SEVEN

Ludic Algorithms

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Llull's Great Art

"Calculemus!"

Jonathan Swift's Gulliver, on the aerial leg of his *Travels,* finds himself in the lofty scholastic community of Laputa, where he encounters a professor with a strange device. The mechanism consists of a series of rotating blocks on which are inscribed words in the Laputian language and which, in use, resemble nothing so much as a mystical foosball table (figure 7.1). A few vigorous turns of the crank (for which the professor employs a team of undergraduates) produce what Robert de Beaugrande might call a "combinatoric explosion" of information: words combine randomly to produce sense and nonsense, the finest fragments of which are diligently recorded as the "wisdom" of Laputa. In this manner, Swift tells us, "the most ignorant person at a reasonable charge, and with a little bodily labour, may write books in philosophy, poetry, politics, law, mathematics, and theology, without the least assistance from genius or study."[1]

The Laputian device, a "Project for improving speculative Knowledge by practical and mechanical means," and Swift's unflattering description of the professor who invented it, are sometimes thought to satirize Gottfried Wilhelm Leibniz, whose 1666 *Dissertatio de Arte Combinatoria* made far-reaching claims for the ability of mathematical and mechanical languages to generate wisdom and solve conflict.[2] Leibniz went so far as to suggest that, in the future, every misunderstanding or disagreement "should be nothing more than a miscalculation . . . easily corrected." Disputing philosophers could take up their abaci and settle even delicate theological arguments mechanically, saying "Calculemus!"—"Let us compute!" (Leibniz).

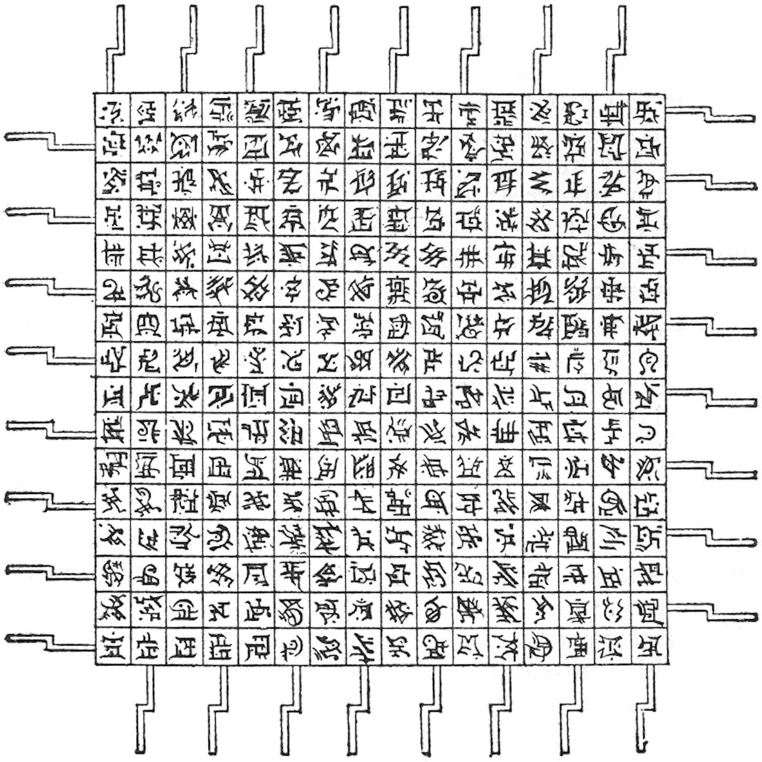


Fig 7.1: Swift's "Literary Engine." *Gulliver's Travels,* 1892 George Bell and Sons edition. Project Gutenberg.

In fact, a better-supported candidate for Swift's vitriol is Leibniz's acknowledged predecessor in the combinatoric arts, a colorful medieval polymath and sometime poet, rake, and martyr named Raimundus Lullus, or Ramon Llull (ca. 1232–1316). Lull's chief invention was a so-called Ars Magna of inscripted, inter-rotating wheels developed in the latter decades of the thirteenth century and articulated in a treatise titled *Ars Generalis Ultima*. Its purpose was at once generative, analytical, and interpretive, and while its primary subject matter was theological, Llull was careful to demonstrate the applicability of the Ars Magna to broader philosophical and practical problems of the day. In other words, Llull's wheels constituted a user-extensible mechanical aid to hermeneutics and interpretive problem solving (figure 7.2). Properly understood, Llull and his Great Art can take their place, not in the soaring halls of Laputian "speculators" and pseudoscientists, but among a cadre of humanists with fresh ideas about the relation of mechanism to interpretation.

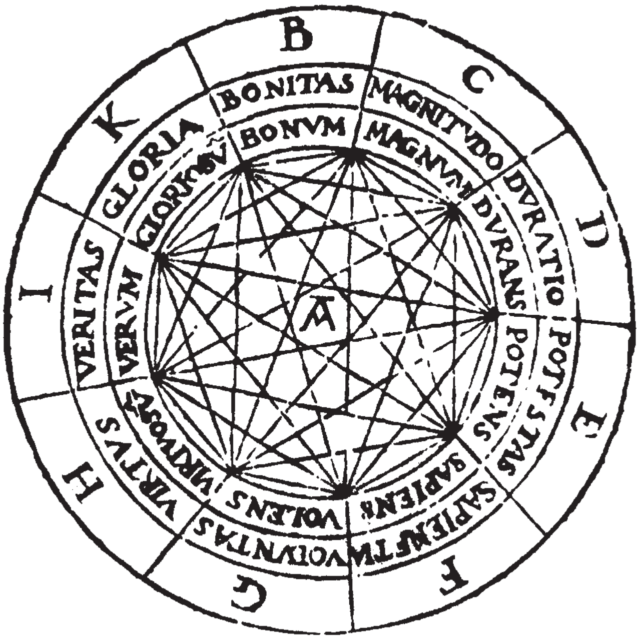


Fig 7.2: Lullian Wheel. Wikimedia Commons.

A review and description of Llull's tool, with attention to its structure and function and to past misunderstandings as to its purpose, will help situate instrumental issues that many digital humanities projects must address today. Among these are problems involved in establishing scholarly primitives and developing the rules or algorithms by which they can be manipulated in creative and revelatory ways.[3] Llull also provides a framework in which to examine the relationship between algorithmic and combinatorial methods and subjective hermeneutic practices, and to demonstrate the utility of performative instruments or environments that share in his design model. This is a model for mechanisms that are generative, emergent, and oriented toward what we would now call humanities interpretation.

