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Material Energy Information: Toward an Analog Code

According to the classical notion of codes, symbolic elements like signs are usually regarded as immaterial elements and therefore act according to special logical or mathematical rules, which can be treated completely separately from the physical reality they can represent.[1] Addressing the idea of an analog code goes beyond this classical idea of alphanumeric code based on discrete symbolic elements such as letters and numbers that has been implemented on Earth. The analog can also transcend the fundamental antagonism between technical operations and nature, which has been the basis for modern engineering and, above all, for its most recent version as digital technology. The strategy of implementing symbolic operations that determine how things work and what they are transforms physical reality into a passive carrier of human intentions. This strategy and its corresponding features have been vastly executed and inserted into our physical and social reality for at least 200 years and on an unprecedented scale since the 1950s, thus producing a tremendous impact on nature and Earth. The dominant *modus* of implementation has to be considered as an essential cause of the Anthropocene crisis.

In contrast to this logic of implementation related with so-called "immaterial" symbolic or digital operations, I will present in the following a new relationship between material, energy, and information, where materials are no longer seen as passive carriers, where the symbolic is not at all immaterial activity, and where the symbolic is intimately related to energy. Conceiving this constellation relies on the decisive shift toward the idea of active materials as an embracing quality of both the symbolic and the material.[2] This shift is fundamental since the dichotomy of activity and its inert material basis is still an unquestioned foundation of our modern culture. Above all, since the nineteenth century, modern technology is based on passive materials—such as iron and steel, concrete and silicon—and has excluded the materials' own activity (e.g., wood) as a failure, defect, or dysfunction. Even digital hardware is based on a neutral material carrier for the execution of the externally programmed activity.

1 For the notion of code see: Friedrich Kittler, "Code (or How You Can Write Something Differently)," in *Software Studies: A Lexicon*, ed. Matthew Fuller (Cambridge, MA: MIT Press, 2008).

2 Peter Fratzl et al., ed., *Active Materials* (Berlin: De Gruyter, 2021).

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A New Workbench

Against this painful heritage of "spirit," "pure symbolic operations", and "immaterialities" separated from their material basis, this decisive shift from the material's passivation to the usage of its own activity responds at the same time to the present-day anthropocenic urgency—deeply linked to the destructive impact of modern technology. This strategy will have enormous consequences: it allows, first of all, to think and conceive the idea of a fusion of the symbolic and the material by experimenting with the materials and designing the corresponding new artifacts that blur the boundary between culture and nature. Here lies the necessary and pivotal challenge: only then will our present century "have been"—if such a future perfect will exist for mankind—and if so, it will have been the beginning of a merging of the symbolic and the material, of code and matter, of nature and technology. It will no longer be guided by digitally implementing alphanumeric code into physical reality and the ruling of nature; it will no longer be cybernetic by separating the information flow from the working machine.

This small but far-reaching shift toward active matter faces a triple challenge: firstly, to examine the fundamental structures of the inherent activity of matter in nature, and secondly, to make evident the extent to which this activity was and still is ignored within most of our technologies and human cultural activities, and thirdly, to transform these new insights into a new idea about matter and its relationship to energy and information which finally has to provide the conditions of possibility for different design strategies. All this means, in an essential way, resetting our modern cultures. Moving the switch from passive matter to active materials therefore responds to this triple challenge by integrating three fundamental perspectives: experimental practice based on biology, physics and materials science, historical and critical epistemology of the humanities, and practice-based design-driven projecting, which need to be combined as mutually completing features within an integrative approach of a large variety of disciplines (fig. 1).

To do so, one needs a workbench where the still isolated features, materials, and objects that are necessary for developing such a transversal and integrating perspective can be brought together. This kind of table establishes a space of encounter for materials and structures: wood, woven tissue, felt structures, biofilm layers, plywood, sheets of paper, etc. This collection seems to be as surrealistic as the dissection table in Lautréamont's famous poem "Les Chants de Maldoror," where a sewing machine and an umbrella meet.[3] For André Breton, this ensemble exemplified the "convulsive

3 Breton talks about "the fortuitous meeting of two distant realities on an inappropriate plane (this is said as a paraphrase and a generalization of Lautréamont's famous phrase: 'As beautiful as the fortuitous meeting of a sewing machine and an umbrella on an operating table')." André Breton, "Surrealist Situation of the Object [1935]," in *Manifestoes of Surrealism* (Ann Arbor: University of Michigan Press, 1969), 275.

Fig. 1: Operating table.

beauty" of surrealism,[4] and in *The Order of Things* Michel Foucault took it as a challenge that strongly attacks our modes of thinking.[5] In our case, it represents a completely changed mode of action: it is a real workbench displaying a "convulsive activity" of materials, where you actually have to roll up your sleeves and work with your hands.

Beyond the Graphic Surface

After centuries of transforming physical realities into symbolic operations flattened on paper, we have arrived at a situation where this strategy can and needs to be changed in a fundamental sense (fig. 2).

