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PRIMARY RESEARCH

Computerization in the study of Athenians

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Abstract

This paper reports the progress made in the computerization of the Athenian study, which compiles and studies data about the persons in ancient Athens. We first summarize the issues and solutions on data storage since relational databases were applied in the study in the 1970s. We then detail the recent progress on the computerization of the project, which includes a method to digitize squeezes and an approach to develop an interactive map to facilitate the study of ancient Athens. The squeezes are paper impressions of ancient inscriptions. There is a high demand to digitize squeezes and make them freely available to humanities scholars worldwide. The proposed method generates bright digital images from low-relief ancient Greek characters on paper by convoluting 4 images of the same squeeze taken from different angles via the “Lazy Susan” platform. An interactive digital map of ancient Athens is highly helpful for the study, which visualizes the geographic information of ancient Athens and relates Athenians with their locations. The interactive map is developed based on the Leaflet, which is free and open source. The progress reported in the paper will greatly promote the computerization of the Athenian study.

I. INTRODUCTION

Ancient Athenian studies involve research into the persons and places of ancient Athens. Of the 1500 ancient Greek city-states or "poleis", Athens and with the area around Athens, Attica, was the largest and, through much of its history, the most important [1]. After a period of legendary monarchs, Athens' history begins with the prescient lawgiver Solon, then two generations of tyrants who were followed by what was arguably the most important invention in the history of government, a system of democracy devised by a person named Cleisthenes in the year 508 b.c.e. [2]. Cleisthenes organized the various and differing natural communities of Attica, called demes ("peoples"), into larger and increasingly artificial groups called trittyes ("thirds") and phylai ("tribes" or "classes"), 140 of the first, 30 of the second, and 10 of the third, to form a system of representative government called democracy ("action of the power of the people") [1]. Athenian democracy, with several subsequent modifications, lasted a millennium. Ancient Athens is widely and justifiably referred to as the birthplace of democratic government.

An essential feature of the foundation of this first and longest-lasting democracy was the requirement that every citizen be given a surname which was the adjectival form of his family's deme at the time when Cleisthenes drew up his system. Someone from Marathon added after his own name and the name of his father, a third name, Marathonios, and he and his descendants, regardless of where they subsequently lived in Attica, kept this epithet as a politically defining part of their name. All known ancient Athenian citizens, linked with their demotics where they are preserved, are now recorded in the Athenians Project database [3].

In addition to natural resources of silver, which Athens first used to pay for a strong navy for defense, and excellent clay deposits, from which Athens developed an outstanding pottery industry, Attica was also endowed with excellent sources of marble on both Pentelicon and Hymettos mountains which were close to the city [4]. Beginning in the mid-

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dle of the fifth century under Pericles, Athens diverted part of its silver resources to fund the construction of a showcase of enduring architecture on the Acropolis and at numerous other sanctuaries throughout Attica; masterpieces like the Parthenon and Erechtheum still elicit the awe and admiration of people today, 2500 years after their creation [5]. Marble had another purpose, perhaps less obvious at first, but of greater significance from a future perspective: it was the prime vehicle for inscriptions, words written on stone. Attic inscriptions on marble have come down to us by the thousands, and they comprise, along with texts on other imperishable materials like pottery, silver coinage, and lead, a thesaurus of texts regularly classified as follows: (1) laws and decrees in which the Athenians demonstrated their love of order and government, (2) dedications on which the Athenians honored, and hoped to obtain honors from, both mortals and deities, (3) inventories in which the Athenians advertised their punctilious accounting abilities and also held government officials accountable, (4) catalogs of many kinds and classes from elected government officials, judges and juries, army recruits, to members of various clubs and societies, and last (5), ubiquitous gravestones on which the names of people bearing every Athenian demotic and most ethnics of the ancient Greek world were recorded [4, 6].

Permeating this mass of documentation, of which we have offered only a summary, was a common theme or purpose, an exuberance of pride in the individual (private) and in the state or community (public); these people became addicted to writing; especially writing on imperishable material. Their government was a democracy, and democracy required literacy and emphasized the importance of the individual. The Athenians became obsessed with seeing their names in indelible print: this was their vehicle to immortality. How else can we explain the fact that although the population of Athens was no more than 150,000 persons at any time, we know the names, scattered over a millennium, of more than 100,000 people? There exists no parallel for such an efflorescence of epigraphical literacy [7].