Llull's intriguing device is widely recognized as a precursor both to computer science—in its emphasis on a mechanical calculus—and to the philosophy of language, in its use of symbols and semantic fields.[4] After early popularity in the universities of Renaissance Europe, however, it met with sharp and lasting criticism.[5] François Rabelais's Gargantua warns Pantagruel against "Lullianism" in the same breath as "divinatory astrology"; it is "nothing else but plain abuses and vanity."[6] And Francis Bacon describes the Ars Magna as "a method of imposture . . . being nothing but a mass and heap of the terms of all arts, to the end that they who are ready with the terms may be thought to understand the arts themselves." Such collections, Bacon observes, "are like a fripper's or broker's shop, that has the ends of everything, but nothing of worth."[7]

Modern critics also deride Llull. Even Martin Gardner, whose 1958 *Logic Machines and Diagrams* views the Ars Magna as foundational to the history of visual and mechanical thinking—Llull is Chapter One!—suggests that the best uses for his once-influential combinatoric system are (in Gardner's words) "frivolous": for example, to generate possible names for a baby, to work anagram puzzles, or to compare and combine colors for application in design and interior decorating.[8]

Gardner holds that any more sophisticated or scholarly use of Llull's device—particularly in fields like history and poetics—is wholly inappropriate. The spinning wheels, when applied to humanistic subject matter lacking in native "analytic structure" and for which there is "not even agreement on what to regard as the most primitive, 'self-evident' principles," generate only circular proofs. "It was Lull's particular distinction," Gardner writes, "to base this type of reasoning on such an artificial, mechanical technique that it amounted virtually to a satire of scholasticism, a sort of hilarious caricature of medieval argumentation."[9] We may not wish to go so far (like his great proponents Peter Bexte and Werner Künzel) as to claim Llull as "der erste Hacker in den himmlischen Datenbanken" (the first hacker of the heavenly databases!), but it seems clear that the most scathing criticisms of the Ars Magna stem from a fundamental misunderstanding of the uses to which Llull meant his device to be put.[10]

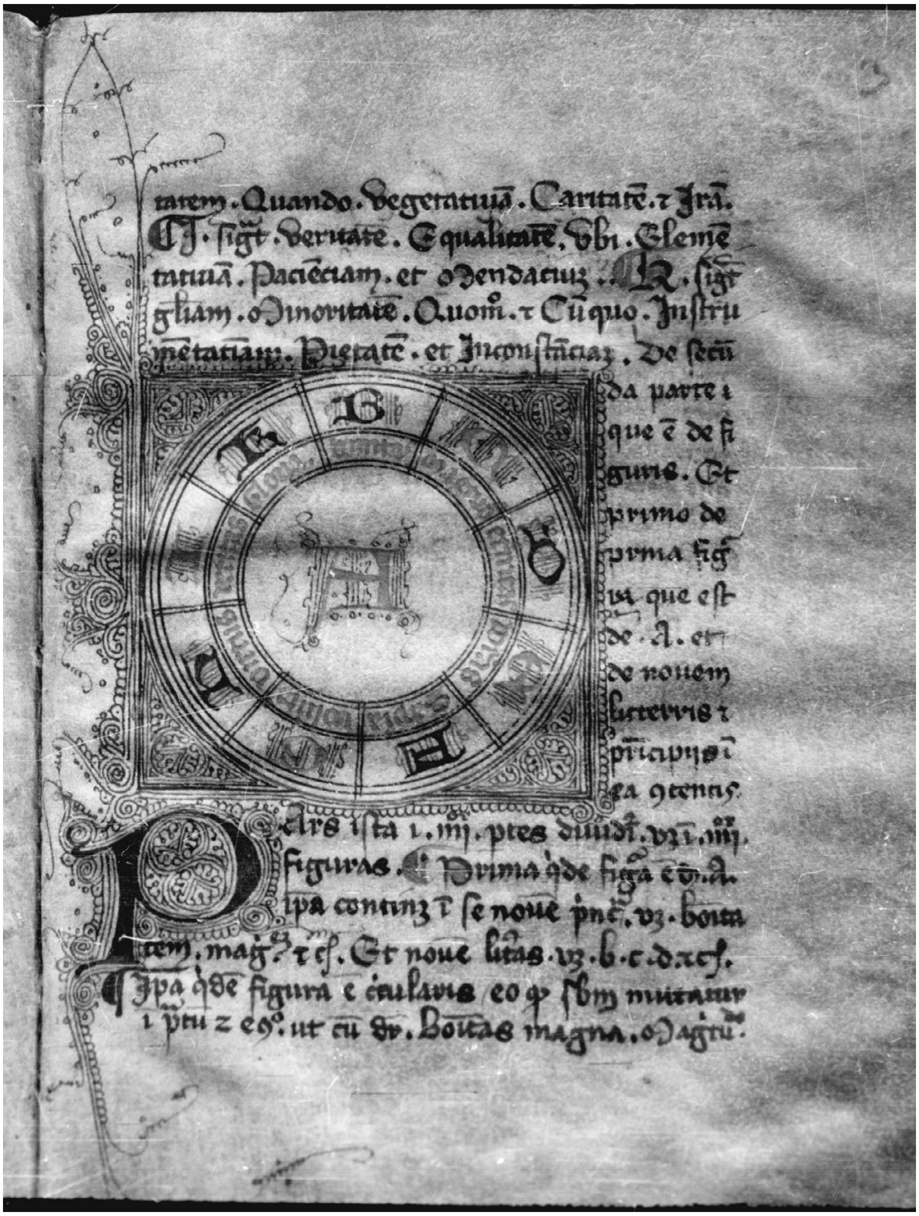
Künzel is right, in *The Birth of the Machine,* to describe Llull's system of interlocking, inter-rotating wheels as an ancestor of the Turing machine, a logic device, "producing results, statements—output of data in general—by a clearly defined mechanical algorithm."[11] However, we would be wrong to assume, as Bacon and Gardner did, that we are to interpret as truth the statements generated through this algorithm (that is, by Llull's proscribed procedure of marking and spinning wheels and diagramming their results). In fact, the linguistic combinations that Llull's wheels produce are only meant to be interpreted. That is, Llull invented a device for putting new ideas into the world out of the fragments of old ideas and constraining rule sets, but left the (inherently subjective) evaluation and explication of these emergent concepts up to a human user—a person explicitly figured in his writing as an *artista.* Llull's machine generates "truthful" formulations equally with falsehood, and makes no claim about or evaluation of its own output: "naturally, only the artist using the machine is able to decide which statement is true and which is false. The machine independently produces both: the universe of truth and the universe of the false, step by step."[12]

"Right Round, Baby, Right Round"

In building the Ars Magna, Llull began by establishing a manipulable alphabet of discrete, primary concepts or primitives on which his algorithmic and mechanical procedures could operate. The most commonly accepted (and least complex) version of this Art associates nine letters of the Latin alphabet, *B* through *K,* with fundamental aspects of divinity: goodness, greatness, eternity or duration, power, wisdom, will, virtue, truth, and glory. The letter *A* stands in for the Divine, and is placed at the center of a circular diagram (figure 7.3), which in itself becomes a hypothetical definition of God.[13] When lines are drawn to connect each of the nine letter-coded aspects (showing in binaries, for example, that God's goodness is great [*BC*], God's virtue lies in truth [*HI*], etc.), Llull expresses the basic relational character not only of divinity, but also of his very notion of an *ars combinatoria*. Combinatoric elements are not simply reordered, as with Swift's Laputian machine; here they are placed for careful consideration in conjunction.