4 "La beauté sera CONVULSIVE OU ne sera pas" (Beauty will be convulsive, or it will not be at all). André Breton, *Nadja* (Paris: Editions Gallimard, 1998), 161. See also: Raymond Spiteri, "Convulsive Beauty: Surrealism as Aesthetic Revolution," in *Aesthetic Revolutions and the Twentieth-Century Avant-Garde Movements*, ed. Aleš Erjavec (Durham, NC: Duke University Press, 2015).
5 Michel Foucault, *The Order of Things: An Archeology of the Human Sciences* (New York: Vintage Books, 1994), XVI.

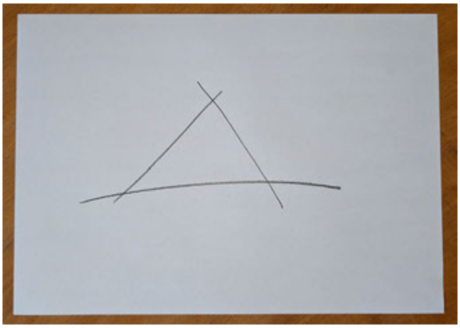

Fig. 2: Sheet of paper with text.

The classical way of projecting everything into the 2D space of texts and images has a lot of advantages, one of which is the reduction of complexity in the mode of processing information. Graphic surfaces have had a decisive impact on all cultures that used this medium over long periods of time, from stone surfaces to papyrus, wax, paper, or silicon. It was regarded as some sort of external mind and memory, or, vice versa, the mind was also imagined as a surface. Graphic surfaces contain at least three different types of operations: 2D operations, when the whole surface is used in its simultaneity by plane geometry, 1D operations, when there is a focus on sequential, linear operations, and, perhaps the strangest, 0D operations, when points are taken into account as unextended elements, incisions, perforations, or fundamental absences. This is in its essence a flat geometrical world that allows the performance of drawing, writing, and calculating as three fundamental symbolic cultural procedures that occur on that graphic surface but are related by its symbolic character to absent physical realities that could be represented by them.

Symbolic operations were regarded as extracted from the physical world or the "book of nature" to the graphic surface, fostering the idea that there exists a separated and isolated realm of the symbolic. René Descartes identified it as a space of thinking at the scale of a mathematical point that can represent the physical world without being physical.[6] This dichotomy of the symbolic and the physical is represented if not produced by the graphic surface, and above all by the elements of the alphanumeric code. It seemed as if the world of symbolic codes even controls the physical realm: this is the case in all our technology seen as an implementation of our ideas and codes into our material environment.

This strategy becomes even more obvious in digital technology that fully inherited this dichotomy. Alan Turing still envisioned the computer as a paper machine: "A man provided with paper, pencil, and rubber, and subject to strict discipline, is in effect a

6 René Descartes, *Meditations on First Philosophy: With Selections from the Objections and Replies,* ed. John Cottingham (Cambridge, UK: Cambridge University Press, 1996), 37.

universal machine."[7] This machine exists only on paper,[8] but also transforms the classical sheet of a graphic surface into a long tape, the interface between the physical world and the symbolic alphanumeric operations becoming a flat and neutral physical surface. Symbolic procedures require a passive carrier where materiality does not intervene actively.

Graphic surfaces are a medium to process and store information, and they also make transmission possible. If we look at the history of symbolic operations, it is above all transmission that has fundamentally changed our alphanumeric code: from postal systems for transmitting graphic surfaces in terms of letters to telegraphic systems, an important shift to electrification and sequentialization took place. This included the fundamental transformation of code from images, words, and letters to the endless chains of dots and dashes, 0 and 1. Under the conditions of electric transmission, the alphanumeric code maintained and even radicalized its fundamental separation from the material. This focus on transmission essentially shaped our idea of code and information.

Today, however, we have arrived at a moment when we can overcome this fundamental dichotomy of the symbolic and the material and move out of this passive surface, or paper machines. Already in 1959, in his famous lecture "There is Plenty of Room at the Bottom," Richard Feynman announced this move from the graphic surface to the interior of the material, when he speculated about the possible micro-storage of the *Encyclopedia Britannica* on the head of a pin as a minute surface. Feynman also proposed to leave the graphic surface for using the 3D interior spatial structure of the material for processing information.[9] This transformation is still a challenge today: moving beyond the fundamental separation of the symbolic from the material, the Cluster of Excellence "Matters of Activity" (MoA) focuses on material activity as a new mode of symbolic material operation, of relating information, energy, and material. We step out of the flatness of paper and classical switching circuits, and we do not follow the shift to electrification: rather, we have to switch from passive graphic surfaces to active material interfaces.

This shift can easily be experienced on the flatness of an office desk with a classical sheet of paper that is used as a passive and blank surface of writing (fig. 2).

