of, say, 20 KM on a side, centered on the Forum. The organization of the time structure over this spatial cell is in terms of events. All major events occurring in this cell are inserted at their appropriate places along the time dimension.

Recently developed methods can successfully derive meaningful topics from collections of written documents. In its simplest iteration, these automated, data-driven methods analyze documents as a so-called 'bag of words', without regard to linguistic relationships. Although detailed contextual meanings may be lost, the methods are quite flexible and can be used to derive topics from the underlying content that, under human analysis, are meaningful. Such methods allow the collection of documents to provide patterns of content to an analyst, including how the individual documents cluster into related groups and the nature of their relationships.

A powerful related method we have used for text-based analysis is based on a Bayesian approach that automatically learns a set of topics for a document collection. The topics, each described by a set of most relevant keywords, are then assigned appropriately to each document in the collection. The Stanford Modeling Toolbox makes such tools accessible. Such approaches can be applied to full-text documents (papers, essays, reports, books--including works of fiction. One example examined by our group is from a collection of NSF proposals. Twenty topics were automatically extracted from the proposal collection. The topics, some of which are labeled, describe the themes of the NSF directorate. These themes are displayed using ThemeRiver timeline software, where each colored band shows the ebb and flow of particular topics across a horizontal timeline.

Coupled with these tools, for an intertwined visual analytics of Rome, we must add means to extract entities indicating time, location, actors (people or groups), and references (e.g., building names, neighborhood names, etc.) for each document section related to given topics. Many techniques already exist for this sort of geo-temporal analysis. Among the most powerful of these tools are those built around FactXtractor, developed at Penn State. A collection of interactions permit one to filter by topic, time period, related proposal, among others.

How might we convert disparate collections of events into intertwined histories? We begin with information already organized and available such as Richardson's *New Topographical Dictionary of Ancient Rome*. By digitizing these texts, their relevant content could be analyzed with topic modeling and entity extraction for additional topics, related events, and for relations among topics. The initial, high-level event extraction could be achieved manually or semi-manually in support of significant meaning; main events would reveal themselves readily. Even if incomplete in terms of main events, this initial timeline would soon be filled in by the topic modeling and event extraction step upon analysis of subsequent texts.

Additional texts containing syntheses of social history, ecclesiastical history, architectural history, etc., would then be added, building up a series of 'scaffoldings' to form broad outlines of events for each of these histories. With this initial structure, we can then cast our net wider, to other books and documents, using the initial collection as a 'training set' for the broader sets of texts, to enrich existing topics

and events, and to uncover new ones. Ultimately, we would consider this set of scaffoldings together, seeing how they intertwine and connect with one another. Simply seeing events from different histories in close proximities of time and place may be sufficient to infer relationships, including those of possible cause and effect. Once identified, such events may then be explored more deeply. Ideally, topic modeling could be tuned to automatically reveal potential relationships in more detail, and relate events from different histories into a comprehensive history.

The relative significance of events is assessed by examining text collections that can identify events mentioned across multiple collections. We have already developed a process for the NSF program impact study, where we followed programs that covered particular research areas over time, even as the names and to some extent the focus of the programs change across time. We overcame this problem by tracking the underlying scientific principles that have permanence over time and evolve slowly. Our analysis revealed main topics and trends, including new topics, over time. Topics that appear across several subjects are cross-disciplinary, as are proposals that have multiple salient topics. This approach can also infer the impact of a particular program on the underlying science. (We can see how a research area evolves after a particular funding program is begun.) It can also reveal what research areas a program is actually funding, as distinct from what the program *thinks* it is funding.

Vast collections of imagery associated with a city like Rome are widely available. Recent advances in what visual analytics call 'image semantics' have led to breakthroughs in automated analysis of image content. In this approach, semantics of imagery are determined for higher-level image understanding – whether images depict beach scenes, urban scenes, etc. Such techniques are robust; that is, they can recognize beach or traffic scenes even under conditions of different lighting, viewpoint, or activity. New topics for automated understanding can even be user-created by selecting sets of training images for the desired topics. These methods have already been applied to digital image collections such as Flickr.

For the intertwined histories described here, such methods would need to be extended to analysis of drawings, paintings, and prints. Some work has been done with drawings--especially map drawing understanding. With such tools, map content can be associated with geographic views of relevant events. Other methods can now successfully consider image and text content together. Such methods permit automatic derivation of more reliable descriptions for images (e.g., from captions or closely associated text).

Finally, we will utilize methods to automatically extract architectural imagery from perspective views painted or captured at different times in its history. Recent methods automate the creation of highly detailed 3D models from archival photographs and paintings, combine both photos and paintings to generate 3D models of historical structures and combine automated 3D reconstruction with a probabilistic model that can determine the most plausible temporal ordering of the original photographs.