Resultant graphs—which, as we will later see, Llull considered to be dynamic rather than static—form the simplest interpretive tool of the Ars Generalis Ultima. The art is properly thought of as interpretive rather than explicatory, because the conjoined components of the definition of God that it expressed were not meant to be accepted flatly by its audience, but rather contemplated, analyzed, and above all contrasted against the opposites implied by the structural workings of the diagram—the qualities of fallen mankind. Rich rhetorical expression in these combinations comes into focus through the user's own faculties of comparison and analogy as generated structures suggest, for example, that the power of human rulers (letter *E*)—unlike that of the defined divinity—is not always commensurate with their wisdom (letter *F*).

As a next step, Llull's binary relationships are complicated by the application of a separate assemblage of meanings attached to his established alphabet, and a further series of diagrams. The concept of "an ending" in these elaborations, for example, may be interpreted as it relates geometrically to labeled notions of privation, termination, or perfection. Therefore, even the graphic organization of Llullian concepts participates in an expression of the enabling constraints under which his concepts are meant to function and through which they are enlivened.



3

tatem. Quando. vegetatiuā. Caritatē. τ Irā.
CI. sigt. veritate. Equalitatē, Ubi. Eleme
tatiuā. Paciēciam. et Mendaciuz .. K. sigt
gliam. Minoritatē. Quom. τ Cūquo. Instru
mētatiam. Pietatē. et Inconstāciaz. De secū
da parte i
que ē de fi
guris. Et
primo de
prima fig
ra que est
de. A. et
de nouem
litteris τ
p̄ncipijs i
ea ɔtentis.
P Ars ista i. iiij. ptes diuidit. vz i. iiij.
figuras. Prima q̄de figa est. A.
Ipa continz i se noue p̄nc. vz. bonita
tem. mag. τ c. Et noue litas. vz. b. c. d. τ c.
Ipa q̄de figura ē circularis eo q sbm mutatur
i p̃tu z eco. ut cu dr. Bonitas magna. Magnitu.

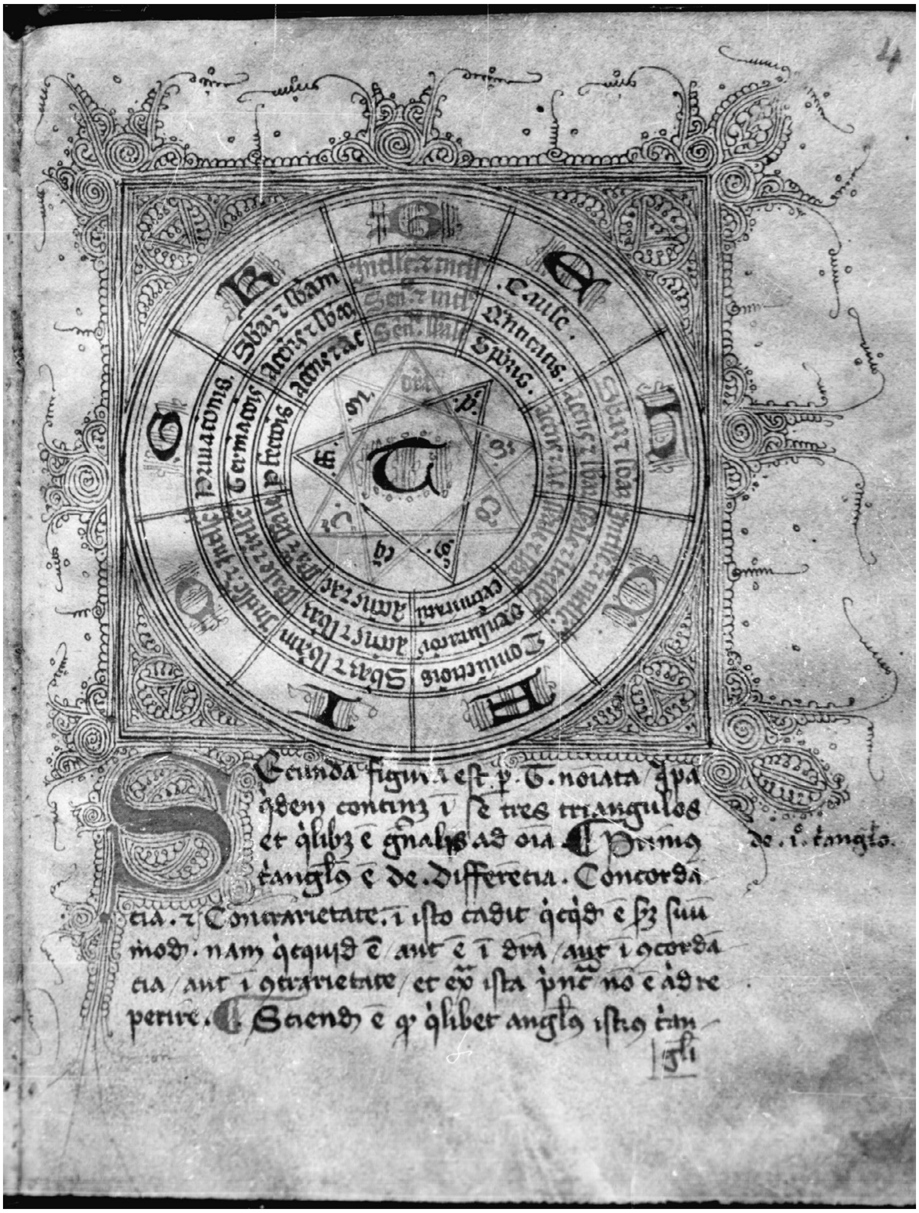
Fig 7.3: Llull's Figure A. Ars Brevis, Biblioteca El Escorial, Madrid Ms. f.IV.12 folio 3r. Digital reproduction, Raimundus-Lullus-Institut, Freiburg.

Llull's embodied relations permit the generation—for further analysis—of a phrase like "goodness has great difference and concordance." An elevated pronouncement, indeed, but steps are taken to constrain output that could otherwise provoke an overly general discussion, through a generative process involving the insertion (via separate diagrams, figures 7.4 and 7.5) of a set of specific sense-perceptive and intellectual relations. A statement like "goodness has great difference and concordance," then, is presented by Llull's circles not as an eternal truth, but rather in order that it be interpreted within a specified context—that of sensual and intellectual differences—and in all the embedded relations among those fundamental domains.

For all its complexity and utility in generating relational assertions, thus far the Great Art limits itself to binary structures, and to interpretations based on fundamentally invariable graphs and matrices. With the introduction of a novel fourth figure, however, Llull expands his system from binary into ternary relationships, and moves from abstract algorithm and diagrammatic reasoning into the realm of mechanically aided hermeneutic practice (figure 7.6). He does this first by adding to the semantic weight of the primary alphabet a set of interrogatives (who, what, why, etc.) or—as he puts it—interpretive prompts. The prompts become part of a functioning rule set for procedure and elucidation when they are inscribed, along with Llull's other encoded alphabets, on *volvelles*—exquisite, manipulable, inter-rotating wheels.