When the environment is very humid, paper is no longer an obedient passive, neutral, and flat carrier for drawing and writing—it starts to act itself. The direct interaction with the environment intervenes: under these circumstances, paper becomes a disturbance, transforming the sheet into something dysfunctional (fig. 3).

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7 Alan Turing, "Intelligent machinery [1948]," in *The Essential Turing: Seminal Writings in Computing, Logic, Philosophy, Artificial Intelligence, and Artificial Life: Plus The Secrets of Enigma,* ed. B. Jack Copeland (Oxford: Clarendon Press, 2004).

8 Sybille Krämer, *Symbolische Maschinen: Die Idee der Formalisierung in geschichtlichem Abriß* (Darmstadt: Wissenschaftliche Buchgesellschaft, 1988), 171.

9 Richard Feynman, "There is Plenty of Room at the Bottom: An Invitation to a New Field of Physics," *Caltech Engineering and Science* 23, no. 5 (1960): 22–36.

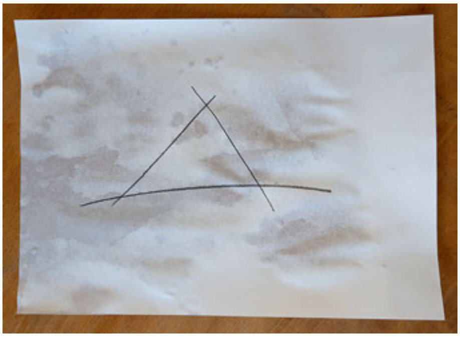

Fig. 3: Same sheet wrinkled by humidity.

The history of texts has suffered these processes: when one talks about Euclidean geometry, it refers to a text written more than 2,300 years ago, a physical text that is no longer existent. There is a fragment from 100 AD that is the only part of the oldest still existing material version of Euclid's famous *Elements* (fig. 4).

Fig. 4: Papyrus fragment of Euclid's *Elements.*

Geometry obviously did not survive only on graphic surfaces but was transmitted by practices and instruments. The example of the papyrus shows something very clearly: to generate a stable symbolic memory on the flatness of graphic surfaces, the activity of the carrier is silenced and suppressed. Long-term storage was and still is a great challenge within a world of active matter, since the intrinsic activity of the graphic support always produced severe alterations and decay.[10] Above all, historical objects to be kept as cultural heritage in museums—which is a rather modern mode of constructing history—shows the huge effort that is necessary for storing them as stable memory.[11]

In the case of paper, the material base of cellulose is a vegetal fiber structure produced by extracting fibers from their original structure in plant tissues that is destroyed in the production process and transformed into a rather passive, relatively dry and thin, felt-like structure that is also quite flexible. By adding water, an immediate, uncontrollable activity occurs.[12]

The disturbance of the classical scenario of flat symbolic operations leads back to the objects on the table, where the sheet of paper is not part of a book or a library, but a material 3D object among a whole series of already-mentioned active materials. The activity of the cellulose fibers that was silenced in the sheet of paper has now become the object of concern: with active materials we enter a new field, where materials are no longer seen as passive, where the symbolic is not at all immaterial, both different modes of active processes intimately related to energy.

External Code

Material activity, which is the object of our research, goes beyond implementing alphanumeric code into physical reality; it will no longer be cybernetic by separating the flow of information from the working machine. The classical relationship of material and symbolic operation that has been demonstrated by the sheet of paper can easily be explained with the technical example of widely used robotic arms.

A robotic arm is a piece of material mechanics. There are controllable joints connecting stiff elements to a kinetic chain that defines their possible movements. But only the double input of external energy and code for producing the controllable movements makes the passive material arm move. This structure follows the classical three-part model of machines separating motor, transmission or gearbox, and working unit as it was coined at the Paris École Polytechnique in the early-nineteenth century.[13]

The robot is also shaped by the historical development of electrical machinery and the corresponding passive materials. The industrialized and standardized design of artifacts, combined with electrification and digitization emphasized the necessity that

10 Elena Verticchio et al., "Climate-Induced Risk for the Preservation of Paper Collections: Comparative Study among Three Historic Libraries in Italy," *Building and Environment* 206 (2021): 1–16, https://doi.org/10.1016/j.buildenv.2021.108394.

11 See Peter Miller and Soon Kai Poh, ed., *Conserving Active Matter* (Chicago: University of Chicago Press, 2022).

12 Hannelore Derluyn et.al., "Hygroscopic Behavior of Paper and Books," *Journal of Building Physics* 31, no. 1 (2007): 9–21, https://doi.org/10.1177/1744259107079143.

13 Jean Victor Poncelet, *Traité de mécanique industrielle: exposant les différentes méthodes pour determiner et mesurer les forces motrices, ainsi que le travail mécanique des forces*, vol. 2 (Liège: 1845), 15.

technical operations are grounded on passive materials, electrical energy, and, finally, electrically processed information. As a result, symbolic control operations were separated from the mechanical operations of the working machinery, or, in terms of electricity, low-current engineering of information processing was separated from high-current engineering of the working machine. Since the early days of cybernetics, matter has been conceived as a passive carrier of energy and information and has thus suffered an even sharper distinction from the symbolic, as Norbert Wiener put it: “Information is information, not matter or energy. No materialism which does not admit this can survive at the present day.”[14] This triple separation is fundamental for digitally controlled and electronically driven technology.

