Hand Drawing Versus Computer Vision in Archaeological Recording

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As 3D scanning and photogrammetry are supplanting traditional illustration techniques with increasing speed, archaeologists and architectural historians have sounded alarms about what stands to be lost if hand drawing is altogether eliminated from fieldwork. This paper argues that the most direct threat is to a particular form of archaeological illustration which does not necessarily share the advantages attributed to other kinds of drawing. Recording by means of "technical drawing" communicates a collectively agreed interpretation of the ancient record, and its primary benefit is not stimulating creative thought but rather enhancing human observation. A review of two cases comparing the illustration of ancient Greek architecture through analogue and digital methods indicates that, in practice, both approaches draw attention away from the ancient subject and focus it on distracting protocols for the great majority of the time spent in the field. Even so, technical drawing requires a protracted, in-person scrutiny of the subject, whereas 3D technologies pose a genuine risk of altogether eliminating meaningful human interpretation from the recording process. The greater efficiencies of digital techniques suggest a path forward, as time once allocated to tedious stages of technical drawing might be applied toward more thoughtful interpretive tasks. However, such measures must be deliberately integrated into a digital research program through planning around the very different cadences of the digital process.

Key words:
archaeological illustration, building archaeology, field practices, interpretation, pedagogy, photogrammetry, technical drawing, 3D recording.

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1. INTRODUCTION

Recently archaeologists and historians of ancient architecture have come to rely on a range of digital technologies in their daily routines at the site. In particular, 3D recording and reconstructive techniques have prompted revolutionary changes in the way many archaeologists and architectural historians interact with material, potentially a "paradigm shift" in fieldwork [Roosevelt et al. 2015]. The situation has come about rapidly following technological breakthroughs of the 2000s: the first in

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the availability of powerful yet inexpensive computing systems, the second in high-quality digital camera sensors, and the third in the field of computer vision – where pattern-matching algorithms grafted onto older close-range photogrammetric software have enabled a largely automated reconstruction of dense 3D surface models from series of photographs [Lowe 2004; Luhmann 2010; Remondino 2014]. These passive image-based modeling techniques have propelled the rise of 3D archaeological recording at multiple scales, expanding to whole sites and landscapes via drone photography [Campana 2017; Nex and Remondino 2014; Waagen 2019], and individual artifacts through parallel developments in active laser or structured-light 3D-scanning systems [Guidi 2014]. The minimal equipment required for and flexibility of photogrammetry has allowed many more researchers to record, study, and illustrate antiquity in 3D through an entirely digital process than was conceivable just a decade ago.

In this article, I will examine some of the methods which are concurrently being supplanted by the turn to digital technologies. My focus is the archaeological branch of scientific illustration which many fear is facing obsolescence, or handmade "technical drawing." As a recording method reliant on fastidious measurement, technical drawing may be differentiated from other sorts of creative freehand compositions – sketches, watercolors, and the like. Archaeologists and architectural historians have recently raised alarms about what might be lost during the rapid shift to new methodologies which are undermining a well-established and valorized craft, profoundly altering routine practice at the site, and inevitably interrupting our engagement with the ancient material. What aspects of research activity and intellectual engagement are transformed by the adoption of 3D technologies, and what do we stand to lose in a future without recording by hand?

2. RECENT DISCUSSIONS OF 3D RECORDING VIS-À-VIS TECHNICAL DRAWING

The advantages of 3D recording were enthusiastically extolled during the first years after they were deployed in the archaeological field. The advantages include dramatic increases – when compared to traditional recording methods – in the efficiency, detail, and accuracy of data collection; the possibility for disseminating 3D media online; and the rich variety of analytical or experiential modes for visualizing point clouds and triangulated meshes [e.g., Beale and Reilly 2017; Buell et al. 2020; Campana 2017; De Reu et al. 2013; Douglass et al. 2015; Limp 2016; Mara and Krömker 2017; Murray et al. 2017; Opitz and Limp 2015; Roosevelt et al. 2015; Sapirstein 2016; Sapirstein and Murray 2017; Taylor et al. 2018]. Many such works have implied that, because the digital methodologies demonstrably improve some aspects of research, they would inevitably replace established techniques [see Morgan and Wright 2018: 144–45]. As put by the Kaymakçı Archaeological Project, where photogrammetry rather than paper drawing was used for primary recording, "[w]ith these traditional – even 'signature' – tools of the archaeologist now rendered unnecessary, if not obsolete ..., a shift to a digital paradigm is unmistakable" [Roosevelt et al. 2015: 339].

Other voices have identified various ways in which virtual models are problematic. Criticisms include the misleading impression of "authenticity" created by such representations [Garstki 2016; Jensen 2018; Jones et al. 2017; Moser 2012: 297–99; Rabinowitz 2019: 100–01], or the exclusive focus on the visual at the expense of other senses [Eve 2018]. Conscientious source-side criticism is essential in order to mitigate implicit biases throughout the process of digitizing and transforming geospatial data [Richards-Rissetto and Landau 2019]. Some have even questioned whether disembodied interaction with digital models can lead independently to genuine insight and intellectual discovery [Edgeworth 2014; Garstki 2016; Howland 2018]. The standard mode of 3D display in a dynamic, single-viewpoint rendering is another source of dissatisfaction [Carlson 2014], and 3D scans are often heavily post-processed in ways that conceal the underlying data before publication. For example, photogrammetric models of trenches or buildings are routinely traced with 2D vectors to prepare final illustrations where the 3D source data may not appear at all [e.g., Campana 2017: 286; Kimball 2016]. Similarly, several teams of computer scientists have developed software techniques to convert 3D scans of archaeological objects into black-and-white line drawings in a style mimicking that of a traditional illustration [e.g., Gilboa et al. 2013; Wilczek et al. 2018].

Others value aspects of traditional methods which are plainly absent from 3D analogues. Digital practitioners themselves often acknowledge that the two modes of representation are so fundamentally dissimilar that one method of recording is incapable of replacing the other [Campana 2017; De Reu et al. 2013; De Vos 2017; Garstki 2016; Huggett 2017; Limp 2017; Murray et al. 2017; Molloy and Milić 2018]. Huggett describes how the turn to digital apparatuses, or “cognitive artefacts,” in archaeology transfers a considerable degree of agency to machines which modify, reduce, and even wholly replace branches of human cognition [Huggett 2017]. James has raised issues with the turn away from handmade visuals to simplified digital tools, a process of “de-skilling” accompanied by the general degradation of visual literacy [James 2015]. Caraher, in his advocacy of “slow archaeology” as an antidote to an institutional pressure toward efficiency, highlights traditional pencil-on-paper drawing as a mechanism for spurring introspective and creative thinking [Caraher 2016]. Most germane to the current discussion, however, is Morgan and Wright’s [2018] recent review of the changes in archaeological illustration. They emphasize important differences between the process of tracing lines over a photographic view of a site projected on a tablet screen, and that of generating a drawing by hand on a blank (or simply gridded) sheet of paper. Each of these studies recognizes the special place occupied in the archaeologist’s toolkit by hand drawing – a complex process coordinating eye, mind, and hand which cannot be offloaded unproblematically to mechanical recording systems [also see De Vos 2017; Eve 2018; Huggett 2015: 89–90; McFadyen 2011; Schuller 2002; Wickstead 2013].

If 3D recording is displacing technical drawing in archaeological fieldwork, then we should compare the impacts of the two approaches in a systematic way. This paper addresses two principal topics which have been underexamined in the recent discourse. First, it investigates the objectives of traditional recording methods and their relationship with critical thinking. Second, it compares technical drawing and photogrammetric modeling in two scenarios involving architectural illustration, appraising the cognitive demands elicited by each stage of the respective processes. In actual practice, 3D methods greatly outperform hand drawing for objective recording, yet they also introduce very different cadences into the fieldwork and significantly disrupt the interpretive process. The conclusions recommend how potential losses in thoughtful analysis incurred by the shift to 3D recording might be mitigated through adjustments to current pedagogical and fieldwork practices.