While versions of Llull's wheels have been fashioned from a variety of media (including, most interestingly, the copper "covers" of a portable Italian Renaissance sundial masquerading as a book), they typically took the form of paper circles secured within incunabula and manuscripts by small lengths of string (John Dalton). The compartments, or *camerae,* of an outer circle would be inscribed on the page, while two inner circles were fastened on top of it in such a way as to permit them to rotate independently, mechanically generating interpretive problems based on ternary combinations of the alphabetic ciphers inscribed on them.

Llull's wheels appear deceptively simple, but for the basic combination of two letters alone, they are capable of posing thirty-six issues to their human interpreters: twelve propositions (such as "goodness is great") and twenty-four questions or philosophical problems (like "what is great goodness?" and "whether goodness is great") multiplied down the succession of associations between, for example, goodness and difference, goodness and concordance, and so on. When three rather than two primary elements are combined with their associated questions or interpretive rules, as is enabled by the embedded, rotating wheels, even more complex problems can present



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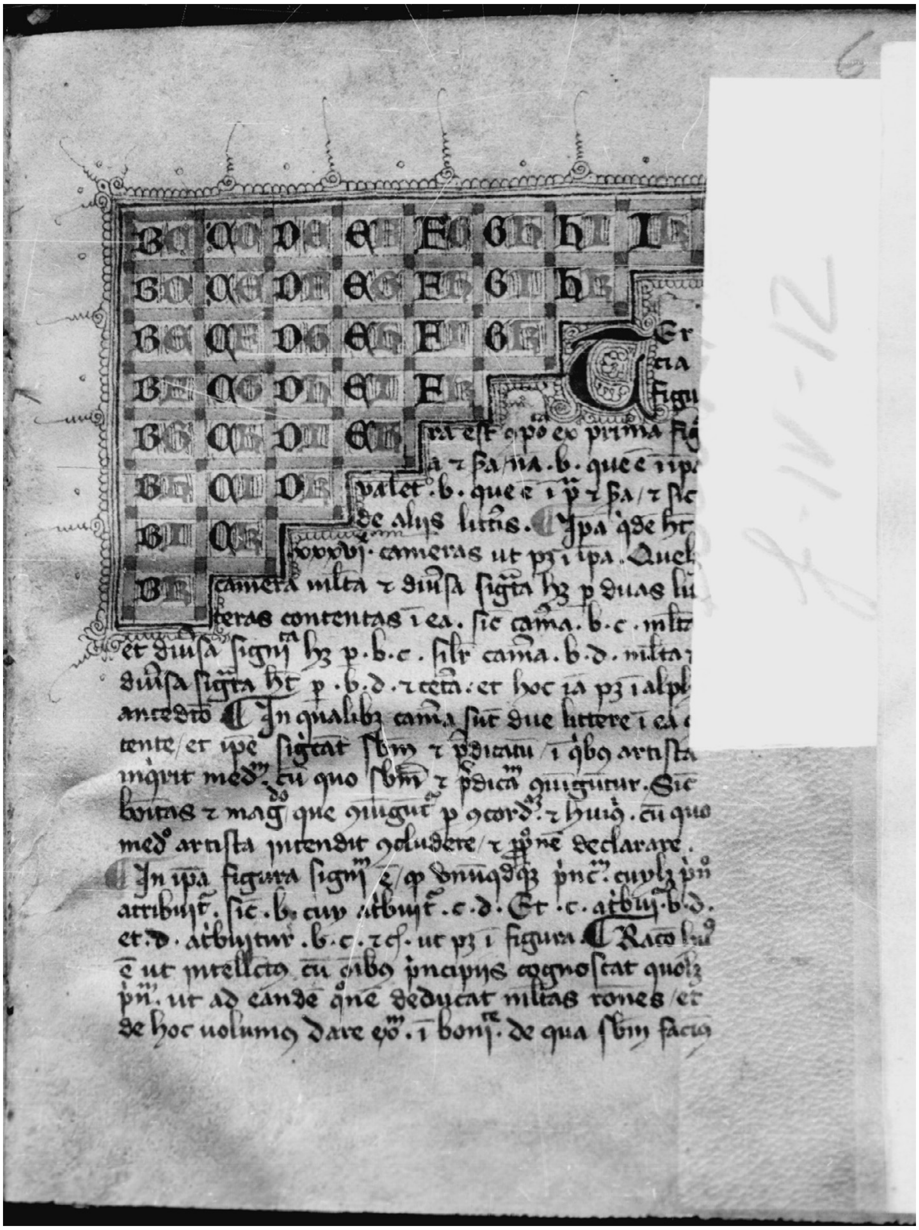
Secunda figura est .T. noiata qua
quem continz i se tres triangulos
et qlibz e gnalis ad oia. ¶ Primus
tanglo e de. differetia. Concorda
tia. 7 Contrarietate. i isto cadit qcqd e sz suu
mod. nam qcquid e aut e i dra aut i ocorda
cia aut i otrarietate et ex ista pne no e adre
petire. ¶ Sciend e q qlibet anglo isto tan
tli

de .i. tanglo.

Fig 7.4: Llull's Figure T. Ars Brevis, Biblioteca El Escorial, Madrid Ms. f.IV.12 folio 4r. Digital reproduction, Raimundus-Lullus-Institut, Freiburg.



6

BC	CD	DE	EF	FG	GH	HI	IK
BD	CE	DF	EG	FH	GI	HK	
BE	CF	DG	EH	FI	GK		
BF	CG	DH	EI	FK			
BG	CH	DI	EK				
BH	CI	DK					
BI	CK						
BK							

