Title: “Lithics Visualization Project for Analysis of Patterns and Aesthetic Presentation”

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Our project uses digital image processing and new visualization techniques to analyze a set of 500 late Pre-Neolithic B (ca. 7500 – 6000 BCE) arrowheads from Jordan. Berryhill is a photographer and art historian who works at the intersection of art and scientific visualization, Levy is an anthropological archaeologist who leads a team in developing digital tools for field and laboratory research, and Manovich is a new media theorist who directs a lab that is developing visualization techniques for working with large image sets. We employed digital image processing software to measure a number of visual attributes of every arrow from the high-resolution digital photographs, including texture, colors, shape, and contour. We then used HIPerSpace tiled supervisualization system (286,720,000 pixels) to interactively organize images of the arrowheads according to dozens of different combinations of their attributes, while exhibiting aesthetic qualities. The presentation will discuss new patterns and insights enabled by this new research methodology. This approach transcends traditional archaeological and artistic approaches to material culture.

Keywords:

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More than a year ago due to a special event, Fulbright Association colleagues opened doors for me to experience projects going on at the California Institute for Telecommunications and Information Technology (Calit2). What caught my interest specifically was the Center of Interdisciplinary Science for Art, Architecture, and Archaeology (CISA3). CISA3 develops “new tools and techniques to reconstruct and analyze the history of great works [of] art, monumental structures as well as archaeological sites and artifacts.”[1] These entities collaborate with the Jacob’s School of Engineering and the Divisions of Arts and Humanities and Social Science at UCSD. [**fig. 1]**

Knowing of my previous documental photography projects plus interests in how art, science and technology have blended together historically, fellow Fulbrighters at UCSD encouraged me to talk with Tom Levy, distinguished professor of anthropology/archaeology and associate director of CISA3. After contacting Tom and providing some photo samples of previous projects, he invited me to the UCSD campus for a meeting to look over their sizable collection of Jordanian artifacts. The small pressure flaked Neolithic arrowheads **[fig. 2]** especially intrigued me and within two weeks, a lab location was set up with photo equipment. My initial goal was to shoot 500 images of these prehistoric tools, the size of each piece averaging about an inch (2.54 cm) in length, for their department’s digital databases. As I photographed them, they were

loaded into Lightroom software with pertinent metadata for the analytics. **[fig. 3]** During the recording process and after a serendipitous weekend experienced in Monterey, California's art museums, a new idea unfolded into something unexpected—photographing the lithic tools for an interactive cultural analytics project—and, potentially more. **[fig. 4]**

As an artist/art historian, it dawned on me to also present them as an aesthetic art piece, displaying an integrated blend of art, craft, technology, history and science. After shooting several of the Neolithic flints and some experimentation, **[figs. 5 & 6]** I made a two-dimensional mock up of several of the arrowheads in an array pattern. **[fig. 7]** After discussing the idea with Tom Levy, he contacted Lev Manovich, professor of New Media at UCSD, also a Calit2 associate.

Tom, Lev and I met with graduate student Vid Petrovic in Calit2 located on the UCSD campus, who uploaded my first set of high-resolution photos into the HIPerSpace digital display. **{figs. 8-13]** This ultra-scale visualization environment is close to 32 feet wide and 7.5 feet tall and is made up of a multi-tiled system of 70 Dell displays arranged in columns. The combined resolution of the network is more than 286.7 million pixels. It was exciting to see the small arrowheads blown up to nearly twelve feet long on the giant screen. We were awestruck by the beauty and craftsmanship of the Neolithic flint-knappers' detailed work. Tom was especially interested in how Lev's cultural analytics tool kit could be used to identify meaningful archaeological patterns within the large collection of 500 arrowheads; Lev was interested in applying his algorithms to a different realm of material culture.

However, along with the camera's macro lens' high magnification, came increased ability to see soft shadowing and subtle debris--essentially unwanted details for blue screen. **[fig. 14]** Lev indicated that even small traces of drop shadow would not be suitable for algorithm software applications. A new challenge arose to work out lighting and equipment set ups that would eliminate the shadowing while still visually describing the form and delicate intricacies of the lithics. Through some experimentation, a successful solution was reached by utilizing a small high quality light box, evenly balanced desktop level lighting and reflectors. I proceeded to re-shoot the 500 arrowheads using these techniques. Dorsal and ventral views of each arrowhead were photographed with a cm scale included, and then cataloged with individual metadata within Adobe Lightroom software. Small samples were developed for testing. The next critical step was conducted with Lev and his associate, Jeremy Douglass who loaded the first sample set of 100 of the prepped images to check suitability and for the purpose of archaeological categorizations such as location, size, shape, type, color, locus and basket. **[fig. 15]**

