Rulers and Dividers: A Technology of Design

Philip Luscombe

Introduction

Rulers and dividers enable the discovery and definition of distances. Both tools, shown in Figure 1, can be used as instruments with which to determine the dimensions of a nascent artifact. Although they are similar in their capabilities, there is a fundamental difference in the nature of these two tools. A ruler is used to specify distances according to standardized systems of measurement (e.g., inches or millimeters), whereas dividers are used to “step out” proportional relationships, by fixing their points to a distance and walking them across a surface. In what follows, I compare these alternative techniques of layout and consider how they ask us to conceive of an emergent design in very different terms.

Figure 1

This comparison first requires reflection on the role of measurement systems in design practice. My paper therefore begins with a brief history of these systems. I clarify that, despite their ubiquity throughout contemporary practice, standardized units of measure are not a prerequisite of design work. I discuss pre-industrial methods of designing and making both to demonstrate this lack of necessity and, for those unfamiliar with divider use, to introduce how proportional systems of layout work.

Central to my discussion of rulers and dividers is the idea that tools and techniques can be understood not only in terms of their capacity for achieving goals, but also according to the ways in which they inform processes of design. This approach promotes the role of action and the external world in cognition. To this end, the paper draws inspiration from the theory of extended mind—specifically, the concept that human cognition not only takes place inside the brain (or body) but also is distributed across the tools we use. Although this theoretical grounding is rarely applied in studies of design and making practice, I show that it provides a useful basis from which to interrogate the ways our tools and techniques structure processes of design.

In a discussion of the paper’s broader implications, I suggest that we might conceive of this sort of inquiry as an exercise in technology. If we ignore the conventional definition of the word and instead follow a line of French scholarship that takes *technologie* to be the study of techniques, analyses like the one presented here can be considered a technology of design. I use the study of rulers and dividers to demonstrate how such a technology, founded in an appreciation for the extendedness of mind, could be pursued more generally. For example, I suggest how a similar interrogation of the role of measurement systems could be applied to CAD software. In this and many other areas of design practice, the proposed role of technology would be to better understand the ways in which tools and techniques might steer, support, or potentially compromise our processes.

Systems of Measurement

The earliest known systems of measurement saw ancient builders lay out dimensions using distances found on their body. The convenience of having such measures (quite literally) to hand meant that distances like the cubit, which was the distance between the point of the elbow and the tip of the middle finger, were in widespread use across many cultures.[1] Using dimensions defined by arms, feet, fingers and hands, the designers and makers of antiquity were able to develop, remember and share the information required to lay out their work. Variation inevitably existed between distances measured by different individuals, but these discrepancies were not considered problematic. Accuracy in the joints of woodworkers, masons or metalsmiths relied on their ability to fit one component to another according to the specifics of an individual circumstance, rather than precise adherence to a universal system of measurement.[2] In contrast to the contemporary scenario of distributed labor, production lines, and outsourced components, exact definitions of distance offered few advantages when parts were made to fit locally.

Figure 2

Beyond the convenience of being readily available on any job site, distances found on the human body also provided ancient builders with a collection of dimensions that had useful proportional relationships. For example, the cubit was divided into six palm widths (see Figure 2). A measurement made using the thumb could be multiplied 12 times to approximate the length of a foot. The distance between the tip of the nose and the fingertips of an outstretched hand equaled three feet, and an arm span was twice this length.[3] Again, although such distances would vary between individuals, these proportional relationships across the same person's body were usefully consistent. Using simple divisions and multiplications of these measures, artisans were able to discover structurally sound and beautiful proportions, as they designed and made artifacts of lasting appeal.