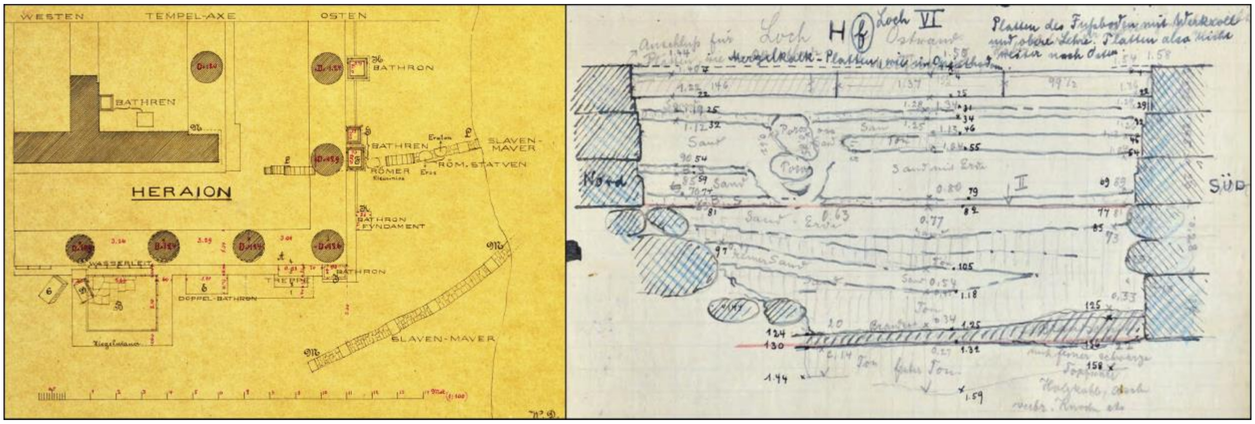

Figure 1. Renderings by Wilhelm Dörpfeld during excavations in the Temple of Hera at Olympia. Plan: southeast corner with late antique walls, since removed, in 1877. Section: stratigraphy inside the cella, 1907 [Courtesy Staatliche Museen zu Berlin – Antikensammlung, Archive].

3. RECORDING AND INTERPRETATION IN ARCHAEOLOGICAL VISUALIZATION

The origins of archaeological and architectural technical drawing may be traced back to the Renaissance. Architects and designers such as Leon Battista Alberti established the orthographic view in the planning and study of buildings [Pilsitz 2017: 73–74; Schuller 2002: 7], and by the latter 19th and early 20th centuries – when excavation techniques were being standardized by figures such as General Pitt-Rivers, Wilhelm Dörpfeld, or Mortimer Wheeler – professional architects and surveyors could rely on tools and graphical conventions already established in their respective fields in order to meet the needs of archaeological recording (Fig. 1) [Harris 1989: 22–28; Morgan and Wright 2018: 137–39; Piggott 1965; Schuller 2002: 7–8]. Already by the 18th century, protocols for artifact illustration were being adapted from fields in the natural sciences that produced representations of specimens [Adkins and Adkins 1989; Blunt and Stearn 1994; Moser 2012; 2014]. The aforementioned conflict between objectivity and subjectivity observed in 3D models [e.g., Garstki 2016; Jensen 2018] had already been recognized in "scientific" archaeological drawings. Illustrators and collaborating archaeologists sought to present an objectivized portrayal of a reality which they had encountered at the site or museum, yet they were obliged to do so through an obviously artificial and interpretative stylization [Ambrosio 2014; Edgeworth 2003: 257; Moser 2012: 297–99; 2014; Piggott 1965: 166]. These dual aims must be disentangled before commenting on which aspects of archaeological illustration are most impacted by the arrival of 3D technologies.

Recording, on the one hand, seeks objectivity through measurement, most importantly through accurately scaled projections of a three-dimensional space onto a two-dimensional sheet of paper [Adkins and Adkins 1989; Hope-Taylor 1966]. The drawing preserves what could be perceived – a trench in the midst of excavation, or a faunal specimen on the illustration table – even after its subject becomes inaccessible [Edgeworth 2003: 242; Harris 1989: 69]. In this capacity, technical drawings are purely empirical, eyewitness accounts from an episode of field research [Amelung 2019]. The orthographic view is alien to human perception [Edgeworth 2003: 246–57], but it encodes

Cartesian space in a fashion that is able to yield new measurements in the future – something which is otherwise lost in a point-to-point dimension taken on site or a photograph.

Interpretation, on the other hand, is embedded throughout the entire endeavor. As Hope-Taylor stated, an archaeological drawing "should be *selective*, a considered intellectual appraisal ... of certain facts and observations, but it is bound to eliminate others" [1966: 108 (emphasis added)]. An accompanying photograph might assuage a reader's doubts over whether that selection of elements is valid, but the important point is that the drawn image has been pared down to convey as clearly as possible what mattered to the researchers at some moment during their work. Both recording and interpretation have communicative aims, but they are realized on the same page by very different means. One is an extended exercise in spatial projections, the other in archaeological taxonomy encoded by abstracted symbols (Fig. 1).

Although every drawing should be artfully designed in order to fulfill its communicative goals, the reliance on measurement and abstract conventions lends the process a veneer of objectivity [Ambrosio 2014; Bateman 2006; McFadyen 2011; Piggott 1965]. The protocols severely restrict creativity on the part of the illustrator to formal matters such as the selection of line weights, patterns, and where to position the selected elements on the page [Adkins and Adkins 1989; Amelung 2019: 335–40]. The result is expected to represent some well-formed interpretive consensus among all those involved in its production rather than of an individual, and technical drawings are frequently the assembled input of several illustrators [Bateman 2006; Carlson 2014; McFadyen 2011; Morgan and Wright 2018]. By following the protocols faithfully, an illustration might conceal interpretive disagreements accrued along the way beneath a style which announces to its viewers a neutral, unflinching authority: "This is what we witnessed. This is what mattered."

With this understanding of technical drawing in mind, it is important to address the panoply of archaeological imagery, from impromptu sketches and diagrams to imaginative reconstructions of past life, which do not share in the positivistic goal of spatially accurate recording (Fig. 2). Indeed, non-technical drawings have been the subject of the preponderance of historiographic scholarship on the visual materials created by and for archaeologists [e.g., Moser 1998; 2001; 2012; Smiles and Moser 2008; Wickstead 2013]. Whether created for investigation, imagination, communication, aesthetic pleasure, or any of the other myriad reasons that people draw, such images are very differently motivated than is technical drawing.

The tendency to treat all kinds of drawing as members of a single species is apparent in many of the concerns recently expressed over the rise of 3D recording. On the one hand, technical drawing is credited with a degree of creativity due to its filiation with other kinds of image-making, even though it purposefully rejects such individuality. On the other, non-technical forms of image-making would not appear to be threatened – at least in any straightforward way – by 3D recording. Archaeologists rely heavily on perception and visual reasoning [e.g., Gibbon 1990; Shelly 1996], but the interpretive or diagrammatic images involved in these thought processes typically do not rely on accurate measurement, and thus are largely unrelated to 3D products.

This overly broad definition of drawing has led to the construction of problematic analogies between archaeological technical drawing and visual practice in other fields. For example, the comparison to practicing architects [e.g., Morgan and Wright 2018: 146–47] overlooks that field's early adoption of "Computer-Aided-Design" (CAD) software for the generation of blueprints. Unscaled freehand sketches are still fostered as means to imagine and experiment with new forms [Edwards 2008: 16–23, 214–25; Pilsitz 2017; Scheer 2014; Zambelli 2013], but such architect's sketches do not to pretend to serve as a measurable record of an objectivized reality. Other comparisons to drawing in commercial graphic design, or the "line" as a metaphor in social anthropology [Ingold 2007; 2011: 220–26], are similarly distant from the issues raised by archaeological technical drawing in its particular objectives of recording and depersonalized interpretation.