This remarkable prosopographical heritage did not pass unnoticed in the scholarly world, and at the beginning of the 20th century, the great German epigrapher, Kirchner, compiled a 2-volume work called “Prosopographia Attica,” which contained 15,500 entries in the main register and another 1,200 in the addenda, all the people of ancient Athens from the archaic, classical, and Hellenistic periods who were known to him in 1900 [7]. It is no disparagement of Kirchner's magnificent achievement to point out that it had limitations: his cut-off date of 30 b.c.e. excluded two-thirds of the material (Athens is prolific with inscriptions from the later Roman era); he accepted only bona fide Athenian citizens, thereby removing every foreign resident or metic, all slaves, and many women. More importantly, his work was completed just before the commencement of a new series of excavations in the heart of Athens [7].

From the very beginning of the modern phase of the Agora ("marketplace", cf. agoraphobia) excavations in 1931, it became clear that inscriptions were to be a common find. On the first day of the excavation 25 were found [8]! The late Benjamin D. Meritt [9], an early appointee at the Institute for Advanced Study in Princeton following Albert Einstein, and overseer of the Agora inscriptions, began to keep a card catalog of the names on the documents. Other scholars contributed to this hand-written compilation, and over the next 40 years, this prosopographic file, as it was known, grew to more than 100,000 entries [7]. This collection, of course, included the most famous Athenians, like Socrates, Pericles, and Plato, but the file also contained thousands and thousands of persons of lesser importance, of whom we may know only a fact or two, sometimes next to nothing, for in reality, often the source of our information is so damaged that only a letter or two of a person’s name have survived.

Computerization has been applied to the study of Athenians on identifying individual cutters of Greek inscriptions [10], on the architectural and topographical survey of ancient Corinth [11], and in the digitization of late-antique texts [12]. In this paper, based on the progress made on the Athenians project, we discuss how the information of Athenians is managed with databases, how the low-relief squeezes are digitalized into bright and legible images for dissemination, and how the use of the information of Athenians is enhanced through an interactive map created based on the open-source Leaflet. Our efforts in the computerization of ancient Athenian studies belong to the area of digital humanities [13]. We apply computerization to the study of the ancient Athenians to facilitate data and information management and dissemination. To the best of our knowledge, this is the first attempt to digitize squeezes by convoluting images taken with the “Lazy Susan” platform and the first attempt to create an interactive map for Athenian study with open-source Leaflet.

II. RELATIONAL DATABASES FOR ATHENIANS

Back in the 1970s, relational databases were used in computerizing ancient Athenian studies [7]. Relational database technology of the 1970s did not know how to handle ancient Greek characters, especially passages of varying lengths. Ancient Greek is significantly different from

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Modern Greek, and in those early days, there was no concept of Unicode/UTF-8. The Ancient Greek characters were mapped onto a multi-byte encoding scheme so they could be entered and displayed on HDS VT-100-like terminal with an encoding/decoding ROM. This needed something more than the standard CHARACTER data type, not only to deal with encodings and control characters but also variable-length text data. This resulted in the addition of a new "Athenians" data type that supported the requirements.

Generalizing the concepts resulted in character and text data types capable of storing not only encoded ancient Athenian text in both fixed and variable length formats but also almost any other data encoding, including multi-byte character data such as Japanese and Chinese.

Generalizing that data type concept further resulted in the creation of an environment within the database system that allowed for user-defined data types. This allowed the database system to have a very rich data type base as well as the ability to add more custom data types as required by applications.

Since the original Athenian data could be stored as images of the original stone inscriptions or even squeezes (paper impressions showing ancient Greek characters in relief), the variable length binary data type was added. To provide meaning for the binary data, user-defined functions, including stored procedures and triggers, were added. User-defined functions were used to provide a lookup table mapping of the ancient Athenians encoded data to UTF-8/Unicode for web search and display [3].

We were pushing the technology of the relational database model to include user-defined data types, user-defined indices, user-defined functions, storing variable text and binary data, ability to port the relational database software across a rapidly evolving 16-, 32- and 64-bit technology with the ability to preserve and maintain all the data that were transcribed over a 30-year period. Looking back, the ancient Athenian studies is a stellar classical humanities application of Database Technology that pushed relational database technology above and beyond relational expectations.