Lithics Background

[fig. 16] As is generally known, the Neolithic period had its own technological advances and instigated significant social change due to the domestication of plants and animals necessitating the establishment of settlements. The resulting chipped stone tool production led to a variety of useful implements. These lithics are important for archaeological research and artifact studies within their context as the small, stone pieces from the Neolithic (PPN) period ((8500-5500 BCE) are more durable than other types of material culture. The arrowheads or points are also important for material culture study

and warrant broader investigation in themselves. In southern Jordan's copper ore Faynan district, the PPNB arrowheads used in this study come from the site of Tel Tifdan excavated by UCSD and Department of Antiquities of Jordan archaeologists in 1999.

The term "lithics" covers a range of these crafted tools, from larger hammer stones and blades from naviform blade cores, projectile points, scrapers, drills and small bead piercing tools. The naviform core size was determined based on the types of tools desired by the Neolithic stone chippers. The cores are important as they are quite distinct and representative of the PPNB lithic technology found throughout the eastern Mediterranean region.[2] There are non-formal and formal lithic categories. The non-formal or 'ad hoc', so named by Steven Rosen in Levy and Rosen's article on chipped stone industry[3] shows little evidence of retouching. Our lithic of focus, the arrowhead, point or projectile, is a formal tool and was used primarily for hunting. It represents the greater number of lithics found in this region of Jordan known as Faynan of the southern Levant.

[fig. 17] Three categories of arrowheads are included in our project: Jericho, Byblos and Amuq points. Most of the arrowheads in this collection are of the latter two types. There are two basic parts that make up the arrowhead—the body and the tang. The body is the wider section and the tang is the more narrowed end. Briefly, Jericho points have tangs that are often triangular in shape and have angles of 90 degrees or less. The Byblos point is generally recognized as having tangs that show angles greater than 90 degrees and are often asymmetrical. Amuq points look more leaf-shaped and elongated. [4]

[fig. 18] Overall appearance of a typical arrowhead on the dorsal view shows multi-facets angling along both sides of a raised spine which may or may not have a narrow flattened

ridge running centrally down the length of the tang and body. The ventral view or backside is mostly flat. Flint-knapping technique used to render the points is a method that has been practiced for thousands of years by different people groups in various parts of the world. There are two types of flint-knapping: percussion flaking and pressure flaking.[5] In basic terms, a hand-sized rounded hammer stone consisting of a non-flaking type of rock such as granite or sandstone is used to hit the edges with a downward strike (percussion flaking) on a concoidal fracture stone. Once a suitable flake for an arrowhead is dislodged through the striking motion and shaped by additional knapping (pressure flaking), final steps may be taken using a small tool such as an animal horn or antler to further crimp and refine the edges. The pressure technique is applied on the dorsal and ventral sides. Some typical stones found from the Jordanian excavation are flint and basalt.

After 15 years of research in Jordan, thanks to the generosity of the Department of Antiquities of Jordan, UCSD holds a sizable collection of artifacts from the Faynan region on permanent loan and our arrowhead assemblage is derived from this collection. Wadi Faynan is centrally located in Jordan in the administrative district of At Tafilah (latitude 30.63, longitude 35.45). The area is 154 kilometers (about 96 miles) south of the capital city of Amman but closest to the city of Aquaba which is just across the border from Israel's city of Eilat. The word, "wadi" is Arabic for valley, streambed or gully and these are extremely dry except during rainy seasons where severe flooding may occur. The "Siq" in Petra is an example of what this type of extreme flooding can create. **[fig. 19]** Every year, Levy's team of professors, graduate and undergraduate students, colleagues and volunteers sets up camp with tents and labs close to the excavation. They

proceed with the proposed work and for several weeks, students are taught the practices and methods of field archaeology. Recording information accurately about the strata and found objects is paramount, as once an area has been excavated, it cannot be reversed. General to specific protocol is employed such as site > area > square > locus > basket>shape or type. Each item is collected with this specific information recorded on the front of its plastic baggie and on the ventral side of the arrowhead. **[fig. 20]**
Here is an example of procedure taken from Tom Levy's forthcoming book, *The Mountains were of Copper: 10,000 years of Ancient Mining and Metallurgy in Faynan, Jordan*:

> Excavations at Tell Tifdan began in June, 1999, and lasted for approximately 10 weeks. Approximately 50 students, staff and workmen were involved in the field work which concentrated on two areas: J and M. A total of seventeen 5 x 5 meter squares were excavated covering an area of ca. 425 m^2. Four major strata were identified at the site and labeled from surface downward as Strata I, IIA, IIB, and III.[7]

The site was initially sectioned off into areas that were to be excavated. Within these, they mapped out 5 x 5 meter squares on the surface. The next step involved assigning locus numbers with a total of 259 loci (places in layers of earth or human made features such as walls, floors, spaces) opened for the 1997 season. Every locus (place) was given a number and as each arrowhead was found it was given a basket number.

To track and coordinate the visual information between our three disciplines and specifically, to provide protocol for Lev Manovich's analytic work, this essential metadata was attached to each image of each arrowhead,

dorsal and ventral views as follows: WF001_7_10027_byblos_1

(area>locus>basket> arrowhead type>dorsal view)

Lev Manovich's specific part in the project was to develop visualization techniques for working with our initial image set of 500 pieces. His techniques brought a unique solution to the contentious if not impossible challenge of how to organize and work with massive media data sets that will be easily accessible and directly usable by investigators**.** Lev shares a bit of background in this quote:

> A number of interconnected developments which took place between 1990 and 2010 – digitization of analog media collections, decrease in prices and expanding capacities of portable computer-based media devices (laptops, tablets, phones, cameras, etc.), the rise of user-generated content and social media, and globalization which increased the number of agents and institutions producing media around the world – led to exponential increase in quantity of media while simultaneously making it much easier to find, share, teach with, and research.[8]

He explained that traditional methods of observing objects, noticing patterns then making interpretations are no longer viable. Traditional interfaces for presenting image collections display a small subset of images at a time on a two dimensional grid in a single row or as slide shows (interfaces of the Library of Congress to their digital collections). Each have value, but one can only observe a limited number of items at a time. Patterns and "shapes" may be missed without this whole approach. This new interface allows viewing the contents of an entire collection—all at once.

Relying on these earlier experiences with more contemporary media, we asked Lev to apply the technology to the digitized arrowhead images with our designated classifications for sorting. **[fig. 21]** Starting with a basic Excel Spreadsheet, the digital image processing software was then used to measure a number of visual attributes of

each arrowhead photograph, including over a dozen of separate measurements of its shape and contour. The software outputs a spreadsheet containing these measurements which is then joined with the existing metadata. **[fig. 22]**

As Lev further explained, the project utilized ImageJ, a popular digital image processing free application commonly used in the sciences. Software Studies Initiative adopted ImageJ as a basic tool to measure various visual properties of images and video, and created a number of extensions for processing large image sets. In our project, we first automatically mask each arrow against background, and then use ImageJ build-in command to generate over a dozen separate measurements of the shape's outline. **[figs. 23-26]** (These kinds of measurements were never done by archeologists previously.)

[fig. 27] Once the measurement of each arrowhead in every photo is complete, we use ImagePlot software developed by Software Studies to create high resolution visualizations where the arrows are positioned according to various combinations of these measurements, as well as the categories normally used by archeologists to describe these artifacts. ImagePlot runs on regular desktops and computers. We also use another software designed by the lab which allows generation of such visualizations interactively on HIPerSpace, one of the largest visualization systems in the world which combines 70 30-inch monitors to offer 36,000 x 8,000 resolution. The goals are to explore similarities and differences between 500 arrowheads in a more precise way than allowed by language-based categories, and to identify new meaningful dimensions for their comparison based on numerical measurements of their shapes.

The HIPerSpace tiled supervisualization system is incorporated to interactively organize the photographs of the arrowheads according to dozens of different

combinations of their attributes.

While interactively displaying the data for research, as an artist, creative opportunity showing the artifacts' aesthetic possibilities was inevitable. Inspired by Lev, I could see that various disciplines, including art, could now "observe a physical scene directly with your eyes, [and] you can look anywhere in any order."[9]

Our presentation showcases new patterns and insights enabled by these innovative research methodologies. From an artist's perspective, the initial image study presented here in **[fig. 28]** is inspired by the arrowheads, maps, diagrams and aerial views of excavations of Wadi Faynan. Historical/cultural significance, beauty and craft of these arrowheads, singularly and in visual composition come together to create and enable new work out of old.

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