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valet. b. que e i p̄ ⁊ s̄a / ⁊ sic
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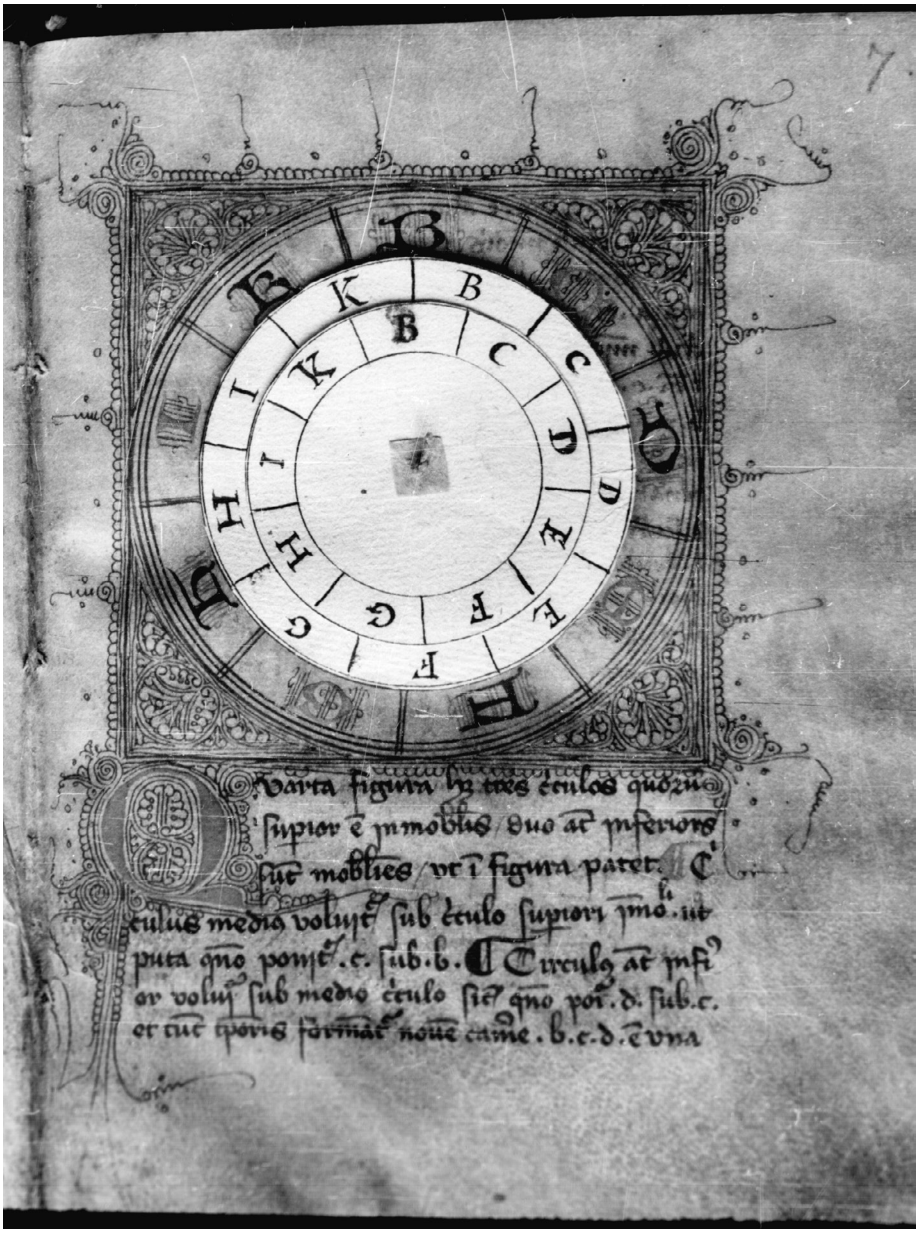
xxxvj. cameras ut pȝ i ipa. Quel
camera multa ⁊ diusa sigta hȝ p duas lit
teras contentas i ea. sic cama. b. c. mlt
et diusa signa hȝ p. b. c. silr cama. b. d. multa ⁊
diusa sigta ht p. b. d. ⁊ cetera: et hoc ia pȝ i alph
antedcto. In qualibȝ cama sut due littere i ea c
tente / et ipe sigtat sbm ⁊ pdicatu / i qbȝ artista
inqrit medm cu quo sbm ⁊ pdicatm cungutur. Sic
bonitas ⁊ magdo que cuingut p cord. ⁊ huiu. cu quo
medo artista intendit cocludere / ⁊ sunt declarare.
In ipa figura signm e / qr vnuqdqz pnc. cuiulz pn
attribuit. sic. b. cui atbuit. c. d. Et. c. atbuit. b. d.
et. d. atbuitur. b. c. ⁊ cet. ut pȝ i figura. Racio hui
e ut intellectus cu oibȝ pncipijs cognoscat quolz
pn. ut ad cande qne deducat multas rones / et
de hoc volumꝰ dare exm. i bonit. de qua sbm facim

f-IV-12

Fig 7.5: Third Figure, Half Matrix. Ars Brevis, Biblioteca El Escorial, Madrid Ms. f.IV.12 folio 6r. Digital reproduction, Raimundus-Lullus-Institut, Freiburg.


7
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Quarta figura hz tres c̄culos quorũ
ſupior ē īmobilis / duo aũt inferiores
ſūt mobiles / vt ī figura patet. ¶ Cir-
culus medius voluit ſub c̄culo ſupiori īmobili. ut
puta qn̄o ponit .c. ſub .b. ¶ Circulꝫ aũt infi
or voluit ſub medio c̄culo ſicut qn̄o poit .d. ſub .c.
et tūc tporis formant noue camere .b.c.d. ē una

Fig 7.6: Llull's Fourth Figure, The Volvelle. Ars Brevis, Biblioteca El Escorial, Madrid Ms. f.IV.12 folio 7r. Digital reproduction, Raimundus-Lullus-Institut, Freiburg.

themselves: for example, “whether goodness contains within itself difference and contrariety.”[14]

Llull works out the results of his generative machine in tables similar to the half matrix used to express the simple relations of his first circular figure. In the Ars Brevis of 1308, a simplified version of his Great Art, the corresponding table has seven columns—but Llull’s Ars Generalis Ultima presents the relations that emerge from expanded iterations of the rotating wheel concept in a table with no less than eighty-four long columns. Each alphabetic expression in these tables has been algorithmically, logically, and mechanically generated for rhetorical and hermeneutic purposes, in service to what Stephen Ramsay has called “humane computation.”[15] The cumulative effect is of an “extraordinary network of systems systematizing systems,”[16] and yet the Llullian apparatus exists in service of interpretive subjectivity.

Llull is thought to represent the “earliest attempt in the history of formal logic to employ geometrical diagrams for the purpose of discovering nonmathematical truths, and the first attempt to use a mechanical device—a kind of primitive logic machine—to facilitate the operation of a logic system.”[17] Llull’s wheels can be thought of as the “hardware” of this system, with the interpretive method he advocates for their use serving as software, expressed, along with output from the devices, in user manuals like the Ars Generalis Ultima.

It is important to remember, however, that most of the diagrammatic figures generated by Llull’s wheels do not explore “truths” at all, but instead pose interesting queries and hypothetical situations for their users: for example, “when it might be prudent to become angry” or “when lust is the result of slothfulness.” Llull also uses the wheels to help puzzle out such “typical medieval problems” as “If a child is slain in the womb of a martyred mother, will it be saved by a baptism of blood? . . . Can God make matter without form? Can He damn Peter and save Judas?” Llull’s *Book of the Ascent and Descent of the Intellect* moves beyond the theological sphere to apply his method to eight categories of natural philosophy, in order to pose and suggest possible answers to scientific problems like “Where does the flame go when a candle is put out?” or “Why does rue strengthen the eyes [while] onions weaken them?”[18]

In the books accompanying his charts and diagrams, Llull sometimes offers full arguments and commentaries on such questions, sometimes outlines the combinatorial processes by which the questions could be addressed using his wheels, and sometimes simply demonstrates diagrammatically that such sophisticated questioning can be generated by means of the Ars Magna. At no point does Llull imply that his machine can produce “truth” independently from its human user, no matter how scientific his alphabetic abstractions appear. Instead, he himself tells us that the system employs "an alphabet in this art so that it can be used to make figures as well as to mix principles and rules for the purpose of investigating the truth."[19] That is, the mechanism enables interpretation through visualization, by making the core elements it operates on and the rules by which it plays explicit. The flat generation of combinations is not the point of his Great Art: that is not hard to do. In addition to the requisite hardware, Llull provides his users with a clearly specified method for analyzing both process and output outside of the generative system—and more importantly, for refining that system iteratively, based on subjective human assessment of its mechanical output. Interpretation is the real activity of the Ars Magna, not the spinning of wheels.