In their book, *By Hand & Eye*, woodwork instructors and theorists George Walker and Jim Tolpin refer to these methods of design and production as "artisan geometry."[4] Their investigation of the subject leads them to study the tools and techniques used by the artisans of what they call the "pre-industrial" age.[5] With just a pair of dividers, a straightedge, string and a mark-making tool, and without any recourse to complex mathematics, Walker and Tolpin show how designers and makers were able to accurately lay out all the angles, curves and shapes they needed. Rather than being specified by standardized units of distance or degrees of angles, these designs were made with reference only to proportional relationships. Instead of asking, "How high is this base dimension in inches?" when making a piece of furniture, "pre-industrial artisans would have asked, 'How tall is this base in proportion to the case above it? How wide is this leg in proportion to its height? How much does this leg taper in proportion to its width at the widest part?"[6] Very often, the first dimension of a design was fixed according to the designer or maker's own body. For example, a chair seat could typically be set to two hand spans high.[7] With their dividers set to the width of a hand span, or simple whole number divisions of this dimension, designers could then determine the sizes of the chair's other elements (see Figure 3). In this mode of working, a system of measurement is developed alongside each design, unique to the demands of the task. Designing in this way focuses attention on the association of parts and wholes.

Figure 3

Only with the advent of industrialized production did shared units of measurement become valuable. When component parts began to be made in multiples, to be assembled later along a production line, their sizes needed to be closely controlled. Although we see some evidence of rudimentary standardization in pre-industrialized society (e.g., cubit rods made of wood or stone were used in ancient Egypt), the need for precisely defined, shared units of measurement grew only with the demands of mechanized production. Walker and Tolpin explain that "as cutting tools were bolted to machine fixtures rather than guided by hands… we began needing numbers to feed machines"[8] (Figure 4 illustrates one example of this development, by contrasting a hand saw with a table saw interface).

Figure 4

My interest here is not to argue against the obvious usefulness of standardized measurement systems and the associated tools and techniques that use them. Conceiving of how modern production processes could work without shared measures is impossible. However, despite their contemporary ubiquity, the methods of pre-industrialized production demonstrate that standardized and precise units of measurement are not a prerequisite of design practice. As happened throughout antiquity, working without these units is certainly possible—until they are required to be fed into a machine or specified on a drawing for third-party production.

Throughout this paper then, I do not present dividers and the associated use of proportional layout systems as a relic of bygone artisanal techniques. In many situations of design practice, they can be understood as an alternative to drawing freehand or using a ruler or any other method. In comparing the use of dividers and rulers, the topic of interest is not the limits of their capacities, or what they can and cannot be used for. I compare the tools not to suggest that they are interchangeable or of equivalent function, but as a means to explore how these alternative methods of discovering and defining distances structure the process of design. This exploration is undertaken to acknowledge the influence of tools and techniques on the process of working things out—an approach that requires us to first consider the relationship between tools and cognition in more detail.

Extended Minds and the Significance of Tools

In their paper, *The Extended Mind,* philosophers of mind Andy Clark and David Chalmers begin by asking, "Where does the mind stop and the rest of the world begin?"[9] Drawing on a range of examples in which cognition is shown to rely on two-way interactions between people and things, Clark and Chalmers' answer is to look beyond the limits of the skull, skin or body. The mind, they argue, should be reconceived to include features of the external environment. In situations like rearranging Scrabble tiles, using a pen and paper to solve math problems, or interacting with navigational instruments, Clark and Chalmers find *extended* cognitive systems. Throughout all kinds of activities, they claim, we use our environment to help work things out. From an extended mind perspective therefore, thinking does not only take place within the confines of our heads, but is spread out into the world. Clark and Chalmers thus regard the "general paraphernalia of language, books, diagrams, and culture" all to operate as parts of extended minds.[10]