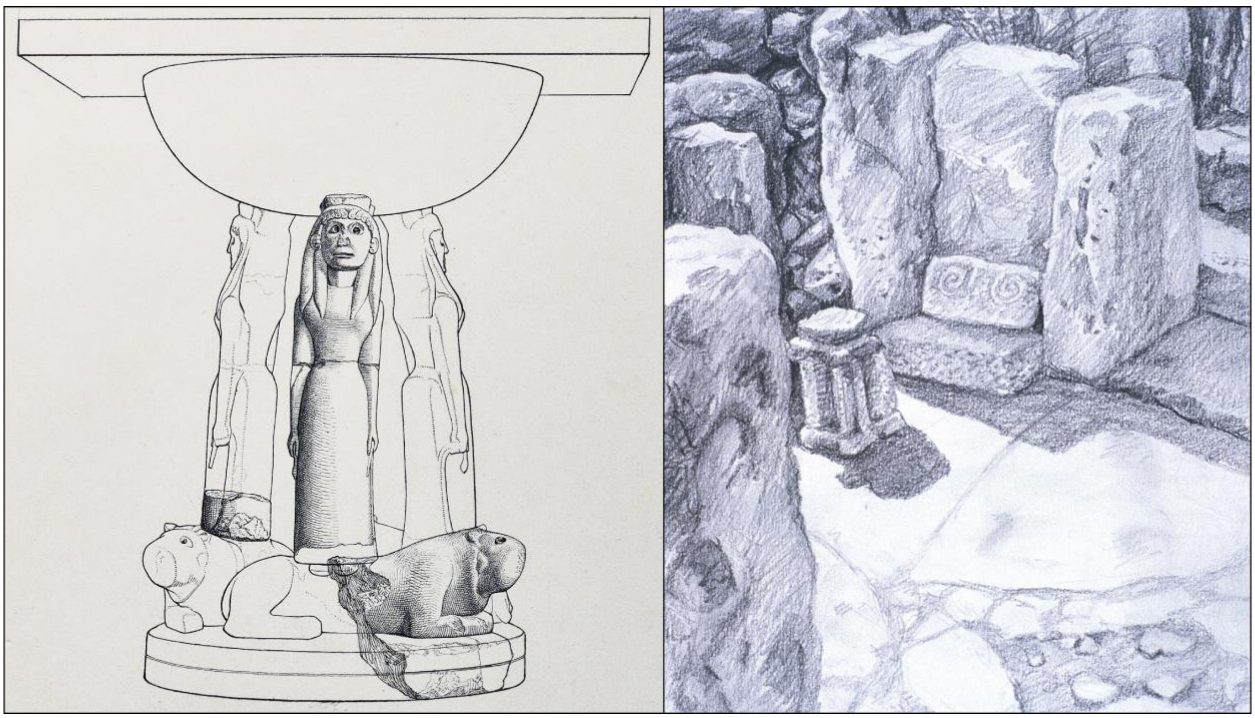

Figure 2. Left: restoration of a basin from Olympia [after Treu 1897: fig. 24]; right: sketch of the megalithic architecture at Ħaġar Qim, Malta [author].

More germane analogies might be sought in the sorts of technical drawing fostered by fields which share the archaeological desire for empiricism and clarity. Botanical illustration, for example, is still practiced today both by academic researchers [Ben-Ari 1999; Blunt and Stearn 1994; Moser 2012] and a vibrant community of freelance and hobbyist illustrators [e.g., Humphrey 2018]. Photography and other mechanical forms of recording are more dominant in botany than in archaeology or architectural history [e.g., Simpson and Barnes 2008], but hand-drawn depictions of plant morphology are not uncommon in recent scientific literature (Fig. 3). Archaeological and botanical technical drawings share many attributes in common. Both are conceptual models, an interpreted view of reality that is preoccupied with taxonomy [Moser 2014]. The two are highly conventional, preferring the precision of grayscale or black-and-white lines and multiple, flattened views arranged side-by-side on the page in order to convey the diagnostic features of the subject as clearly as possible [Ben-Ari 1999; Carlson 2014]. Botanical as well as other branches of biological illustration also depict change over time – such as the life cycle of an organism, or a blossom that opens only at night – not unlike the sequence of activities captured in stratigraphic sections and state plans of an excavation. Furthermore, the process of creating such images is credited "as the impetus for scientific discovery, rather than simply illustrating the discoveries made by botanists" [Ben-Ari 1999: 607].

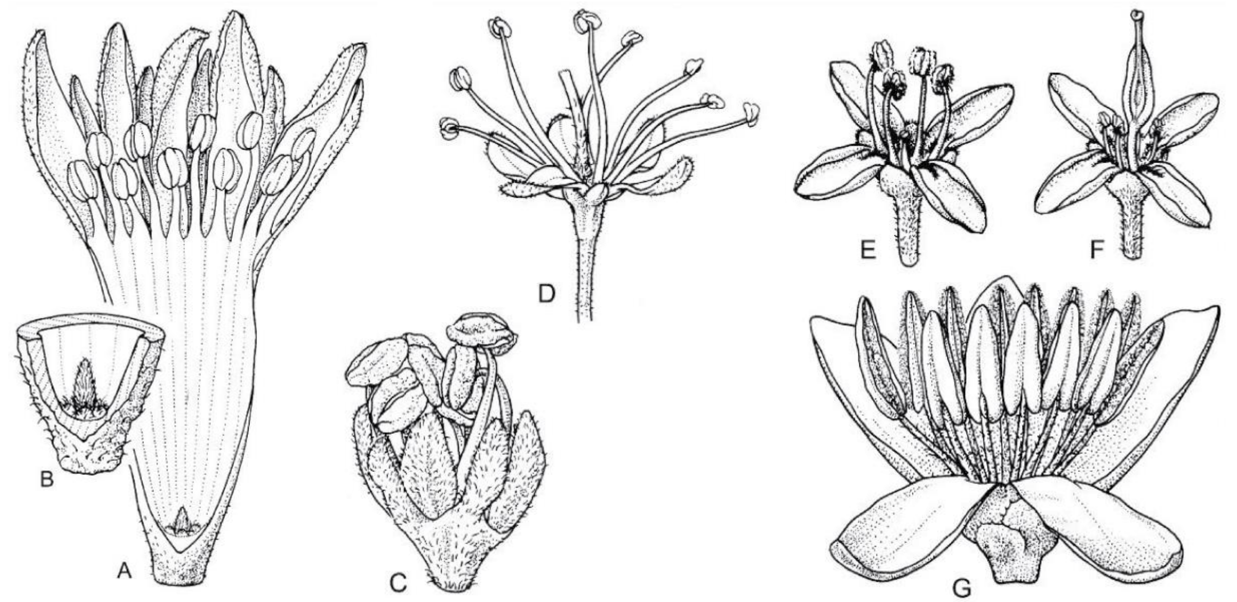

Figure 3. Botanical illustrations by Catherine Wardrop [after Herendeen et al. 2003: fig. 2].

Archaeologists too are liable to describe the "deeper understanding" of a subject gained by drawing it in a systematic fashion [e.g., Olsson 2016: 416]. On one level is its pedagogical value, where drawing techniques learned through practice contribute to a student's professionalization and ability to evaluate other archaeological illustrations [Bateman 2006; Goodwin 1994; James 2015; Morgan and Wright 2018: 145–46]. On another, technical drawing requires an unusually close scrutiny of the subject, and the creator is liable to observe many new details, some of which may prompt questions, insights, and reinterpretations [Hope-Taylor 1966: 108; James 2015: 1200; McFadyen 2011; Murray et al. 2017: 7–9; Olsson 2016: 416]. Indeed, the ways in which "inattentional blindness" caused by familiarity can be mitigated through illustration have been explored in many related contexts, from botanical hand drawings to digital simulations in paleontology [Amelung 2019: 345–51; Ben-Ari 1999: 608; Ingold 2011: 223–25; Limp 2016]. Another important parallel is found in the Germanic tradition of *Bauforschung* (an archaeology of ancient and historical buildings) and its allied field of monument preservation, where visual recording is recognized as essential to understanding [De Vos 2017; Letellier 2007; Dallas 2007; Schuller 2002: 9–15].