A relational database uses two relations or tables to store Athenians [3, 7]. A Main relation of 15 attributes or fields, and a References relation of 8 attributes or fields. In the Main relation, each individual has been assigned a unique identifying number, then his or her name is listed along with additional formatted information on social status, demotic or ethnicity, profession, kin, relationship, date, and so on. There are, for example, numerous levels of certainty for the status and nationality of each individual. Two of the attributes, namely date from and date to, were specifically designed to facilitate chronological searches, and other attributes of variable length are repositories for material that may be later expanded and formatted into additional attributes or relations. The References relation contains documentary data, i.e., the evidence for the information in the Main relation, for example, the inscription or the author where the data may be found, the precise location of a reference, i.e., the line number in an inscription or section in a literary text, the type of document, and the full text as it appears in a certain author or on a certain inscription. The latter, having suffered considerable damage over the years, may often be difficult to read, and the cited texts regularly are controversial since they are dependent on the subjective reading by a number of epigraphers. Provision, accordingly, has had to be made for variant readings, with an additional facility for indicating a ranking of the reliability of different texts where appropriate [7].

III. SQUEEZES DIGITIZATION FOR SHARING

The squeezes are essentially white paper three-dimensional impressions of ancient Greek writings on stone [14]. They are formed through beating, by means of a specially designed brush, soft, wet, moldable paper, often filter paper obtained from a chemistry laboratory, into inscriptions where letters are carved in shallow cuttings below the flat surface of the stone; when dried the squeeze thereby becomes a three-dimensional mirror-image of the original document, and the letters now appear raised in relief.

Squeezes are no longer legally obtainable as the Greek government wishes to preserve all their ancient artifacts. Because there is physical contact between the paper plus brush and the surface of the inscription, in the making of a squeeze, slight damage, virtually imperceptible with a single impression, is caused to the surface of the stone. The result has been that the taking of squeezes is now generally banned, except under very special circumstances, by the governments and ministries in charge of antiquities. Currently, researchers must travel to specialized museums and libraries to study the squeezes. We have several thousand squeezes available to us. By digitizing these squeezes, we will be able to catalog and put them on a website for all humanities researchers to share.

In this paper, we introduce a method to digitize squeezes based on the "Lazy Susan" platform. When digitizing a squeeze with the "Lazy Susan" platform, both proper lighting to illuminate the low-relief surface and a quality camera to capture the details are needed. For each squeeze, four images are first taken, and for each of them, a different an-

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gle of light is shined onto the squeeze. The four images of the same squeeze are then convoluted into one final image of the squeeze [15]. This allows the low-relief writing of the squeeze to be more legible.

The "Lazy Susan" platform is as shown in Figure 1, consisting of a 15-inch "Lazy Susan" at the base, screwed on the top of a 1-square-meter board. A tripod and a camera are set up on top of the board. The squeeze is placed directly beneath the tripod. The wireless flash is set up outside of the board. When the platform rotates, the camera and the squeeze rotate together, and the flash shines a different angle of light onto the squeeze. The "Lazy Susan" platform allows a camera to take different lit images, each with a light source progressively moved 90 degrees. One drawback of using the "Lazy Susan" platform is that the four images taken from different angles of the platform may contain some shifting from each other due to the instability of the tripod. This may create inconsistencies in the pictures and affect the quality and the amount of details captured.

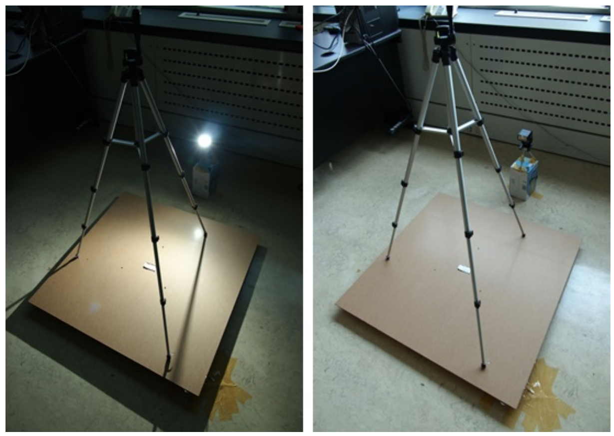

Fig. 1. The "Lazy Susan" platform

To address the instability issue of the camera, each of the four images taken for the same squeeze is first registered to the correct position before they are merged. The shifting between two images due to the instability of camera can be corrected by finding the translation parameters (values of shifting in X and Y axis) and moving the shifted image into the opposite direction. The easiest way to find the translation parameters is to slide an image on the other image and calculate the sum of absolute differences between overlapping pixels. Optimal translation parameters are obtained when the sum is minimized. Fortunately, each squeeze image contains a grid lines background, so it is sufficient to find the parameters from the grid line on the image edge [16]. Shifting correction is repeated until all four images are correctly registered.