A critical foundation for both Clark and Chalmers' thesis and my discussion of tool use is a bi-directional understanding of thought and action. The theory of extended mind promotes the idea that actions are performed not just to advance toward a goal, but also to help work things out. Rather than seeing tool use as a means by which to transcribe predetermined forms onto paper, screens, or three-dimensional materials, an extended approach to cognition recognizes that there are occasions when tools are used to find out what these forms should be. Cognitive scientists David Kirsh and Paul Maglio here provide a useful distinction by describing two kinds of action: pragmatic action and epistemic action. The former refers to actions intended "to bring one physically closer to a goal," and the latter sees actions "performed to uncover information that is hidden or hard to compute mentally."[11] For example, rearranging Scrabble tiles can be considered epistemic action in that the tiles are moved to help reveal how they might be used in the game. When parts of the world are used in this way—so that, "were it done in the head, we would have no hesitation in recognizing [it] as part of the cognitive process"—then Clark and Chalmers believe the things used should be recognized as the components of minds.[12] "In a very real sense," they write, "the re-arrangement of [Scrabble] tiles on the tray is not part of action; it is part of thought."[13] Importantly for this paper, the theory of extended mind proposes that wherever we find such epistemic action, a "spread of epistemic credit" should occur across the non-human components of minds.[14] The comparison of rulers and dividers here is both an attempt to bestow them with epistemic credit and an exploration of how we can better understand design tools and techniques in these terms.

I have drawn on the theory of extended mind to offer a readily understood introduction to the methodology underlying this paper. Note, however, that Clark and Chalmers were not, and are not, lone voices in calling for this view of cognition. Examples of a similarly distributed approach stretch back before Clark and Chalmers' theorizing of the extended mind.[15] And in more recent years, such examples can be found with ever-increasing frequency.[16] I've relied on the theory of extended mind here not to suggest that it is unique but because, in and among the different terminologies applied by various authors, it offers a concise explication of this general, cross-disciplinary tendency toward distributed models of cognition. Clark and Chalmers are themselves alert to the similarities between their own work and that of others; they draw on other studies to stress that their work is much more than an exercise in redefining the word "mind": "[S]eeing cognition as extended is not merely making a terminological decision," but proposing a way of thinking about cognition that "makes a significant difference to the methodology of scientific investigation."[17] Conceiving the mind as a system that includes features of the external environment allows interactions with that environment to be subjected to novel analyses.[18]

The Extended Mind and the Study of Design Tools

I propose that this reframing of action, as a part of thought, provides a useful grounding from which to consider the significance of tools and techniques during processes of design. However, despite the widespread interest across other disciplines, few applications of the work on extended mind can be found in the literature on design and craft. As architect Lars Spuybroek observes, "tools are usually understood as mediators, as in-between instruments, as if the goal already exists, as if the end has already been reached."[19]

One exception to this assumption can be found in Henrik Gedenryd's exploration of the extendedness of cognitive processes and design practice in his dissertation, "How Designers Work."[20] The subject of Gedenryd's dissertation can be summarized as a question: Why do designers work the way they do, when the traditional theories of cognition and design say that designers should be doing something quite different?[21] As implied by this question, Gedenryd is critical of what he terms "intramental" accounts of cognition.[22] In such accounts, all thinking takes place "in the head," in the words of Clark and Chalmers, isolated from action in the world.[23] Gedenryd uses studies of design sketching to demonstrate that sketches are not used only to render pre-existing ideas, but also to provide feedback throughout a design process.[24] The practice of sketching helps to discover previously hidden qualities or characteristics of an emergent design. Gedenryd's analysis of thinking and drawing thus "gives little justification for treating them as separate activities, but rather as two aspects of one single activity. Thinking and sketching go on in parallel and mutually enable one another to move forward."[25]

Throughout his dissertation, Henrik Gedenryd's primary interest is to use evidence from the practice of designers (in particular, their employment of sketching and prototyping techniques as means of thought) to challenge overtly mental accounts of human cognition. In sympathy with works like that of Clark and Chalmers, Gedenryd seeks to advance the extended understandings of cognition more generally. However, in bringing together the practice of design with theories of extended cognition, he provides a rare example of their compatibility that benefits design theory as much as it does cognitive science. For the remainder of this paper, I draw on the insights of extended mind theory and its promotion of the role of action in thought.