The kind of understanding gained from a technical drawing is directly attributable to how its creation enhances observation. The process requires a highly analytical view of the subject, which the illustrator breaks down into a set of features plotted sequentially, usually beginning with the overall layout and moving down to increasingly fine details. Filling the page forces her to pay attention to features which might have been deemed insignificant at first. Most importantly, however, the illustrator must conduct a series of low-level interpretations while deciding how to portray each element in the conventional scheme. Any new information gleaned by the illustrator which is at variance with the consensus interpretation invites a reappraisal of the whole subject by the team. In this sense, technical drawing may be classified as a heuristic tool which serves the primary empirical objective of recording, but with a secondary potential to enhance perception and the quality of interpretation [Amelung 2019: 337].

How then does this species of hand drawing compare with its digital analogues? On the one hand, we may recall the critical distinction made by Morgan and Wright [2018: 137, 143–45] between *looking* at a subject when manually drawing it on a blank page, and *tracing* it on a handheld tablet by adding vectorized silhouettes over an orthographically projected photograph. Tablets, however, do not inherently prohibit creative illustration through direct observation, and in fact support stylus input and graphical tools which simulate many different traditional media. On the other hand, 3D recording does not offer such flexibility. Active scanning systems or passive photogrammetric recording generate data that are purely empirical and thus entirely omit the latter, communicative goals of drawing. Indeed, in a survey of students and experts asked to compare the two media, a common criticism of the 3D models was their lack of the kind of meaningful interpretation inherent to hand-drawn plans [Rabinowitz 2019]. Neither do 3D scans promote observation at the site; to the contrary, machine vision is a "cognitive artefact" which was intentionally designed to supplant human perception. Thus the heuristic value of a technical drawing, even in the fairly restricted formulation demonstrated above, would surely be undermined in a scenario where hand drawing was entirely replaced by scanning. On these grounds, we might immediately assume that 3D recording is irreparably deficient.

The next section addresses these issues through two cases from my experience as an architectural illustrator and researcher. The first, about recording building foundations through hand-made technical illustrations, is contrasted with the second, where photogrammetry was applied to a partially standing monument. The descriptions consider the impact on the research, and in particular human observation, of the analogue and the digital approaches. A final discussion then assesses how differences predicted on purely theoretical grounds impact archaeological practice.

4. TECHNICAL DRAWING AND 3D RECORDING IN PRACTICE

4.1 Architectural recording at Kalamianos, eastern Argolid

"The Saronic Harbors Archaeological Research Project" (SHARP) conducted fieldwork from 2007–2011 near the modern coastal town of Korphos in the eastern Argolid [Pullen and Sapirstein 2020; Tartaron et al. 2011]. A principal aim was to record the extensive architectural remains of dozens of collapsed buildings abandoned after the Late Helladic III period at Kalamianos, a previously unknown Mycenaean harbor settlement. Architectural recording preceded the analysis of the building plans, construction techniques, and organization of the newly discovered urban site. As a survey project, SHARP conducted no excavations, but the architecture was exposed above the modern ground level throughout the site, and many complexes at Kalamianos were preserved sufficiently for stone-by-stone architectural drawing. As director of architectural recording, I drew alongside and supervised up to five assistants working together in the same complexes (Fig. 4).

Figure 4. Architectural investigation at Kalamianos. Left: initial clearance; right: drawing in reference to measuring tapes [SHARP photographic archives].

This case has been selected since the recording team not only logged thousands of hours over its two major seasons (2009–2010) of investigation, but also because we kept track of the hours invested in each stage of the drawing process. As a result, these stages can be compared to the next case study of photogrammetric recording not only for impacts on archaeological reasoning, but also in terms of the time invested in labor.

The ensuing discussion assumes a familiarity with the basic methods of field illustration, which have been described elsewhere [Morgan and Wright 2018: 139–42]. The protocols at SHARP were similar to those used for drawing trench plans, with the exception that only a single surface layer was being examined. The methods otherwise reflect how illustrators of hand-drawn plans and elevations nowadays rely extensively on digital tools. The drawings were based on a dense network of "Ground Control Points" (GCPs) previously marked in ink on the site and measured with "Total Station" (TS) or "differential GPS" (dGPS) equipment. Except for the drawing in the field, the rest of the work occurred entirely within GIS and drafting software.

Table 1 breaks down the drawing procedure into stages for one medium-sized building complex and for all buildings over the two principal seasons of technical drawing, reporting the approximate time invested, the area documented per hour, and where attention was focused at each stage. SHARP invested considerable labor in clearing vegetation at first to explore and then to clarify the built features (Table 1: Stage 1). Although the objective was architectural discovery, the physically demanding and often unpleasant work of removing tough, thorny shrubbery from the building sites was a significant distraction from studying the ancient remains. Distinguishing built features from debris was also exceedingly difficult due to the incomplete view afforded while one was in the midst of cleaning (Fig. 4: left).

Table 1. Stages and engagement during the technical drawing process of SHARP

Stage	**Subject**			**Center of attention**	
	Building 4-VI (125 m^2 drawn)	All buildings (1735 m^2 drawn)	Rate	Ancient remains	Other foci
1) Clearing, exploration during and after discovery	70 hr (6)*	900 hr (5–10)	2 m^2 / hr	low	Vegetation
2) TS/dGPS survey for wall cataloguing	8 hr (3: TS)	100 hr (2–3)	20 m^2 / hr	moderate	GCPs
3) TS/dGPS survey for detailed plans	12 hr (3: TS)	180 hr (2–3)	10 m^2 / hr	low	GCPs
4a) Stone-by-stone drawing: plotting lines	72 hr (2)	1,450 hr (11)	1.1 m^2 / hr	low	Plotting
4b) Annotating drawings	8 hr (2)	150 hr (11)		high	–
5) Compositing fieldsheets and aerial imagery (GIS)	3 hr (1)	40 hr (1–2)	50 m^2 / hr	none	Matching features
6) Tracing digitized plans in Adobe Illustrator (c)	40 hr (2)	500 hr (2)	3.5 m^2 / hr	none	Tracing
7) Sorting layers, applying conventions to plans	7 hr (1)	80 hr (1)	20 m^2 / hr	moderate	Classifying
Total	220 hr	3,400 hr	0.5 m^2 / hr	~600 hr	~2,800 hr

* The number of staff members is given in parentheses after their combined hours

Some interpretive work occurred during subsequent measuring and cataloguing of built features (Table 1: Stage 2), but this step was conducted by a separate SHARP team and resulted in only a preliminary understanding of a structure. The immediate goal of the documentation team was to map and describe features across the site regardless of whether they might eventually be the subject of more intensive analysis and technical drawing.[1] Both the overview and detailed surveying (2–3) were directly engaged with the remains insofar as teams were identifying which parts of a site would be drawn. However, attention was split between marking suitable GCPs at stable positions, and the TS or dGPS operators were preoccupied with their equipment.

The greatest quantity of skilled labor went into producing field drawings (Table 1: Stage 4a). Starting from a sheet printed with GCPs at 1:50 scale and clipped to a drawing board, each illustrator began by fixing measuring tapes on the ground along the wall segment or other area of interest, and plotting these as reference grids on the page (Fig. 4: right; 5a).[2] The next challenge was to plot the silhouette

[1] The time spent measuring wall positions is tallied in the table, since only that part of the documentation contributed directly to final plan drawings.
[2] Drawing squares were impractical since they were difficult to align with the GCPs and the irregular surface, but the SHARP system worked analogously.

of every block belonging to or in contact with features. Since the eye is poor at judging absolute distance, illustrators relied instead on finding patterns in the stones that could be accurately transformed to the page through visual interpolation, and then filling in the gaps progressively until every stone had been included. Each illustrator developed personal techniques for this interpolation and a recognizable drawing style, but to an outside viewer the procedures and results would appear much the same.