Material is considered a neutral carrier both of external energy and information implemented in the physical gears. In the case of the robotic arm, the gearbox is assisted and replaced by the digital code. The kinetic chain is not mechanically constrained by the joints, but able to perform several degrees of freedom. Where in mechanical machines, the desired movement is controlled by the code executed by the mechanical constraints arranged by the connected devices, in digitally controlled machines, the code is completely separated from the material mechanics and has to be transmitted from outside in order to execute its programmed procedure. This obviously allows more flexibility in coding compared to the reduced mode in gear-controlled mechanisms.

The external character of electric code is also reflected within information theory: Claude Shannon’s theory is based on the idea that information has to be transmitted from a sender to a receiver. The receiver is considered an empty entity; it contains no information about its own behavior and thus completely depends on the transmission of the external electrical code. Thus, the receiver is a passive material whose essence is to receive and obey the external code (fig. 5).

It is obvious how this structure and arrangement shapes the idea of materials as a neutral substance that depends on receiving energy and information in order to become active and programmable. Within this context, any self-activity of the material or some kind of external condition is seen as failure or disturbance and as such has to be strictly inhibited. Therefore, the device has to be isolated from possible impacts from outside—in the case of electrical machines, this requires above all dry conditions. Programmable material, which is often described within the context of active materials, is thus actually a passive material whose activity is the result of externally coded and activated operations.

Classical digital technology emphasizes information transmission and processing as a sequential flow. Therefore, hardware is based on matter used as a neutral carrier for the transmission of electrical signals that flow through matter: the material of switching circuits can be regarded as a material flowchart. In this way, symbolic logical

14 Norbert Wiener, *Cybernetics: Or Control and Communication in the Animal and the Machine* (Cambridge, MA: MIT Press, 1961), 132.

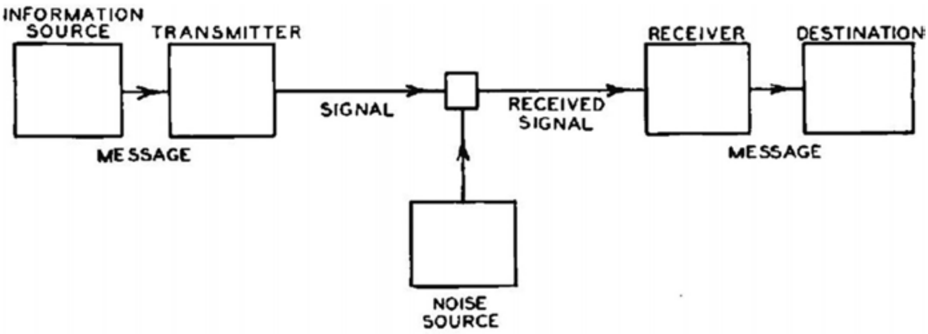

Fig. 5: Diagram of a general communication system, in Claude Elwood Shannon, "A Mathematical Theory of Communication," *The Bell System Technical Journal* 27 (1948), 381.

operations that over more than 2,000 years were processed on papyrus or paper could be "interpreted," as Claude Shannon did in his master's thesis of 1936, as electric switching circuits, and transferred from paper to electronic machines.[15] Information processing and transmitting is thus deeply shaped by these electrical conditions and relies on the inactive character of its material carrier.

Active Materials

This relationship between code and material is completely different in biomaterials (fig. 6). A comparison with a robot shows that the awn of an Erodium seed is—also in contrast to the sheet of paper—an extraordinary case of active cellulose structures. The material performs a strong torsion by drying and elongation through humidity, both as reversible operations.[16] The change of temperature and humidity between day and night triggers and fuels this activity every day, pushing the seed into the ground step by step. On earth, the sun floods the natural system day by day, altering the environmental conditions periodically. This change provides energy to the materials and makes the awn move. The clock-rate of this operation that triggers the inner activity of the material is low, in general two per day, and, accordingly, so is the resulting speed of the material's movement.

Bio-material is an open system and consists of heterogeneous structures and corresponding properties that depend on environmental conditions, mainly humidity and temperature. It is the environment that interacts with the material cellulose structure

15 Shannon's master's thesis of 1936 was published two years later as an article: Claude Elwood Shannon, "Symbolic Analysis of Relay and Switching Circuits [1938]," in *Collected Papers*, ed. Neil J. A. Sloane and Aaron D. Wyner (New York: IEEE Press, 1993), 474.

16 Michaela Eder et al., "Wood and the Activity of Dead Tissue," *Advanced Materials* 33, no. 28 (2021): 1–15, https://doi.org/10.1002/adma.202001412.