Despite their hermeneutic teleology, Llull's devices participate closely in two traditions that exhibit a vexed relationship with humanistic interpretation. Any "step-by-step" production of what Künzel terms interpretive "universes" is by nature an algorithmic production, and the mixing of principles and rules on which Llull's work depends is a nice elaboration of the notion of an *ars combinatoria.* An appreciation of both of these traditions and the methods that support them is critical to our understanding, not only of Llull and his interpretive devices, but also of the promise of digital tools and environments—that they might augment our methodologies and offer greater latitude to humanities scholarship.

Performance and Interpretation

Fitting Four Elephants in a Volkswagen

Llull is often listed among the first philosophers "compelled to delineate clearly a general method" for deriving conclusions.[20] Frances Yates goes so far as to assert that the "European search for method . . . began with Llull."[21] We now commonly accept that "logical reasoning is, in a sense, computation" and that it "can be formalized and validated by controllable means,"[22] but Llull's clear and materially embodied articulation of this concept has been seen as an advance in Western philosophy, constituting the first major formal extension of traditional mnemonics, a "now-forgotten integral part of medieval education: the complex set of elaborated techniques for reminding and structuring things in human memory in a printless age."[23] Perhaps more important, Llull's devices also implemented, for the first time in Western Europe, the newly translated rule-based work of the Arabian mathematician al-Khwarizmi, from whose name the word "algorithm" stems.

The relationship between algorithmic operation (as both a concrete and an abstract methodology) and the design and use of interpretive toolsets like the Ars Magna is under-appreciated and perhaps easily misconstrued by humanities arts scholars outside of the tight community involved in building, making accessible, and computationally manipulating the modern digital archive. Algorithms, when thought of as remote, inflexible mathematical structures underlying computer programming and the more deterministic branches of science and engineering, can seem irrelevant or even antithetical to the work of scholarship. Practitioners of the digital humanities face the skepticism of colleagues: by building algorithmic text analysis tools, do we unthinkingly imply that the craft of scholarship can be mechanized? Are we tacitly putting constraints-based process forth as substitute for contemplation and insight? Or (a far more insidious assumption) are scripts and software, as the quiet servants delivering us the "content" of an archive, simply beneath our notice? In fact, algorithms—like various hermeneutic methods and historical schools of thought accepted by humanities scholars—can be understood as problem solving and (with a slight methodological recasting I will suggest in a discussion of the "ludic algorithm") as open, participatory, explorative devices.

The algorithm is formally defined as a finite sequence of instructions, rules, or linear steps which, if followed, guarantees that its practitioner—whether a human or machine agent—will reach some particular, predefined goal or establish incontrovertibly that the goal is unreachable. The "guarantee" part of this description is important, as it differentiates algorithms from heuristics, or what are generally called "rules of thumb." Like algorithms, heuristics can function iteratively to solve a problem and can be responsive to human input. Computer programs that modify themselves in response to their users, such as word processing spell-checkers, are sometimes—despite their algorithmic basis—termed heuristic. The heuristic process, however, is fundamentally one of informal trial and error rather than constrained activity according to a set of predefined rules.

Almost any everyday problem can be solved heuristically or algorithmically. For example: I have lost my car keys. Ordinarily, a harried new mother faced with this situation will proceed by heuristics: "I look in my purse. I look in my purse again. I brave the cluttered diaper bag. I check the front door because I have developed a bad habit of leaving them dangling there. I go to the last place I remember holding them in my hand. I ask my husband if he has seen them. I wish the baby could talk." In formal, graph-based problem solving, heuristics are sometimes used to guide the search for solutions, by identifying the most promising branches of a search tree for further exploration, or even by cutting out unpromising branches altogether. The weak point of the heuristic method becomes evident when its user needs to shift gears. I am not finding my keys in the usual places. Should I retrace my steps next? Is it worth considering that I may have locked them inside the car? The basic "problem with heuristics"—in some cases a crippling problem, which could lead to the inadvertent elimination of the entire branch of a desired outcome branch from the search tree—"is how to decide half-way what would be an appropriate next action, i.e. how to design heuristic rules that lead to good solutions instead of bad ones" (Krista Lagus). Tellingly, we often attribute decisions in successful heuristic processes to intuition and those that result in undesirable outcomes to confusion and bad luck.

If the heuristic process fails or seems too unsystematic for comfort, a desperate searcher can always resort to a true algorithm:

```
For each room in the house; and
For each item in the room;
Pick up and examine the item.
If the item appears by objective criteria to be the missing object, terminate the search.
If not, put down the item and continue this loop until all items have been tested.
```

Eventually, if this little program is executed perfectly, I will either find my keys or determine conclusively that they are not in the house. There's a kind of predestination or special providence about an algorithm, formally defined. That is to say, I know to expect one of two prescribed outcomes before even undertaking the search process. And—as its strict definition requires—the algorithm is almost wholly generalizable. If I suspect I have left my keys at your house, I can run the process there. If the misplaced object is a watch, or a hat, the algorithm is equally applicable. (Of course, it is not a very efficient algorithm because it requires me, for example, to pick up and examine the house-cat—and to do so every time it saunters into a new room—but we can easily imagine more elegant versions of this basic method.)

Some common refinements to the concept of the algorithm are particularly relevant to interpretive or hermeneutic activity, which, by virtue of its realm of application, is generally predicated on ambiguity and flux. Algorithms are expected to be both perfectly precise and entirely implementable. An old bubblegum wrapper joke helps to make this point: how do you fit four elephants into a Volkswagen? The algorithmic answer is that you simply put two in the front seat and two in the back. Although those steps are clearly unambiguous, they are impossible to implement. In contrast is a commonplace algorithm for finishing one's dissertation:

Step 1: Write the next paragraph.
Step 2: Repeat Step 1 until dissertation is complete.

This procedure is clearly implementable—graduate students perform it with great fortitude all the time—but it is far too ambiguous to be a "textbook," or even a useful, algorithm. How exactly does one write a paragraph? What criteria indicate that the thing is "complete"? What is a "paragraph," anyway? How does the algorithm know that you are writing a dissertation and not a thesis, or a novel, or a comic book? (How do you know? That is to say, how determinable from the point of view of the algorithm's designer are the elements in this—in any—interpretive field?) And so the algorithm, originally applied to mathematical operations and associated almost inextricably in the contemporary mind with computer science, emerges as a step-by-step, linear, precise, finite, and generalizable process that produces definitive, anticipated results by constraining the actions of the agent who performs the process.