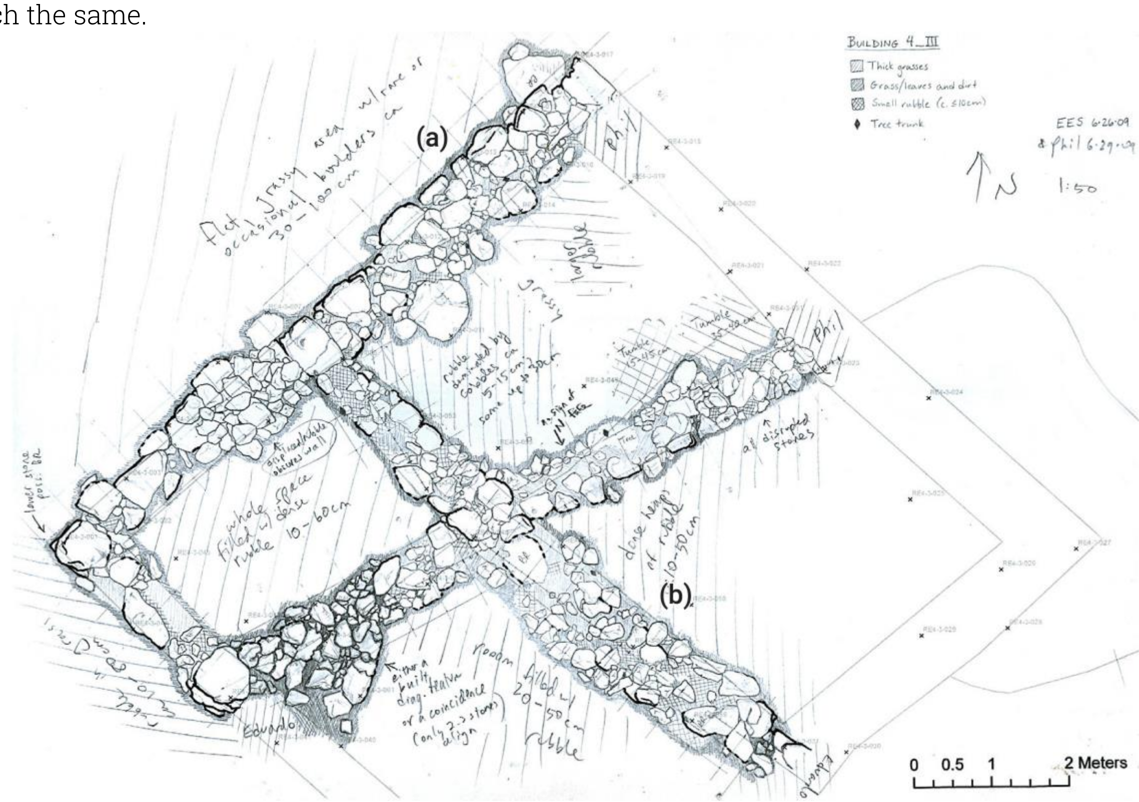

Figure 5. Field sheet for Building 4-III after plotting and annotation by two illustrators. a) traces of the reference grid; b) extraneous stones drawn due to uncertainty [SHARP archives].

Illustrators avoided taking direct measurements as far as possible, since to do so was disorienting. After setting aside the pencil and taking out the plumb bob and meterstick, one easily lost track of the relationship between the drawing and the field of stones below. Instead, illustrators learned to set up their reference tapes between the GCPs so that new lines could be estimated by *orientation* relative to the grid and *proportion* relative to the GCPs and other plotted features, both of which can be gauged by eye. Measurement could then be deferred until the phase of checking the drawing, which occurred immediately after an area had been fully plotted. A general tolerance of ±5 cm error was deemed acceptable at Kalamianos due to the scale and irregularity of the masonry, but more care was taken at the most significant parts of the drawing: for example, the width of a wall or the extents of a room.

Despite the considerable amount of time spent scrutinizing the Mycenaean walls at Kalamianos, the illustrator was usually disengaged from the kinds of interpretive questions that had led SHARP to study the site in the first place. In order to create an orthographic projection, an illustrator needed to position her eyes directly above the feature of interest, a point of view which is seldom conducive to recognizing larger patterns in the area (Fig. 4: right). Furthermore, the illustrators' habit of following arbitrary lines formed by the stones between the GCPs and tapes would often lead them to stray away from an actual built feature into fields of rubble, and many extraneous elements had to be eliminated retrospectively in the final drawings (Figs. 5b, 6). Since attention was almost entirely focused on the shape of no more than a few objects at a time, discoveries were rare during plotting.

Figure 6. Plan of Building 4-XIX after (a) compositing multiple fieldsheets and (b) final drafting [author].

Technical drawing does, of course, entail interpretation, and at Kalamianos the most fruitful observations occurred between sessions of plotting (Table 1: Stage 4b). During breaks, illustrators would sometimes consult one another informally about what they had been drawing, and as supervisor I would formally review every sheet with the illustrator before we applied interpretive conventions together. While much of the architecture could be perceived without difficulty, some areas were damaged and incomplete. Only through the review of the plotted sheets did we begin to recognize walls and other built features emerging from what had at first glance resembled a "sea" of rubble (Fig. 4). A plotted wall, for example, could at this stage be viewed at a stone-by-stone level of detail, together with faces, discontinuities, junctions, and other secondary attributes (Figs. 5, 6a). Both visual and haptic cues were essential to this process of identifying and labelling attributes. Classifying a stone as *in situ* versus rubble often meant touching or peering underneath it to establish whether it was anchored on lower courses of aligned masonry. Uncertainties were also encoded in the conventions, and textual annotations were added at anomalies and areas lacking built features.

Although the latter annotative stage felt the most satisfying after a long session of plotting, it represented a minor fraction of the roughly 1,600 collective hours of drawing in the field (Table 1: Stages 4a–b). The majority of that time was invested in setting up measuring grids and transferring features to 2D silhouettes, rather than considering the nature of those features. Still, an illustrator builds up a repository of observational experiences while plotting (4a), and the subsequent process of marking conventions (4b) was guided by these recent memories of the area. Thus the temporal ratio of roughly 10:1 indicated in Table 1 (4a:4b) somewhat overstates the dominance of rote recording over more thoughtful observation, which might have occurred during as much as 15–20% of the whole process.

The final stages entailed the digitization and drafting of vectorized plans for publication (Table 1: Stages 5–7). Intense concentration was required for some computer tasks – such as pinning GCPs of the scanned drawing sheets to their projected locations in the GIS, or manually tracing vectors over indistinct penciled lines – but it was focused on the software interface, not the ancient remains, which were far from the computer room. Transferring the conventions from the field sheets to the vectorized drawings (7), however, often led to new insights, although this was primarily an artifact of the protocols of collective recording. Since the complexes had been segmented into subareas and features, each illustrator drew just fragments of a building (Fig. 5). Only after digitally compositing and rendering the team's field sheets was it possible to review the whole structure. New questions and hypotheses developed at this stage would be tested by revisiting the site, this time aided by a printed plan (Fig. 6a). On occasion the visits led to minor adjustments to the classification of particular stones, but the most consequential changes were in thinking about circulation patterns, modifications over the life of the buildings, and other higher-order problems that could be investigated only after establishing the facts on the ground (Fig. 6b).

4.2 Photogrammetry and the temple of Hera at Olympia, Elis

From 2013–2015, the "Digital Architecture Project" (DAP) at Olympia recorded *in situ* remains and nearby blockfields from the temple of Hera, an early sixth-century BC structure whose total surface area approaches the total drawn by the illustration teams at Kalamianos (Tables 1–2). Unlike SHARP, the Olympia project was "born digital." The recording was based on photogrammetric survey protocols – detailed elsewhere [Sapirstein 2016; Sapirstein and Murray 2017] – designed not to maximize speed but rather resolution and repeatability, and capable of being carried out by a single researcher with intermittent assistance. Although I did not commission paper technical drawings at the Heraion, it is nonetheless possible to estimate how long such illustrations would take to produce based on comparative data from Kalamianos and elsewhere. Although the efficiency of plotting would be slightly improved by the fact that the archaic masonry at Olympia is more regular than at Mycenaean Kalamianos, the most important difference arises from the error tolerance, which for the Heraion needed to be within ±1 cm generally and ±1 mm at key features. The increased requirements for accuracy, drawing scale (1:10 rather than 1:50), and detail would without doubt increase the overall time invested per unit area relative to that at SHARP, and the projected times for technical drawing at Olympia in Table 2 represent what could be accomplished only through a highly efficient, minimal approach.