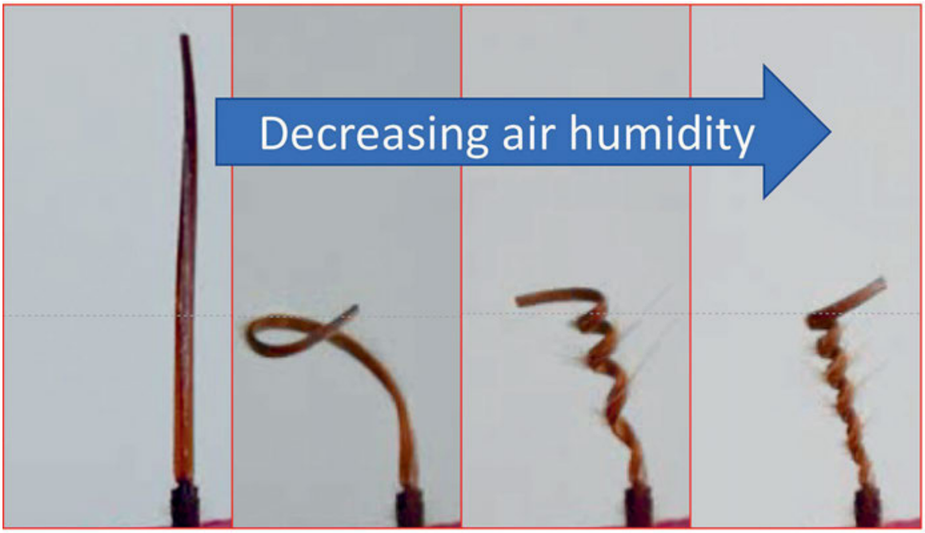

Fig. 6: Erodium awn.

composed of micro fibrils and cell structures with hydrophilic or hydrophobic inner surfaces. This is where Peter Fratzl's research on biomaterial's activity jives with Jürgen Rabe's analysis of material activity driven by internal interfaces, where the attraction of water controls both their mechanical and electronic activities.[17]

The swelling or shrinking of the material as its fundamental activity is performed by the water that enters or leaves the hollow interstices of the cellulose structure. The material structure reacts to the changing environment or boundary condition of humidity and temperature; there is no sender or receiver, but a nested structure of many interconnected layers, where the special intrinsic geometric arrangement of the material defines and controls its performance. In plants, the actual performance depends on the inner geometry of the cellulose fibers whose properties can vary between strong stiffness and high flexibility.

In the case of wood used as a stiff construction material, this intrinsic activity of cellulose has to be minimized as much as possible. Plywood tries to silence this activity when different wood layers are glued together to a rigid staple. The directions of the inner possible activity of every layer are oriented in counter direction so as to mutually neutralize each other. It becomes obvious that passivation or passivity is not an absence of activity, but the neutralization of forces to achieve a stable equilibrium that

17 Hu Lin et al., "Reversible Switching of Charge Transfer at the Graphene-Mica Interface with Intercalating Molecules," *ACS Nano* 14 (2020): 11584 – 604, https://doi.org/10.1021/acsnano.0c04144; Hu Lin et al., "Influence of Interface Hydration on Sliding of Graphene and Molybdenum-Disulfide Single-Layers," *Journal of Colloid and Interface Science* 540 (2019): 142 – 47, https://doi.org/10.1016/j.jcis.2018.12.089.

has the ostensible effect of passiveness. If stronger forces or humidity are applied, the stable structure may "explode" and lose its stability.

The difference between activity and passivity, stiffness and flexibility, however, is also a question of scale, according to which a process appears to be static, slow, or fast. The interaction between environmental conditions and materials structure is the performance, the material itself. The inner structure is organized in terms of interfaces, acting as a filter of its environment and providing the two necessary elements of a mechanical couple. Water that interacts with material surfaces that attract or repel it is a component as essential as the inner geometry and architecture of the material. The interplay between the fluid and the cellulose encodes the activity.

Wood as an exemplary bio-material shows the fitness of an open system in terms of specific functions, containing distributed agency and information embodied within the material structure. The material is not at all passive—it is composed of cellulose, water, and their interaction transformed into activity. All of its material structure is defined by this activity. If the material is taken out of its natural context, it loses its special function. This intrinsic interaction of biological materials depends on a completely different version of relating material, energy, and information that are all integrated into one and the same material structure.

And it is obvious that the analysis of this constellation requires a different approach. Compared to our technology in general, the awn—taken as an exemplary model system—shows a fundamental difference. There is a dynamic cellulose structure that interacts with its environment and thus produces the intrinsic code and energy necessary for the possible performance of a certain function.