Using Rulers and Dividers

As stated, my interest is to explore how tools and techniques structure design processes. The comparison of rulers and dividers is therefore an attempt to bestow them with what Clark and Chalmers call "epistemic credit."[26] Although my focus is on the specifics of these two tools, I hope this work might serve as an example of the kind of study that could be performed more generally, as part of a broader effort to discuss the influence of tools and techniques on design practice. I return to the subject of this potential technology of design in the following section.

Dividing a Line into Thirds

Rulers and dividers are multi-purpose tools. Generally, they can be used in one of two ways: to discover the dimensions or proportions of existing things or to help lay out designs on a surface. Very often, a task requires rulers or dividers to be used in each of these modes—both as instruments of discovery and as tools for marking new features. Here, I describe a simple task that combines these two purposes to illustrate a fundamental difference between the tools.

Imagine we would like to divide a line into thirds along its length. Using dividers, the first task is to approximate a third of the distance and set the points of the tool to this dimension. The distance can then be "stepped out" to check the approximation. Any inaccuracy in this first attempt can be revealed by "walking" the dividers from one end of the line toward the other. If the final step under- or overshoots the endpoint of the line, a third of this dimension should be added or removed, respectively (see Figure 5). With practice, designers might achieve a successful division into thirds on this second attempt. If not, they can repeat the process until the even thirds are discovered. After the dividers are correctly set, they can be used to mark the points of the divisions into a substrate's surface, by applying more pressure throughout another series of steps.

Figure 5

Performing the same task with a ruler, we would first measure the length of the line. This numerical dimension can then be divided by three (see Figure 6). The calculation can be done mentally, on paper or using a calculator. The resulting dimensions of the thirds are then marked using a pen, pencil or knife alongside the ruler's edge.

Figure 2

Using either the ruler or the dividers, an identical result can be achieved: The line can be accurately divided into three lengths. This exercise, then, does not expose the varying capacities of these two layout tools, nor is it an instance of using them in search of an as-yet-undetermined form. However, even this simple task introduces an important difference in the nature of these tools and their associated techniques. This difference lies in the ruler's numerical system of measurement and the dividers' proportional system. A ruler always must refer to the units of a standardized measurement system, where a pair of dividers attends to the relationships of physical, real world distances.

Using Dividers to Design: Questions of Proportion

In the example of dividing a line, we see that the questions that might be resolved using a pair of dividers involve the relationships between different elements. In other words, we might say that *dividers pose questions in terms of proportional relationships*. This phrasing takes seriously the the role that tools and techniques play as extensions of minds. Dividers structure action around the discovery and creation of proportional relationships. Moving on from dividing a line into thirds, this aspect of their character is most apparent if we consider the sequence in which they are used to design previously unspecified forms.

Before dividers are used to mark any point, they first must be set to a particular distance. This distance should be one that is useful in creating the lines and shapes of a design. If it is too large, it does not allow us to mark the smaller dimensions of a design. If it is too small, stepping out long distances becomes unnecessarily laborious. This first task thus introduces a critical concern during the use of dividers: the length of the "module." A module is a distance that can be divided or multiplied repeatedly to create the lines and shapes of a design (see Figure 3).[27]

The module need not be specified in millimeters or inches; designing in this way defines the relationship between elements rather than their absolute dimensions. Unless we aim to create a layout that is the actual size of the finished artifact, the precise distance to which the dividers are set while designing is not critical. Any design created using a module-based approach can be easily scaled up or down at a later stage, by adjusting the actual dimension to which the module is equivalent. Thus, as we design a specific instance of an artifact, we are also creating what might be termed a generative sequence that can be followed to create the same artifact at differing sizes [28] . The scalability of divider-made designs was an advantage exploited by the designers and makers of antiquity. For example, when laying out a pointed arch, alternative sequences can be used to step out the spring and focal points to create arches that have different qualities (see Figure 7)[29]. That such sequences can be easily remembered, shared, and adapted to the particulars of individual circumstances made them highly valuable to the builders of antiquity.[30]