Table 2. Timing and cognitive activity during recording stages of the DAP-Olympia

Stage	**Paper drawing** *hypothetical*	**Photogrammetry (PG)** *actual*	**Center of attention**	
	1400 m² / (5)*	1800 m² / (5)**	Ancient remains	Other foci
1) Cleaning site	~40 hr (5)	150 hr (5)	moderate	Debris
2) Setup TS grid	~10 hr (2)	30 hr (2)	low	GCPs
3) Fine TS / PG survey	~250 hr (2)	25 hr (2)	low	GCPs
Paper 4): Plot / annotate	~2,000 hr / 200 (5)	–	moderate	Plotting
PG 4): photograph	–	15 hr (1)	none	Camera
5–6) Prepare digital results	~700 (2)	80 hr (1)	none	Software
7) Applying conventions	100 hr (1)	100 hr (1)	moderate	Classifying
Total	~3,300 hr	400 hr	Paper: ~500 PG: ~100	~2,800 ~300

* The number of staff members is given in parentheses after their combined hours

** Because it captures the adjacent ground surface and other non-architectural elements, the photogrammetric record has a larger surface area than an equivalent handmade technical drawing.

Photogrammetric recording encourages an exceptionally thorough cleaning. Vegetation, soil, and other elements which a human illustrator can disregard are faithfully recorded in the 3D models just the same as ancient surfaces [Roosevelt et al. 2015; Sapirstein and Murray 2017]. Beyond the undesirable aesthetics, the presence of any intrusive elements will effectively delete the obscured ancient features from the 3D record. Whereas a human illustrator can judge which obstacles to remove during the plotting, the photogrammetrist must identify and remove any potential occlusions prior to photography.

As a result, I devoted considerable efforts to cleaning the Hera temple, probably several times as much labor as would be needed before technical drawing (Table 2: Stage 1). Although I was assisted by local workers, I personally conducted the final cleaning of every architectural surface in order to promote observation and discovery. Unlike in manual plotting, one is not obliged to stand back from the remains and adopt an orthogonal viewpoint to every feature being plotted; instead one is in direct contact with the remains and looking from many vantage points for intrusive elements that might end up in the photographs. Still, the process did not demand as systematic an inspection of the site as did the annotation of drawings. Cleaning naturally draws attention to places that attract plants or debris – corners, crevices, and the like – and there was no convenient way to record observations and interpretations besides jotting notes or sketching on the pages of a fieldbook. Still, my extended presence among the remains while preparing for photography represented an unexpected stimulus for creative thinking about the site architecture.

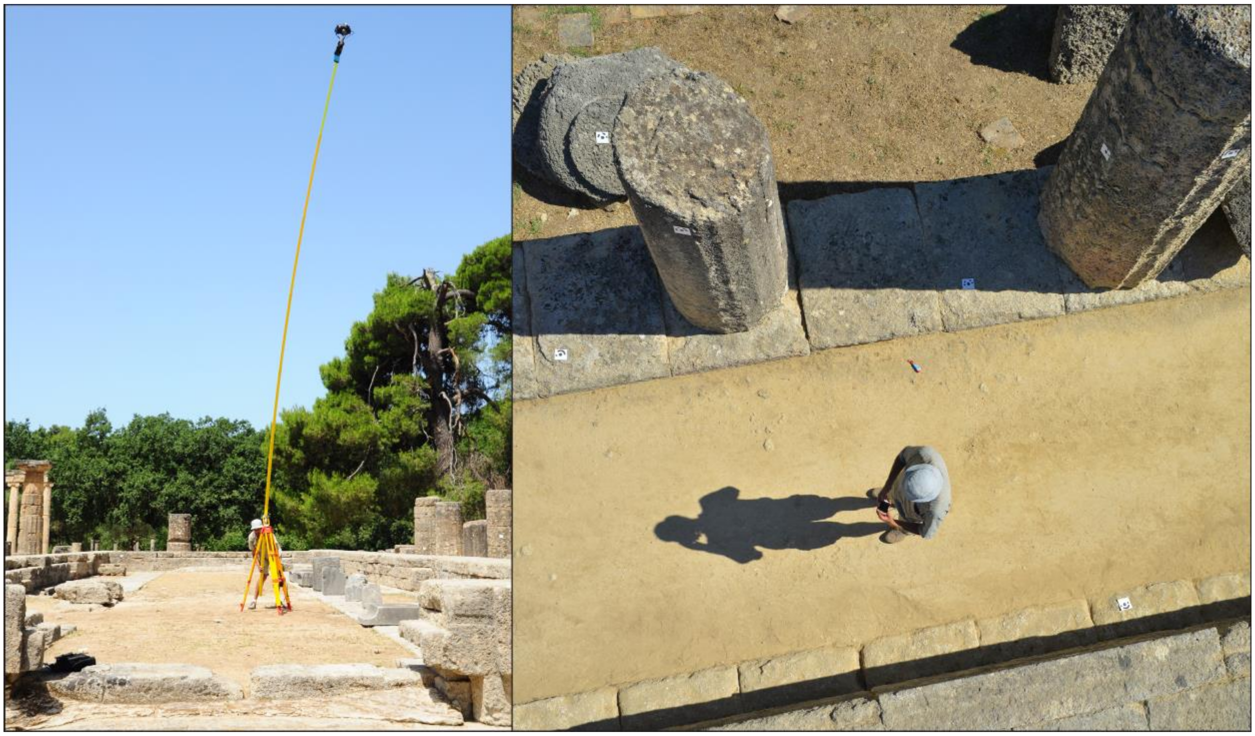

Figure 7. Aerial photogrammetric survey of the temple of Hera at Olympia [author].

Later stages in the digital protocol were decidedly disengaged from archaeological reasoning (Table 2: Stages 2–6). The photogrammetric survey relied on an extensive network of coded targets temporarily fixed on surfaces throughout the site and surveyed relative to another grid of permanent GCPs [Sapirstein 2016]. The initial survey (2) required considerably more TS points measured at high precision than would ordinarily be required before technical drawings, but the photogrammetric fine survey (3), based on aerial photographs of the coded targets, was probably an order of magnitude faster than the measurement of the thousands of TS points needed for manual plotting. In either case, the focus is on fixing points and the operation of the TS machinery rather than on understanding the ancient remains.

After the site survey has been carried out, photography absorbs the researcher's full attention (Table 2: Stage PG 4). At Olympia, I divided the building into segments for photography during optimal and consistent sunlight [Sapirstein 2016]. Due to the large scale of the temple, I was obliged to photograph it in numerous passes with the camera at different heights, including while mounted on a boom (Fig. 7). Batches of photography entailed intense physical exertion in direct sunlight. After completing each batch, I found myself so exhausted that any study of the architecture seemed out of the question until another day. Instead, I processed sets back in the computer studio in order to rest and check whether the photographs would be correctly oriented by the software.