Analog Code

It may be astonishing that a simple awn surpasses digital technology and is able to show that the field of biomaterials can be taken as a starting point for a material revolution and an "analog age" to come.[18]

Today, the enormous distance that defines the classical decisive gap between material and code, matter and mind can be transformed into the analysis of active material, where one can identify the same duality in its essential form: the material and the symbolic. Now, however, active material can be regarded as its intrinsic entanglement and radical fusion. From this perspective, biological material is an example of a different kind of symbolic operation or emergence. The material's structure is the code of its own operation, the motor of the activity and a sensor for being responsive, adaptive and interactive with the environment that is not an additional but an essential element

18 In contrast to Alexander Galloway, it has to be emphasized that we did not yet arrive at all at an age of analog, but the real challenge is bring a future analog age into being. Alexander Galloway, "Golden Age of Analog," *Critical Inquiry* 48, no. 2 (2022): 211–32, https://doi.org/10.1086/717324.

of the material's activity. This kind of machine is integrated—it is symbolic material operation. Material activity, information, and energy are intertwined within one and the same dynamical structure.

This new notion of active or symbolic material changes our classical understanding of material and code. Materials being regarded as different to code do not only symbolically represent but also physically execute their intrinsic information at the same time. This is a downright revolutionary analog device compared to digital coded machines. This is why, today, matter has to be examined as active, coded structures in order to reset the prevalent idea of algorithms and code within matter itself, thus reinventing the analog as a new code.

The material code, which now can be taken as the basic constellation for the analog code, is not a flow or chaotic process.[19] A symbolic system which is not discrete but continuous, material and symbolic at the same time is the very classical realm of geometry. Since Greek antiquity, geometric elements are considered continuous in contrast to discrete numbers and letters. And it was regarded as both symbolic and spatially extended, combining the symbolic and the material (fig. 7).

Analyzing more closely Euclid's *Elements*, one can see that geometric elements are not static objects, but operations and, in a certain sense, essential boundary conditions: the plane is a boundary of the 3D body, the line is a boundary of the plane, and the point is a boundary of the line. In this sense the elements combine presence and absence, the point the boundary of all boundaries, and as such an essential absence. Euclid's point is a *σημεῖόν*, a sign, a relationship, and as such a fundamental operation. Nevertheless, it exists due to its very constraint that makes its activity possible. Therefore, the point is an original difference and an activity that extends itself in terms of angles or lines.

The Euclidean point-sign is in the same way as the Epicurean atom not a minimal passive unity of space or matter but a fundamental geometric operation, *παρέγκλισις* (*parénklisis*), a swerving.[20] Geometry is an ancient analog operative system based on a small ensemble of devices such as point, angle, plumb line, gnomon, lever, spindle, or mesolabium, a system that was explicitly reset in Early Modernity by Leon Battista Alberti, Albrecht Dürer and Leibniz. All these constellations show that over long periods of time—which can be understood as past "analog ages"—the idea of geometric operations had been a basic feature. But still today, this operational character of geometry is crucial for rethinking the analog as a symbolic operation that not only represents what it is referring to, but also performs it as such.[21]

19 There is a real need for a fundamental philosophical perspective on the analog. Only partially relevant: Brian Massumi, "On the Superiority of the Analog," in *Parables for the Virtual Movement: Affect Sensation* (Durham, NC: Duke University Press, 2002); also Galloway, "Golden Age of Analog."

20 According to Cicero, *De finibus bonorum et malorum: Libri quinque* 1 (Cambridge, UK: Cambridge University Press, 2010). See also Michel Serres, *Birth of Physics* (Manchester: Clinamen Press, 2000).

21 This genealogy of geometry as an analogue code is the object of my research over years and will be published soon in two volumes. For elements of this genealogy see: Wolfgang Schäffner, "The Point: The