Work Plan

During academic year 2012-13, one graduate student from computer science and one student from the College of Arts + Architecture will collaborate on the design and implementation of a prototype system for VAIRoma. During all phases of the research, they will meet on a biweekly schedule with all five of the investigators working on the project to review completed work and set specific objectives.

We will first survey available digital text sources since these will be the easiest on which to apply our automatic analysis techniques. We will concentrate on sources for architectural, political/religious history, and urban demographic categories to begin with. These can be book-length texts, scholarly papers, historical records, as long as they are digitized. We will apply topic modeling and geographic, date, and named entity extraction techniques to these collections. For entity extraction, we have developed techniques that are similar to FactXtractor. Concurrently, we will develop initial timelines of main events from the different major sources; these timelines will be augmented with automatically generated events (with some human interpretation added) from the topic modeling. The topic modeling will also be applied to some merged collections from different categories in order to pick up joint topics (and events that may be across topics). We anticipate this work will be complete by the end of the fall 2012 semester.

Although several types of interactive visual analyses can be developed using these analysis results and the 4D GIS structure in which they will be organized, we will concentrate on generating interactive timelines with coupled geographic views to begin with. This is similar to what is done in the Hypercities

project, but the interactive analysis will be much deeper. Based on the topic modeling results, there will be a comprehensive set of events, which can be opened up to reveal sub-events. The topics associated with these events will be shown in detail as they grow or shrink over time. Any selection of events, topics, or a range of time on the timeline will immediately show locations, extent, and other information on the geographic view. Moving a slider over time for a given event or topic will show an animation of the changes over time on the geographic view. (For example, the distribution of people and their status, occupations, etc. over time within the city boundaries Rome would be revealed for the relevant demographic topics.) Conversely, one will be able to interact with the geographic view, selecting areas so that only topics and events for those areas are revealed on the timeline (or are highlighted in the context of the other topics or events). One will be able to get to the appropriate parts of the original collections for a given time range and geographical area, as in Hypercities. But in this case, parts of the texts dealing with a given topic or related set of ideas will be visually revealed and searchable. We anticipate completing this work during the spring 2013 semester.

During the summer 2013 study abroad session in Rome of the College of Arts + Architecture, the VAIRoma system will be tested by Balmer and Frakes, who will be directing the program.

Staff

Professor Jeff Balmer of the School of Architecture at UNCC is Director of the study abroad program in Rome. He is included because of the relevance of his scholarship on the architecture of Bernini and will be a co-director on this project. His responsibilities will be identifying archival sources that are appropriate for integration with the visual analytic interface

Dr Jim Frakes of the art history department at UNCC, with his scholarship engaging Roman art and architecture. He is a leader of the College of Arts and Architecture study abroad program in Rome. He will be a co-director on this project. His responsibilities will be identifying archival sources that are appropriate for integration with the Visual Analytic Interface His commitment will be 5 hours per week.

Professor Eric Sauda is director of the Digital Arts Center at the College of Arts and Architecture, and will be a collaborator on this project.. He will function as the liason between the art and architecture faculty and the Vis Center.

Dr. William Ribarsky is the Bank of America Endowed Chair in Information Technology at UNCC, chair of the computer science department and founding director of the Charlotte Visualization Center. He will be a collaborator in this project because of his expertise in visual analytics.

Dr. Zachary Wartell the Associate Director of the Charlotte Visualization Center. He will be a collaborator in this project because of his expertise in visual analytics.

In addition, two research assistants will be hired with the grant monies, one with the Charlotte Visualization Center, and one with the College of Arts and Architecture (CoAA) at UNC-Charlotte. The choice of one student from each discipline is meant to integrate their work seamlessly, and they will be provided with a dedicated space in which to work together. Their time commitment will be 20 hours per week.

Final Project and Dissemination

The immediate result of this project will be a proof of concept interface for a visual analytic interface for Rome. This interface will be created by the research team and tested by Balmer and Frakes, but the work will be open source and will be made available to all researchers.

The current grant will support a limited selection of data, but we anticipate expanding this work through application for additional funding both through the Digital Humanities Challenge Grant and through funding from the Visual Analytics Centers and the NSF.

The significant innovations concerning the interface and the incorporation of time-based data created by this research will be submitted for publications to conferences and journals in both fields of the humanities and computer science. We anticipate the submission to the following: College Art Association, the American Collegiate Schools of Architecture, the Journal of Architectural Education, and to the VIS, InfoVis & VAST conferences within the computer science community.