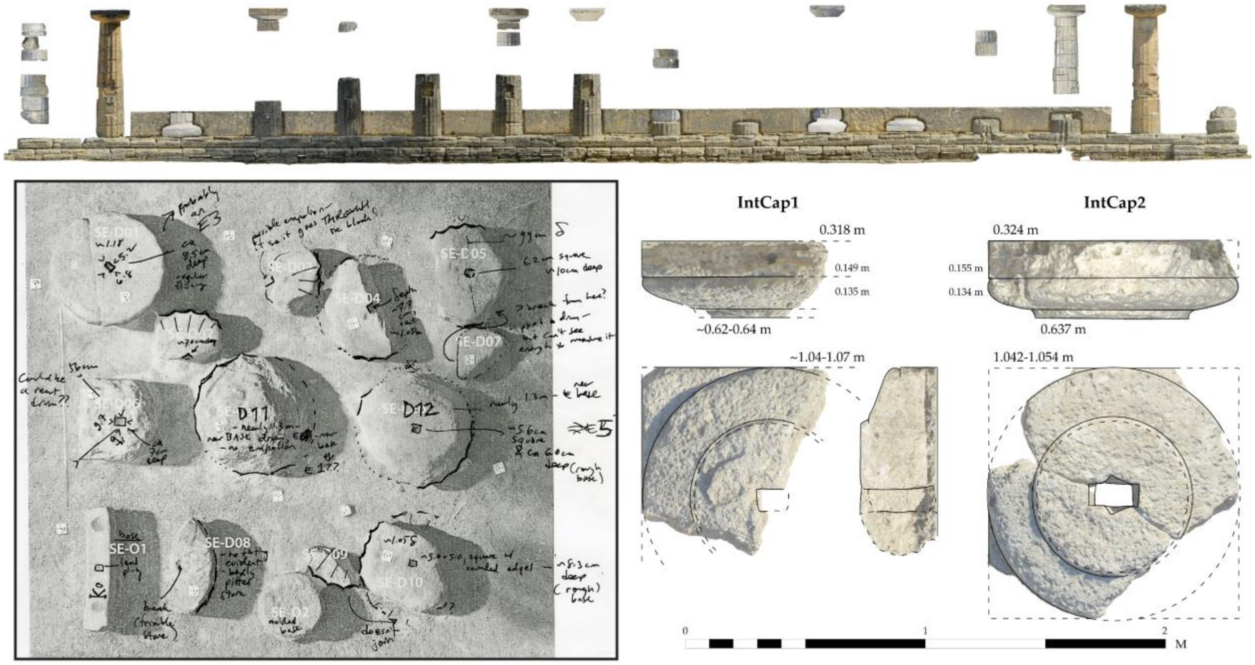

Figure 8. Orthographic views of the temple of Hera at Olympia: (above) virtual restoration of the south peristyle; (left) annotated field sheet; (right) interior capitals with interpretive annotations [author].

In both photogrammetric and traditional recording methods, the computer work off site (Table 2: Stages 5–6) does not involve much archaeological interpretation. However, the photogrammetric software does not even display an intelligible representation of the subject until late in the processing. Under pressure to render multiple sets at once, I quickly reviewed the 3D outputs merely to verify the production of a viable model and moved quickly to the next job. Any creative exploration of the models was thus delayed by several days.

Alternative 3D recording techniques likewise distract attention from the ancient subject. For example, drone-based modeling adds another complex, attention-grabbing mechanism to the photogrammetric process [e.g., Waagen 2019]. Drones and laser-scanning hardware alike discourage the user from exploring the site. For example, with mid-range laser scanners all humans must flee the area while the machine gathers data, lest portions of their bodies become occlusions baked into the resulting point cloud, and one should similarly avoid standing in the way of aerial photographs (Fig. 7: right). With smaller artifacts, the operator of an object scanner is at least nearby, but, as with photogrammetry, attention is focused on the machinery [contra Molloy and Milić 2018].

The first genuinely interpretive phase of the photogrammetric process occurred after the 3D models had been rendered and exported, while preparing orthographic views of each element of the building (Table 2: Stage 7). Inspired by annotated plans and elevations of architecture, the 2D projections became instrumental to the architectural analysis during and after fieldwork. First, the flattened imagery could be navigated much more rapidly than the original 3D data while preserving the original 1-mm resolution, which facilitates the investigation of the Heraion's architectural elements with unparalleled flexibility and speed. Second, similar to the plotted drawings at Kalamianos, orthographic views are indispensable heuristic tools affording a more comprehensive and systematic view of the building sites than could be achieved through unaided human perception [Amelung 2019]. Just as they brought out the built features from rubble-strewn structures at Kalamianos, the projected views at Olympia revealed relationships across the structure which, due to its large scale, were difficult to perceive in person (Fig. 8: above).

Additionally, the orthographic views supplied an ideal equivalent to the annotative phase of the technical drawing at Kalamianos (Table 1: Stage 4b). One technique was to print scaled ortho-photos of an area and then write notes and mark features on the sheet during follow-up visits to the site (Fig. 8: left). The sheets not only contained much more contextual information than a drawing, but as printed copies they were less "precious," promoting more creative, impromptu forms of annotation that could only take place at Kalamianos after the field sheets had been digitally composited and reprinted. The second technique entailed the drafting of vectors and textual annotations over the photogrammetric layers in CAD software for publication. Since a great deal of information is already present in the photogrammetric renderings, vectors can be applied sparingly in order to emphasize key features or indistinct elements, leaving the rest of the interpretation to anyone viewing the imagery (Fig. 8: right).

4.3 Discussion

As these case studies make clear, illustrators undertaking either technical drawing or 3D recording will focus their attention on the ancient subject in a manner conducive to interpretation only at sporadic intervals. In practice, technical drawing at Kalamianos was no more inherently "thoughtful" than was digitization at Olympia entirely "thoughtless." Over the months invested in technical drawing by SHARP, the teams were preoccupied with distracting activities for roughly 80–85% of the time (Table 1). Indeed, as a percentage of the total time invested in recording, the photogrammetric procedure was somewhat more "engaging" than its counterpart, with roughly a quarter of the DAP recording activities focused on its subject compared to about a sixth for SHARP (Tables 1–2). Of course, drawing at Kalamianos involved significantly more overall hours spent thinking analytically. At Olympia, the photogrammetric protocols required less than 15% of the time expected for even the minimal recording by technical drawing estimated in Table 2, and even greater efficiencies have been realized elsewhere [Sapirstein and Murray 2017: 338–40]. Thus, the primary loss in human attention driven by the switch to 3D recording is embedded within a major advantage: its increased efficiency.

Regarding technical drawing's first objective of recording, photogrammetry vastly outperforms hand plotting. Even while saving time, the digital process creates a much more detailed and fully 3D representation of the subject. The resolution of any kind of 3D recording should be higher than its manual equivalent, and, assuming the use of controls to promote repeatability including coded targets [Sapirstein and Murray 2017], photogrammetric accuracy is also superior. At the Heraion, comparison of overlapping sets found that the positions of 95% of the survey targets and the 3D surfaces were consistent within ±1 mm, with the higher errors in the latter limited to crevices and other regions partially concealed from photography which would have been ignored in a typical line drawing [Sapirstein 2016: 141–43]. At a 1:10 scale for an equivalently detailed technical drawing, errors an order of magnitude greater are common in even the most carefully hand-drawn plots, whose mistakes are also irregularly distributed. While the turn to 3D recording does not in itself change the inherently destructive nature of excavation [cf. Roosevelt et al. 2015], controlled implementations of archaeological photogrammetry are without doubt capable of generating a much more thorough and reliable record than their manual analogues.

As for the more thoughtful dimensions of technical drawing, the extended period of cleaning and annotative illustration in the DAP represents alternative mechanisms for observation and interpretation, even if neither is integral to 3D data generation (Table 2: Stages 3–6) as they are to hand drawing. In contrast to the highly mechanized digital recording procedure, the annotations penciled over printed views of the Heraion models, or the vectors added in CAD software deliberately retained the traditional graphical conventions like those applied to the field-sheets at Kalamianos (Table 1: Stage 4b). Such retentions are also found in the tracing of features displayed on a portable tablet in a paperless excavation protocol [e.g., Taylor et al. 2008]. Insofar as they are creating silhouettes around features witnessed while on site, excavators placing vectors over a projected photograph on a tablet screen are creating an annotated interpretation, but by means of a more effective visual aid than a SHARP illustrator referencing only the GCPs and local grids.