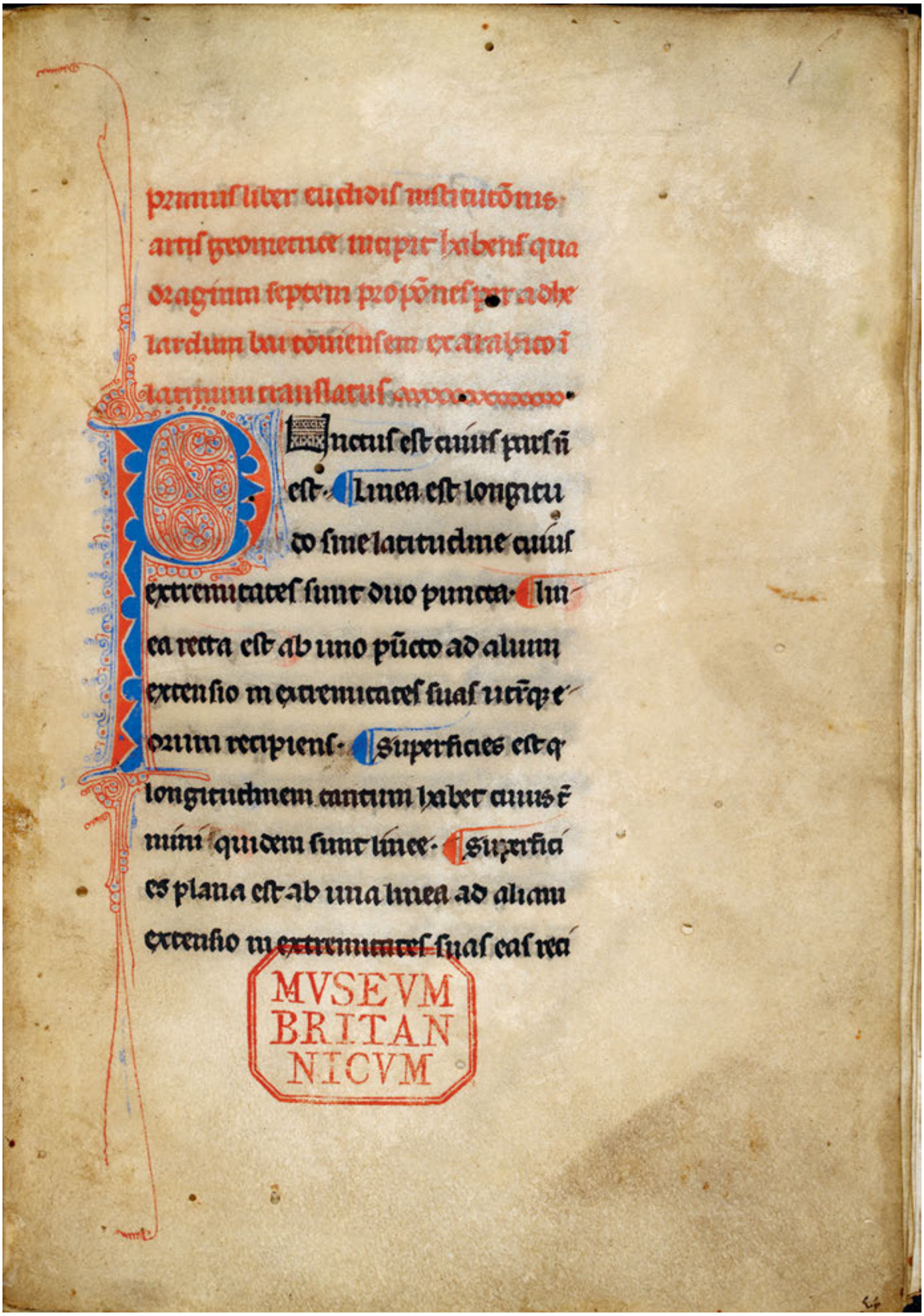

Fig. 7: Euclid, *Elementa* (translated by Adelard of Bath), ed. Johannes Campanus (Venice: Erhard Ratodolt, 1482).

The idea of analog code challenges the classical term of code based on alphanumeric or informational perspectives. In recent years, there have been huge efforts in the field of bio-informatics to go beyond a reductionist understanding of "information under the dominant computational form," as Pedro Marijuán put it in his seminal paper "Information and Life."[22] Erwin Schrödinger already argued in this way, when the gene was regarded as a code: "But the term code-script is, of course, too narrow. The chromosome structures are at the same time instrumental in bringing about the development they foreshadow. They are law-code and executive power—or, to use another simile, they are architect's plan and builder's craft—in one."[23] In a similar way, René Thom criticized the idea of linear code as reducing DNA's "topological complexity . . . and throw[ing] away almost all of its significance."[24] "A finite sequence of letters taken from an alphabet . . . is only one of the possible aspects of information; any geometric form whatsoever can be the carrier of information."[25] Thom refers precisely to geometric structures at work everywhere in the material structures, which becomes the starting point for a new understanding of code.

This kind of analysis is further developed in studies about the insufficient status of information theory to explain functional and interactive modes referring mainly to the transition from nonliving to living, and from living systems to those capable of thought. Terrence Deacon's book *Incomplete Nature* tries to bridge these thresholds by symbolic potentialities that emerge within nested hierarchical structures.[26] My analysis of materials does not primarily address "life" or "consciousness," but focuses these questions on the fundamentally active, symbolic qualities of the material and its coded structure. Consequently, talking about active or symbolic material is not about adding additional dimension to matter, but making the absent potentialities visible beyond the mere presence of a material structure.

Material is not a substance, but a process and a relationship between something present and something absent, something that is not, or not yet. Deacon's focus on absence as a fundamental—and generally overlooked—feature in nature's processes is at the core of the question about symbolic material. In this sense, functions, adaptive processes, and potentialities as basic elements of the symbolic dimension of materials result from this structural absence inherent in the materials' geometric structure. The

Smallest Venue of Knowledge in the 17th Century (1585–1665)," in *Collection Laboratory Theater: Sciences of Knowledge in the 17the Century*, ed. Helmar Schramm et al. (Berlin: De Gruyter, 2005); Wolfgang Schäffner, "Euklids Zeichen: Zur Genese des analogen Codes in der Frühen Neuzeit," in *Bildwelten des Wissens: 7, 2 Mathematische Forme(l)n* (Berlin: De Gruyter, 2010).