Almost as quickly as the application of algorithmic methodology to modern mechanical and computational apparatus became a fundamental aspect of design (with Charles Babbage's 1837 Analytical Engine), algorithms themselves fell under fire as analytical or investigative devices. Babbage's colleague, Augusta Ada Byron King, Countess of Lovelace—the daughter of Lord Byron who is celebrated as the first computer programmer for her elaborations of the Jacquard loom-like cards on which the engine operated—famously critiqued the algorithm:

> The Analytical Engine [and, by extension, the algorithmic method on which it is based] has no pretensions whatever to originate anything. It can do whatever we know how to order it to perform. It can follow analysis; but it has no power of anticipating any analytical relations or truths. Its province is to assist us in making available what we are already acquainted with. [24]

Lovelace's objection hinges on the reasonable idea that an algorithm can yield nothing more than its designer knew to ask it for in the first place. Algorithms are not fundamentally creative or revelatory. They merely perform predefined transformations and produce requested—and therefore anticipated or even presumed and therefore potentially flawed—results. We could see this quality, by way of example, in a purely mechanical performance of our car-key algorithm. The procedure's outcome (confirmation or disconfirmation of the presence of car keys) could be in no way unexpected; it is in fact built inextricably into the process. Algorithms are certainly applicable to problem solving, but Lovelace suggests that they only (perversely) solve problems whose answers are projected, which is to say pre-known.

The Lovelace objection and its descendant Turing machine critiques bear a striking resemblance to Martin Gardner's derisive description of Llull's Ars Magna as a means built toward inappropriate ends, and for the manipulation of intractable objects.[25] In such a case, any application of the algorithmic process to subjects for which, in Jerome McGann's formulation, "imagining what you don't know" is a desirable outcome, seems misguided at best. At worst, the use of algorithmic process in an interpretive or humanistic context could be seen as self-delusion justified through pseudoscientific formalism. (Critiques of "frivolous" combinatorial and deformative text manipulations and dire warnings against AI optimism in our ability to apply computational methods to text analysis participate in this limited acceptance of the uses to which algorithms might be put.)

Algorithms admittedly define and constrain a field of activity, even as they enable certain preordained interactions and solutions. Still, this is not to say that the results of algorithms—and even more, algorithmic methodology as subjective (most likely human) agents could actively and iteratively employ it—cannot paradoxically expand our thinking rather than atomize it, or limit it to presumptive outcomes. The precision a true algorithm requires of its elements and processes assumes a certain determinability and fixity of identity that is difficult if not impossible to maintain in interpretive fields. But to attempt, in data modeling or in performative criticism, an algorithmically enforced specificity is to experience and exploit a productive brand of what William Morris might have called "resistance in the materials" of humanities scholarship. Real challenges and opportunities arise for expanding our understanding of interpretive fields (including, at the most deceptively basic level, graphic and textual book artifacts) in the rigorous and thoughtful application of algorithmic method to our analysis and manipulation of indeterminate objects and ideas.

Lovelace gets at these consequences of algorithmic method in a neglected passage immediately following her well-known "objection." She explains that the Analytical Engine's facility in following rules and orders, producing expected results, and "making available what we are already acquainted with" is effected

> primarily and chiefly of course, through its executive faculties; but it is likely to exert an indirect and reciprocal influence on science itself in another manner. For, in so distributing and combining the truths and the formulae of analysis, that they may become most easily and rapidly amenable to the mechanical combinations of the engine, the

> relations and the nature of many subjects in that science are necessarily thrown into new lights, and more profoundly investigated. This is a decidedly indirect, and a somewhat speculative, consequence of such an invention.[26]

Here Lovelace takes up, in the context of combinatorial mathematics, that product of algorithmic, diagrammatic, deformative, and mechanical method I will cite under the broad rubric of "aesthetic provocation."[27]

The Gift of Screws

After-the-fact (after, that is, data-marking or -modeling) applications of aesthetic provocation are the principal manner in which information visualization enters the broader picture of humanities computing. This is in part because the digital humanities have long orbited the double stars of corpus linguistics and database construction and mining. An intense emphasis on the encoding and analysis of primarily textual human artifacts—coupled with institutional and disciplinary devaluation of methodological training and a sore lack of publication venues for image-intensive work—have contrived to make visualization, from the end-user's perspective, generally a product to be received than a process in which to participate. Nonetheless, algorithmically or combinatorially generated aesthetic provocation, generally thought of as information visualization, has both rhetorical and revelatory power.

Visionary computer scientist Alan Turing, in a noted critique of the Lovelace objection, examines these revelations—the tendency of algorithmic mechanisms to provoke or surprise their users—and ultimately offers us a socialized, humanized view of algorithmic methodology. He begins the discussion with an attempt to reframe Lovelace:

> A variant of Lady Lovelace's objection states that a machine can "never do anything really new." This may be parried for a moment with the saw, "There is nothing new under the sun." Who can be certain that "original work" that he has done was not simply the growth of the seed planted in him by teaching, or the effect of following well-known general principles?[28]

These "well-known general principles" are perhaps commonly thought of by humanists as the informal, heuristic methods transferred to us over the course of a rich and varied education. (One would generally rather take this stance than that; when writing on this subject, one must avoid that quagmire; etc.) But what if Turing means us to understand our day-to-day practices in "following" these principles as little more than the playing-out of socially acquired algorithmic procedures, the output of which in a human context feels like originality, invention? In other words, might we not follow formal, specific (and wholly ingrained) rules even—or perhaps most of all—when we engage in our most creative and supposedly inventive work? What is it, precisely, that inspires us?

There is no question that algorithmic method as performed by humans or machines can produce unexpected (even if, as Lovelace points out, fundamentally predictable) and illuminative results. The religious traditions of gematria and Kabbalah, the conceptual art of Sol LeWitt, John Cage's aleatory musical compositions, OuLiPian literary production, and the procedural experiments of Ron Silliman, Jackson Mac Low, and others (for example, Lisa Samuels's poetic deformations) are primary examples of the inventive application of algorithmic method in the "analog" world. The inspirational power of constraining systems and algorithmic methodology is everywhere evident; it is the reason we have highly articulated poetic forms like the sestina. In a practical, humanities computing context, computational algorithmic processes have been employed to perform revealing and sometimes startling graphical and statistical transformations under the rubric of text analysis. Jerome McGann's Photoshop deformations of Rossetti paintings in the 1990s participated in this tradition. And digital information artists like Ben Fry work through strict systems of constraint in works that fruitfully blur the boundaries between creative and critical production.[29]

The contributions of cognitive science to the humanities over the past few decades have (for better or worse) participated in what Colin Symes terms a "progressive demystification" of fundamental assumptions, long held in some quarters of the academy, about interpretive and artistic creativity. A Romantic vision of the artist unbound, as liberated in thought (a vision perhaps too easily countered with reference to the empowering constraints that drive even Romantic poetic practice), has given way among cognitive scientists to a growing "emphasis on the importance of a structured imagination."[30] According to this understanding, a top-down model of cognition that builds on Marvin Minsky's notion that mental framing devices both structure and filter our thought processes, creativity functions almost wholly through elaborate systems of constraint. The idea that, as Jon Elster posits, "artists tend to maximize their options through minimizing their choices" may strike some as counterintuitive, but creative work in any number of disciplines bears this theory out, and it remains useful despite more contemporary critique.[31]