Figure 3

As a more contemporary example, using a pair of dividers in the practice of designing a chair (e.g., the one in Figure 3) requires us to continually reconsider the relationship of the module to the whole design as we work. Does this distance allow us to create the right kinds of proportions? Are the divisions simple to work with? For example, divisions of 12 (e.g., one-sixth, one-fourth, one-third, and one-half), like those found in the body part measurements of antiquity, offer more whole number fraction options than when using divisions of 10 (with just one-fifth and one-half).[31] Thus, right at the beginning of our design process, setting and resetting the dividers becomes a key concern, as we continually reconsider the relationship between parts, as well as the appropriateness of the module and its divisions for the task. Frequent revision of this setting is often necessary, until a useful module emerges alongside the design work. As designers experiment with the tool, by tentatively stepping out the potential relationships, both the artifact and its own unique system of measurement begin to emerge.

Using a Ruler to Design: Questions of Units

When using a ruler to determine the distance between points, we begin by placing it on a surface so that it spans the two (or more) points we would like to define. Once one of the points has been marked, a ruler allows us to decide on the location of the other points by referring to the markings of a measurement system that run along its edge. These graduated markings are continuous, enabling us to choose any dimension that seems appropriate. Once the first set of points has been marked, the ruler is moved to span the next distance, and we again are required to decide on the dimension.

To again take the extended mind argument seriously, and to consider tools to be an important part of cognitive systems, we might say that *the ruler poses questions in terms of universal units of measure*. Each time the ruler is repositioned, it physically retains no information about the previous decisions made, and we are free to choose any dimension along the continuous scale. Unlike setting and resetting a pair of dividers, the sequence of steps when using a ruler does not ask us to consider proportional relationships from the start. Instead, it allows us to define any feature of a design independently from the others; it allows and even encourages a dramatic shift in attention away from the proportional concerns prompted by a pair of dividers.

Of course, making a design with the same proportional relationships using either a pair of dividers or a ruler would be possible. Indeed, if we disregard the importance of the external world in the process, we might argue that these decisions are always a matter for the internal cognitive capacities of the designer, regardless of what tools and techniques they are using. However, what is clear from the examination here is that a ruler does not structure the task in terms of proportion. We do not need to start by discovering a useful module, and we do not need to step off an emergent design to quickly determine proportional relationships. Any such relationships may be discovered only upon reflection, with reference to the units of measure and through the detour of mathematics.

Discussion: A Technology of Design

The word "technology" typically is used in the anglophone world to refer to objects and techniques that apply sophisticated, relatively novel scientific knowledge. As computer scientist Alan Kay pithily suggests, "what people mean by the word *technology*, is anything invented since they were born."[32] However, in French scholarship, *technologie* has long been a field of academic enquiry: It is the study of techniques. Francois Sigaut, who made the study of techniques a central part of his work as a historian and anthropologist, wrote that "[t]echnology is to technics what linguistics is to language, biology to living beings, psychology to mental activity, epistemology to knowledge, etc." According to this definition, technology is a science that aims "to acquire knowledge on technics."[33]

My study of rulers and dividers can be considered an exercise in this sort of technology. Its aim has been to reveal how these tools and their techniques structure processes of design differently by prioritizing certain qualities over others. The evidence for these differences can be found in the physical and temporal arrangement of the techniques. A ruler is placed on a surface, allowing us to run or jump a pen, pencil, or knife between any of its gradated markings. A pair of dividers walks across a surface, meaning that we cannot leap-frog from one point to another, but must arrive at an end point only having taken and considered each step according to the proportional system of measurement. In the analysis given here, I have framed this difference by focusing on the questions posed by the tools. The techniques of divider use require that we consider questions of proportion, and those of ruler use ask us to determine distances in the shared units of a measuring system.