22 Pedro Marijuán, "Information and Life: Towards a Biological Understanding of Informational Phenomena," *TripleC* 2, no. 1 (2004): 6–19.

23 Erwin Schrödinger, *What Is Life* (Cambridge, UK: Cambridge University Press, 1992), 20.

24 René Thom, *Structural Stability and Morphogenesis: An Outline of a General Theory of Models* (Reading, MA: W. A. Benjamin, 1975), 157.

25 Ibid., 144–45.

26 Terrence Deacon, *Incomplete Nature: How Mind Emerged from Matter* (New York: W. W. Norton, 2012).

symbolic dimension is not an additional element but an intrinsic feature of active materials, and therefore the basic condition of an analog code.

It is helpful to remember again the robotic arm where function seems to be externally added by the code transmitted. However, in contrast, one can invert the classic idea of function. As an effect of constraints imposed on the machine that prevent it from doing everything possible, function is not an addition to its material and energy: "This negative view of function is easily recognized in the case of machine failure. When constraints break down, and previously restricted states or behaviors of the machine become possible, functionality is degraded."[27] Boundary conditions reduce the degrees of freedom and produce information.

Here, the dominant role of structures and morphologies becomes evident: points, point defects, holes, interfaces, hyperbolic structures, etc., geometric operations being the most active elements directed to something absent. Their relational character deeply intertwines structures and environments as boundaries of boundaries, where material, energy, and information are intrinsically related. This shift from substance to process is analyzed at the Cluster, which focuses on weaving, filtering, and cutting as intrinsic features of the material, as active processes producing relationships and boundaries that redefine the property of the material by interlacing the structure and its environment. This is where information and the symbolic emerge as an intrinsic process of materials.

Thus, the pure dichotomy of the symbolic and the material is transformed into an interrelated structure, where the material existence is defined in terms of constraints and absence, thus containing the symbolic. Overcoming this dichotomy, however, does not only change the idea of material from passive to active and symbolic materiality. Similarly, vice versa, the symbolic requires a different material character. The classical idea of ideal symbolic objects is in the same sense dependent on a silenced, passivated, and de-materialized material carrier. If such a de-materialization of material allowed a kind of fusion of the material and the symbolic, the seemingly extracted and abstracted quality of the graphic operation would now need to be conceived as active matter.

Looking back once more to the graphic surface of paper, one can say that it now makes sense as part of the materials' table: it is another starting point—alongside wood, seed capsules, or biofilms—that needs a fundamental figure-ground inversion for making its active matter evident. This is the place of my own research on geometric operations, on points, lines, and angles as active processes, as boundary conditions and constraints of degrees of freedom. The geometric point is a symbolic and spatial operation, it is a fundamental difference and absence, placed at the core of the idea of active materials.

27 Terrence Deacon, "Shannon—Boltzmann—Darwin: Redefining Information (Part I)," *Cognitive Semiotics* 1, no. 1 (2013): 123–48, 129, https://doi.org/10.1515/cogsem.2007.1.fall2007.123.

Outlook

My historical and theoretical genealogies of geometric operations as analog code are linked with the transversal importance of geometry as an operative system within active materials at MoA. Active matter has to be synthetically analyzed so as to make it visible as a decisive historical moment of an extraordinary coincidence in various disciplines, as some sort of contemporary *episteme* and order of things. Dealing with the reinvention of the analog goes far beyond a mere epistemic analysis, and requires feedback-looping speculative and historical epistemology with experimental practice and design projects.

On our interdisciplinary operation table, where this new order of things and analog code can be developed, we put different materials as model systems: seed capsules, biofilms, or felt, all of which consist of highly dynamic structures, mostly based on fiber structures. They become part of a new kind of epistemic endeavor that performs historical, epistemological, and intercultural practices within the science lab through corresponding experimentation of active materials and in the workshops for developing new design processes. We also analyze cultural practices related to active and symbolic materials, traditional practices within, and, above all, outside of Europe. This endeavor is not about extraction but a mode of learning rooted in a commitment to respect cultural integrity and ensure equitable collaboration. As long as design is understood as transferring preconceived design ideas into matter, the material still plays the role of the passive recipient of the design idea. Design, especially in its modern form up to today's 3D printing, is a highly constructivist process relying on programming passive materials. This idealistic core of design is equal to the classical engineering process of implementation and thus part of the same strategy. This approach changes radically when we take the material's intrinsic activity as the starting point for design processes. Thus, result- and shape-oriented design is transformed into an adaptive, process-oriented procedure that includes mutual adaption of material and building process with its environment, comparable to traditional cultural practices developed over long periods of time, and, above all, to natural processes of biological growth. Instead of implementing human intelligence into the world, the thorough analysis of active material is finally directed toward a new kind of design, able to merge technical and natural processes in a nondestructive manner.