Fig. 2. Four images taken for the same squeeze with the "Lazy Susan" platform

After four registered images are acquired, as shown in Figure 2, they are merged using "lighten blending" [16, 17]. Each image is aligned on the top of the previous one as four layers. The "lighten blending" can be calculated by measuring the brightness at the same pixel in every layer. The output is the pixel from the "brightest" layer at that position.

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The convoluted image shows the image with a bright contour around the low-relief character shape on the squeeze, as shown in Figure 3.

Fig. 3. The process of convoluting four squeeze images into one

IV. INTERACTIVE MAP OF ATHENIANS

We propose an interactive map of ancient Athens at the front end of the database to facilitate the visualization of Athenians data. Much of the data around ancient Athens is family oriented, so to search and relate data based on family hierarchies and probabilities and geographical locations are desired features in Athenians search.

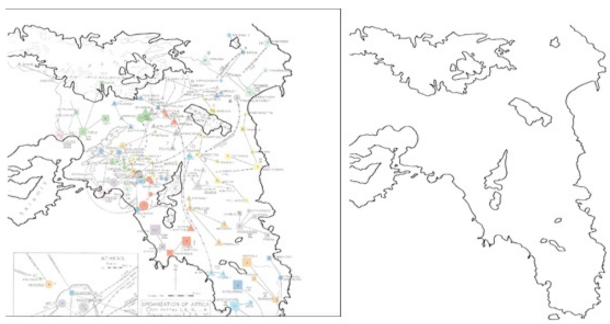

Fig. 4. Convert a rasterized map (left) to a vector map (right)

We intend to implement an open-source interactive map to support humanities research. The interactive map proposed in this paper is based on APIs from the Leaflet [18], which is free and open source.

The proposed interactive map is a digital extension of the Attica maps [1, 19], which is programmed with web programming languages such as JavaScript, HTML, CSS, and PHP and takes advantage of APIs from Leaflet. The interactive map was initially created based on rasterized map images, but it was very soon we found that rasterized images cause pixilation when enlarged [20]. We decided to use vector map images in the construction of the interactive map. With the vector images, the map can be zoomed by mathematical calculation, and no pixilation would be yielded when stretched. To convert a rasterized map to its vector representation [21], we first traced the rasterized map with Illustrator and then drew it by hand to get its full original outlines, as shown in Figure 4.

Since only a part of the map can be accommodated by the screen at a certain zoom level, a map is generally generated in parts called tiles [19]. We need to break the map into tiles so that it will only show the relevant section instead of the whole map for different zoom levels. Figure 5 shows the directory organization of the tiles, where Z denotes the zoom level, and X and Y denote the row and column numbers of the map at the respective zoom level. At a certain zoom level, only the part of the map that corresponds to a certain row and column numbers will be generated and displayed. Each tile of the Attica map is set to 256 x 256 pixels. When a tile at the lowest zoom level 0 is required, the whole map as a 256 x 256 pixels image is displayed, and this is when the map completely zoomed out. A map that has more pixels in both its X and Y coordinates will be used each time it goes up by one zoom level so that each tile at any zoom level is still 256 x 256 pixels, as illustrated by Figure 6 (with three different levels). The tool used for tiling is a C/C++ developed program called "MapTiler" [22], which can tile an image into multiple image formats such as PNG, TIFF, and JPEG.

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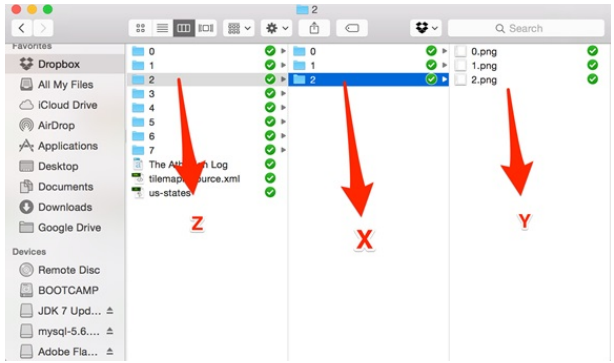