Throughout the paper, I have tried to give a sober account of the differences between divider and ruler techniques, leaving to the reader decisions about the merits of designing while prioritizing proportions or universal units. Indeed, the real value of this kind of technology is that it helps each of us to better identify the relationship between the techniques of design practice and the outcomes, and then to align them accordingly. From a historical perspective, this link between the tools of design and the resulting forms created is clearly seen. Dividers are emblematic of a time in which the study and creation of proportional relationships dominated scientific and artistic thought.[34]

In contemporary design practice, proportions are usually given less consideration. Dividers are not as ubiquitous as they once were—and neither are rulers, for that matter, as computer-aided design (CAD) software has taken an increasingly dominant role in much design development. On this point, we might consider the techniques associated with CAD software. In most cases, as the first line is drawn in CAD software, the user is immediately asked how long that line should be, in either millimeters or inches (see Figure 8). Subsequent lines also are to be specified in these units because each element of a drawing can be considered without relation to those that have been created before.[35] In ruler-like fashion, then, the universal measurements required of modern manufacturing appear to have been transmitted from the tools and techniques of factories into the tools and techniques of design studios. We now feed numbers into the machines that sit on our desks.

Figure 4

As we examine the techniques associated with design tools like rulers, dividers, and CAD software, the usefulness of extended mind theory becomes most apparent. Without this perspective, we instead rely on what Gedenryd calls “intramental” accounts of cognition and infer that tools are mediators used to transcribe pre-existing ideas into reality. In this model, we are limited to discussing only the degrees of certainty with which our tools can achieve a prescribed result.[36] However, by undertaking the kind of analysis demonstrated in the divider/ruler comparison, and by affording things the epistemic credit they deserve, designers can better see and discuss how tools and techniques influence processes of design, prioritizing some decisions over others and emphasizing certain qualities.

A technology of design would thus sensitize us to the ways that tools and techniques structure and support our work, opening up questions across all kinds of design practice. For example, if we design services using sticky notes, do they force us to adopt an episodic, atemporal understanding of life? If we shave a piece of wood to shape, rather than sawing it, do we access valuable opportunities for assessing and revising the emergent result that would otherwise be lost? What if we hack a piece of CAD software to make it pose questions of proportion, as dividers do?

My suggestion for this technology is to acknowledge that every technique has its own *epistemic character*—a character that influences how we work things out and, therefore, what those things will be like. Uncovering the nature of this character would be the work of a technology of design. And its ultimate aim would be to help inform our selection of the techniques that offer the greatest promise for a given task.