Nonetheless, archaeological interpretation is transformed by 3D recording in some concerning ways. First, in the scenarios presented here, the efficiency of photogrammetry led to a reduction not only in duration but also personnel on site, with the many illustrators and other team members at Kalamianos replaced at Olympia by myself, an occasional collaborator, and local workers. At least five and up to a dozen SHARP members had contributed to the interpretation of each complex, resulting in a more diverse, deliberative, and potentially much richer understanding of the remains.

Second, the most fruitful analytical stages are shifted from the core of the technical drawing process to the beginning and end of its digital alternative. As they were being plotted, the drawings at Kalamianos served as intelligible guides to the complex spaces which we were struggling to understand. Perhaps more importantly, their annotation obliged us to examine every plotted element, arrive at some consensus about its function, and apply an interpretive convention to the sheet before continuing. Although the cleaning of the Heraion did promote close architectural observation, no such spatially accurate records became available until the 3D models were fully rendered, making it difficult to preserve those observations at the early stages of the work. Even as improvements in scanning and computational hardware steadily accelerate processing speeds, mechanical recording on site and post-processing in the computer unavoidably creates a lag before outputs can be analyzed: at best a delay of hours, but more often of days or even weeks. When the digital records are not available until after the archaeologist has begun to excavate a new context or the architectural historian has left the site, the embodied experience of applying interpretive conventions on a technical drawing is significantly diminished, or even entirely lost.

5. TOWARD AN INTROSPECTIVE 3D RECORDING

Although hand drawing has been praised as a thought-provoking tool in the context of "slow archaeology" [Caraher 2016], the relative slowness of technical drawing is not in itself innately desirable. As described above, archaeological and architectural technical drawing requires a considerable amount of labor that is neither particularly generative of insight nor well-suited to human ways of seeing. As computer vision inevitably replaces its less efficient forbear in many archaeological scenarios, we should consider carefully the challenge of "retaining the pedagogical, co-constructive, and cognitive qualities of … hand recording" posed by Morgan and Wright [2018: 148] in light of the strengths and weaknesses of both approaches.

In the case studies, human vision has fared poorly as a recording method. Although many kinds of hand drawing are creative and individualistic, technical drawing is instead distinguished by its requirements for spatial accuracy and communication of a collective understanding. Even its aforementioned potential to inspire new observation through extended visual scrutiny is, in actual practice, hampered by the challenge of plotting features in orthographic projection – a highly unnatural and distracting manner of viewing a subject [cf. Edgeworth 2003: 82]. In contrast, scanning systems are immensely faster and more accurate than humans at the capture and projection of 3D data.

Given these advantages and in light of the formidable costs of traditional methods, we may expect scanning to continue to replace hand drawing. I argue that this process of replacement is not inevitably as problematic or transformative as many recent discussions imply [e.g., Campana 2017: 282; Caraher 2016; Carlson 2014; De Reu et al. 2013: 1118; James 2015; Limp 2016; Morgan and Wright 2018; Murray et al. 2017; Schuller 2002], especially given the genuine limitations of technical drawing. At the same time, it is important to recognize that capturing 3D data requires considerably less direct engagement with ancient remains than does technical drawing, and it obviates the opportunity to produce annotations while present on the site. This is true even when a single researcher conducts all phases of 3D recording. However, if clearing and exploration were delegated to separate personnel – as might come about in an active excavation employing a digital specialist assigned exclusively to photography and 3D processing – then the individual generating the 3D record might never directly engage with the ancient remains being captured. Such a divorce from the subject carries many fundamental risks, from incomplete photography to an impoverished understanding of the resulting 3D simulacrum. If a recording system bereft of experienced interpretation has become a new possibility, how should we avoid a potential deterioration in the intellectual aims of archaeological and architectural research?

On the pedagogical level, we must avoid the tendency for over-specialization and compartmentalization of skill already observed in commentaries on 3D recording in archaeological practice [e.g., Beale & Reilly 2017; Garstki 2016; Molloy and Milić 2018; Taylor et al. 2018]. The individuals tasked with operating digital tools should be expected to learn more than just how to operate the hardware and software, including at least the basics of traditional drafting [De Vos 2017: 63–64]. Training students in manual measurement and projection of real-world 3D points to a 2D page would provide a sense of what computer vision is accomplishing, shedding light into the operation of that "black box" – even if indirectly – and revealing where and why the digital process might go awry. More importantly, if we hope to preserve the interpretive eye of the archaeological illustrator, it is essential that those creating archaeological recordings gain experience with this kind of seeing. The 3D specialist would likewise benefit from using the abstracted conventions in traditional media, a familiarity which might promote more intelligible interpretive visualizations derived from the digital recordings [cf. Rabinowitz 2019]. In sum, we should not abandon conscientious efforts to train practitioners in the interpretive strengths of technical illustration even as we allow digital techniques to replace the more mechanical and undesirable aspects of traditional drawing.

As for the collaborative dimension of technical drawing, a more deliberate involvement of 3D visualization staff in conversations about the interpretation of the archaeological record will be needed in order to compensate for the loss of extended periods spent on site drawing by hand. Recording specialists with more formal training in interpretive illustration would be better prepared for such collaboration, especially with training in how to annotate spatial data toward some specific, communicative aim. Furthermore, new venues for disseminating and sharing 3D products open many possibilities for engaging new voices in the discourse. An accurately recorded, detailed scan is a new kind of exploratory tool unparalleled by a traditional hand drawing in its ability to allow a user to revisit the subject virtually [Jensen 2018; Opitz and Limp 2015; Roosevelt et al. 2015]. Such recordings yield new opportunities for critical review by an audience which is not restricted to those who drafted a technical drawing, but extends to anyone with access to the scans.

Concerns among archaeologists about the cognitive impact of 3D recording might be allayed by adapting research schedules to its different pace. The speed of digital tools liberates project members from time-consuming tasks where human vision is ineffectual, allowing minds to be applied to other problems where they excel. Such adaptations will of course vary greatly according to individual project goals. In the case of SHARP one could imagine that the thousand or more hours of labor saved through a photogrammetric recording system would have opened up dozens of additional hours for reviewing each complex with printed plans and elevations in hand, even while documenting a larger fraction of the extant architecture. Since the most valuable interpretive work cannot be completed until the digital models are processed, however, any project turning to 3D recording must take care to allocate enough time in the latter stages of the fieldwork to review the results. In architectural studies like those at Kalamianos and Olympia, the first half of a digital season should be focused on cleaning and recording, followed immediately by processing, so models are ready for analytical review in the latter part of the season [cf. De Vos 2017; Murray et al. 2017]. Alternatively, a project might plan an initial session focused entirely on 3D recording, return to the office for processing, and then conduct a follow-up session on site devoted to critical analysis. When the site is being continually and irrevocably changed through excavation, the recording specialists are obliged to generate models as quickly as possible [Jensen 2018; Waagen 2019], although at least some hand drawing will be necessary until models become available for direct annotation. The tablet-based system at Çatalhöyük, for example, employs an overhead photograph quickly rubber-sheeted to GCPs as the visual reference for contextual drawing, whereas 3D models were reserved for more complex interpretive problems [Taylor et al. 2018].

The turn toward digital methodologies to some degree reflects longstanding institutional pressures in both academic and contract archaeology toward resource-minimization at the expense of craft. Archaeological and architectural researchers who adopt digital recording in this environment must plan carefully how best to make use of the time it saves, some of which represents a genuine loss of on-site human observation. At least some of the time-consuming drudgery inherent to technical drawing can and should be reallocated to computational processes wherever it would most directly benefit critical analysis [Roosevelt et al. 2015: 339]. However, the delay between capture and processing in 3D recording requires that each episode of fieldwork be scheduled so that project members have an opportunity to engage in creative exploration of the site after the preliminary models become available. By transferring the burden of spatially accurate recording from the domain of human illustrators to more capable machinery, a thoughtfully implemented 3D recording system might indeed include creative activities, like sketching subjects freehand [Edwards 2008: 160–169; Olsson 2016], at which people excel.

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