Fig. 5. Directory organization of the tiles

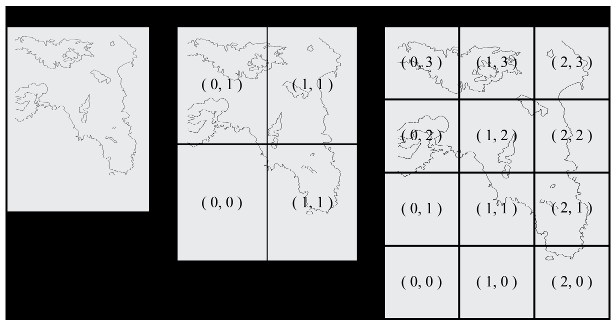

Fig. 6. llustration of tiles at different zoom levels

The proposed interactive map has standard features such as map panning by dragging the mouse while holding the left mouse button and zooming in or out with the scrolling feature of a mouse or trackpad. Map zooming can also be performed by clicking the plus or minus button on the top left corner of the map. There is a layer feature on the left side of the map to turn off map markers for a clean map look, as shown in Figure 7. The map itself visualizes some basic information with colors and shapes. Take the Deme Marathon, as shown in Figure 7, as an example. The large light-purple square in the upper right corner of the map and the Roman numeral IX tell us that Marathon belongs to the coastal trittys or third (it is joined by lines to the 2 other demes of its trittys) of the 9th phyle or class. Mouse-hovering on the light-purple square of Marathon will bring us more relevant information in the pop-up window as shown in Figure 7: The number of Marathon in the natural order of demes (i.e., phyle by phyle through city, inland, coast), the name, i.e., Marathon, the phyle or class, here #9 or Aiantis, the trittys, i.e., coast, then Marathon's size as reflected by its quota or number of representatives in the Athenian government, viz 10, then its location with a commentary which documents the sources of evidence for the location. Clicking on the square will bring up even more detailed information from the databases, such as all people in Marathon and the information on Aiantis.

Fig. 7. Interactive map with mouse hovering on the light purple square of Marathon

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V. DISCUSSION AND IMPLICATIONS

Sculpture and squeeze digitalization has been widely studied [23, 24, 25, 26, 27, 28]. One inscription-digitization project [23] has relied on laser scanners and reflectance transformation imaging systems [29] to highlight letters on the stone. Another squeeze digitization project [24] relies on shape reconstruction to create a 3D image from a 2D photograph of the squeeze. The prohibitively expensive TTI Repro-Graphic 4060 assemblage is used in a third squeeze digitization project [25]. In the project, three images of different exposures need to be taken, and the high dynamic range imaging technique [29] is applied to merge the three images. Due to the need for special hardware and software, these methods are potentially prohibitive [25].

Our work on the interactive map is related to the Pelagios project [30, 31] to enable linked ancient geodata in open systems and the Pleiades gazetteer of the ancient world [32]. The digital map created for the Pleiades gazetteer was implemented using Google Maps API and Google Maps as a background layer. Google Maps API is free but isn't open-source. An interactive map has been proposed using Esri ArcGIS JavaScript API (Application Programming Interface) [33], but Esri ArcGIS is proprietary software [34]. Since we need to display information pulled out from our own databases on an interactive map, Pelagios [30, 31], and Pleiades [32] are not relevant [35]. The interactive map proposed in this paper is based on APIs from the Leaflet [18]. The Leaflet platform is free and open source, which is different from Google Maps [36] or Bing Maps [37]. Although the Leaflet does not provide as many exciting features as Google Maps or Bing maps, such as Street View, it provides all features needed for the study of ancient Athenians.

VI. CONCLUSION AND FUTURE WORK

In this paper, we report the computerization progress in the study of Athenians. We review and discuss how relational databases have been applied to store the information of Athenians. We propose an approach based on "Lazy Susan" platform to digitize squeezes with bright images generated for low-relief ancient Greek characters. We propose to create an interactive map based on the free and open-source Leaflet platform to allow scholars to relate information with geographical locations. Although many efforts exist on squeezing digitalization, not all of them have made digital squeezes available online to help evaluate different digitalization methods. We also need to establish standards and metrics to evaluate digital squeezes and digitalization methods. The interactive map is expected to incorporate and reflect the changes in geographical features over time. A detailed study of the advantages and disadvantages of different methods of creating interactive maps is anticipated. In the future, the original topographical database will be enhanced with digital images and maps showing the findspots of antiquities in Athens and Attica. All topographical material will be linked to the larger databases of prosopographical data. The digitized squeezes will be integrated with the prosopographical and topographical material. The stemmata or family trees will be built based on the probability theory.

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