---

[1] Jeffrey Huw Williams, *Defining and Measuring Nature: The Make of All Things* (San Rafael, CA: Morgan & Claypool Publishers, 2014), 1-6.
[2] David Turnbull, "The Ad Hoc Collective Work of Building Gothic Cathedrals with Templates, String, and Geometry," *Science, Technology, & Human Values* 18, no. 3 (1993): 315–40.
[3] Williams, *Defining and Measuring Nature*, 1-6.
[4] George R. Walker and Jim Tolpin, *By Hand and Eye* (Fort Mitchell, KY: Lost Art Press, 2013), 97.
[5] Ibid.
[6] Ibid., 11.
[7] Ibid., 165.
[8] Ibid., 10.
[9] Andy Clark and David Chalmers, "The Extended Mind," *Analysis* (1998): 7.
[10] Ibid., 8.
[11] David Kirsh and Paul Maglio, "On Distinguishing Epistemic from Pragmatic Action," *Cognitive Science* 18, no. 4 (1994): 513.
[12] Clark and Chalmers, "The Extended Mind," 8.
[13] Ibid., 10.
[14] Ibid., 8.
[15] See, for example, Edwin Hutchins’s study of cognition onboard naval ships (Edwin Hutchins, *Cognition in the Wild* (Cambridge: MIT press, 1995)); Lucy Suchman’s work on the nature of planning in human and computer interaction (Lucy A. Suchman, *Plans and Situated Actions: The Problem of Human–Machine Communication* (Cambridge: Cambridge University Press, 1987); or Andrew Pickering’s account of scientific practice (Andrew Pickering, *The Mangle of Practice: Time, Agency, and Science* (Chicago: University of Chicago Press, 1995).
[16] See, e.g., Tim Ingold, *Making: Anthropology, Archaeology, Art and Architecture* (Oxford: Routledge, 2013); Lambros Malafouris, *How Things Shape the Mind* (MIT Press, 2013); and Jane Bennett, *Vibrant Matter: A Political Ecology of Things* (Durham, NC: Duke University Press, 2009).
[17] Ibid.,10.
[18] See, e.g., C. Knappett, *Thinking Through Material Culture: An Interdisciplinary Approach* (Philadelphia: University of Pennsylvania Press, 2005); and Colin Renfrew, ed., *The Cognitive Life of Things: Recasting the Boundaries of the Mind* (Cambridge: McDonald Institute for Archaeological Research, 2010).
[19] Lars Spuybroek, *The Sympathy of Things: Ruskin and the Ecology of Design* (Rotterdam: V2_Publishing, 2011), 300.

[20] Henrik Gedenryd, "How Designers Work" (PhD dissertation, Lund University, 1998).
[21] Ibid., 101.
[22] Ibid., 8.
[23] Clark and Chalmers, "The Extended Mind," 8.
[24] Gedenryd, "How Designers Work," 104.
[25] Ibid.
[26] Clark and Chalmers, "The Extended Mind," 8.
[27] Walker and Tolpin, *By Hand and Eye*, 153.
[28] For a discussion of how a generative sequences can be employed throughout processes of designing and making, see Christopher Alexander, *The Process of Creating Life,* vol. 2 of *The Nature of Order: An Essay on the Art of Building and the Nature of the Universe* (Berkeley, CA: The Center for Environmental Structure, 2002), 301–2.
[29] Example taken from George R. Walker and Jim Tolpin, *By Hound and Eye: A Plain & Easy Guide to Designing Furniture with No Further Trouble* (Fort Mitchell, KY: Lost Art Press, 2015), 117.
[30] Turnbull, "The Ad Hoc Collective Work of Building Gothic Cathedrals," 323.
[31] Walker and Tolpin, *By Hand and Eye*, 12.
[32] Stewart Brand, *The Clock of the Long Now: Time and Responsibility* (London: Phoenix, 1999), 16.
[33] François Sigaut, "More (and Enough) on Technology!" *History and Technology* 2 (1985): 122. Note that Sigaut here uses “technics” as a synonym of “techniques.”
[34] Such emphasis is clearly expressed, for example, in Luca Pacioli’s 1509 book *De divina proportione (The Divine Proportion)*, which, inspired by the ancient ideas of Vitruvius, cites proportion as the most important architectural concept. See Hanno-Walter Kruft, *A History of Architectural Theory: From Vitruvius to The Present* (New York: Princeton Architectural Press, 1994), 63.; See also Walker and Tolpin, *By Hand and Eye*, 9–10.
[35] To avoid falling into a trap discouraged by Sigaut (of using technological analyses without a proper understanding of techniques), I would note that designing parametrically in CAD software *does* create relationships between parts and wholes. See Francois Sigaut, "Crops, Techniques and Affordances," in *Redefining Nature, Ecology, Culture and Domestication,* ed. Roy F. Ellen and Katsuyoshi Fukui (Oxford: Berg, 1996), 427.
[36] See David Pye’s description of the “workmanship of certainty”, in David Pye, *The Nature and Art of Workmanship* (1968; London: The Herbert Press, 1995), 20.