Perhaps equally peculiar is the suggestion that Minsky's framing system, which is structured hierarchically, could foster the subjective, nonhierarchical, out-of-the-box thinking we associate with interpretive and artistic production. According to this model of cognition, information filters progressively through top-level framing structures into lower-level "terminals." Minsky's primary interest is in the mechanisms of simple perception, but his concept of cognitive frames is equally applicable to more complex linguistic and creative processes. Uppermost frames in this case constitute a "range of primordial scripts" and "default grammars that control the structures of language."[32] There are, however, secondary constraining grammars. Margaret Boden terms these mental constraining systems, which structure critical and artistic thought and production within specific genres, forms, or disciplines, "computational spaces." According to this theory, nonhierarchical cognition is fostered through supporting structures "whose computational spaces or frameworks are derived from particular epistemological and aesthetic domains." These specialized spaces function both within and beyond the primary framing system that hosts them, generating, for instance, "forms of linguistic organization which transgress and even transcend those governing natural language."[33]

Poetic composition provides a clear example of the use of meta-grammars both to organize and to provoke subjective response. This distinction between organization and provocation is an important one because cognitive systems of constraint act simultaneously as matrices in which the fundamental units of language are placed, and as generative processes or algorithms. That is to say, a poet perceives the sophisticated metrical and rhythmic constraints of a sestina not simply as structures, but as a performative or procedural imperative. The linguistic patterns such constraints make impossible are as crucial to the composition of a poem as those they privilege and enforce. In this understanding of subjective response to algorithmic imperatives, poetry is shaped by what it cannot be, and poets by what their chosen forms will not let them do.

Some evidence exists that such genre- and form-specific shaping may become a physical or neurological condition of the performer. Cognitive scientist K. I. Foster has identified in the brain, with repeated linguistic use, a restructuring of the neural circuits or "connectionist pathways that excite mutually consistent arrays of language." Interestingly, these pathways "at the same time inhibit those that are inconsistent with the exigencies of the constraint."[34] For the poet, the development of self-organizing mental systems results in a greater facility, over time, within his most familiar computational spaces and in the production of his chosen forms. And for this reason, writers exercise their faculties by engaging in rhetorical and metrical exercises and linguistic games, such as acrostics, bouts-rimés, or complex forms like hendecasyllabics. (Gerard Manley Hopkins, who constructed poetic matrices of ever-increasing complexity, maintained in his journals—or perhaps sought to reassure himself—that "freedom is compatible with necessity." Likewise, Emily Dickinson's "Attar from the rose" is "not expressed by Suns—alone— / It is the Gift of Screws.") In fact, scientific investigation of the processes underlying poiesis suggests that artistic freedom may only be embodied—artifactually and physiologically—through the necessities of constraining, algorithmic systems.[35]

Experimental and synthetic work in analyzing literary expertise also tends to support a constraints-based reading of the poetic and interpretive process. Cognitive research by Marlene Scaramalia and Carl Bereiter indicates that the presence of strict constraining systems promotes greater linguistic fluency in writers, by lending "form and direction to the more localized decision-making" involved in word choice within a particular genre or format.[36] In effect, as Jon Elster demonstrates, this concentrates creative energies by economizing on the number of aesthetic and subjective choices available to the artist at any one time.[37] Robert De Beaugrande explains the futility of any attempt at artistic composition unfettered by localized systems of constraint in terms of the "combinatoric explosion" that would occur should the range of choices become "unmanageable."[38]

Regardless of our acceptance of the theoretical assertions of cognitive science, the dual operation of computational spaces as structured matrices and generative algorithms functioning both within and beyond Minsky's top-down, framing filters becomes usefully, provocatively evident in our attempts at modeling and encoding the artworks these spaces engender. Poetic conventions generate linguistic artifacts that, despite the regularity their constraining patterns enforce, are essentially nonhierarchical. This fact is attested to by the infelicity of common text markup systems at capturing poetic (as opposed to informational) organization hierarchically.[39] We should also note that constraint does not operate at the same, uniform scale throughout a creative or interpretive procedure, but rather shifts in specificity depending on choices made and exigencies encountered. And all these notions are complicated by a necessarily performative slant to any algorithmic or constraints-based methodology.

The Ludic Algorithm

What may look inaccessibly, mechanistically algorithmic in (for instance) the OuLiPian project might be better understood as a ludic algorithm, which I posit as a constrained, generative design situation, opening itself up—through performance by a subjective, interpretive agent—to participation, dialogue, inquiry, and play within its prescribed and proscriptive "computational spaces." This work may embed within itself a proposed method, but does not see its ultimate product as simply the output of a specified calculation or chance operation. In fact, the desired outcome of a ludic algorithm is the sheer, performative, and constructive enactment of the hermeneutic circle, the iterative "designerly" process we go through in triumphing over interpretive or creative problems we pose ourselves.[40] In undertaking such activity, we are more than Jacques Bens's "rats qui ont à construire le labyrinth dont ils se proposent de sortir."[41]

Turing touches on this brand of dialogue in his contemplation of the relationship between a machine (the very embodiment of algorithmic process) and its fallible, creative human interlocutor:

> A better variant of the [Lovelace] objection says that a machine can never "take us by surprise." This statement is a more direct challenge and can be met directly. Machines take me by surprise with great frequency. This is largely because I do not do sufficient calculation to decide what to expect them to do, or rather because, although I do a calculation, I do it in a hurried, slipshod fashion, taking risks. Perhaps I say to myself, "I suppose the Voltage here ought to be the same as there: anyway let's assume it is." Naturally I am often wrong, and the result is a surprise for me for by the time the experiment is done these assumptions have been forgotten. These admissions lay me open to lectures on the subject of my vicious ways, but do not throw any doubt on my credibility when I testify to the surprises I experience.
>
> The view that machines cannot give rise to surprises is due, I believe, to a fallacy to which philosophers and mathematicians are particularly subject. This is the assumption that as soon as a fact is presented to a mind all consequences of that fact spring into the mind simultaneously with it. It is a very useful assumption under many circumstances, but one too easily forgets that it is false. A natural consequence of doing so is that one then assumes that there is no virtue in the mere working out of consequences from data and general principles.[42]

If its performative and cooperative components are not appreciated, Turing's notion of algorithmic surprise could lead to justification of a grossly limited vision of the interpretive activity possible in digital environments, an idea of algorithm that restricts its application to after-the-fact "aesthetic provocation." In fact, the real "surprise" involved here is less a matter of the algorithm working to its inevitable result on a set of data (as in a conventional information visualization) than of what that action, under observation, reveals about human thought processes. Turing is not a passive recipient of algorithmic output, but rather a predictive, constructive participant in its fashioning and reception. He makes assumptions, holds expectations, and awaits algorithmic response as just another part of a feedback loop. He is, in this, a reader of algorithms and their output, just as we are all readers of the machine of the book. Still, despite the cumulative (socializing and humanizing) effect of Turing's assessment, as Ramsay reminds us, "to speak of an algorithm is usually to speak of unerring processes and irrefragable answers"—not of the participatory and iterative work of humanities interpretation.

Turing's vision of the imperfect, risk-taking, intuitive human in conversation with a precise, calculating, fundamentally surprising machine partner is now familiar to us not only from science fiction and technological speculation but from our daily lives. We experience this brand of surprise perhaps most often as frustration in our interaction with algorithmic mechanisms (like telephone voice-response systems and the purgatory of the Department of Motor Vehicles)—interaction that can make us feel more like passive victims than active participants. We must realize, however, that Turing is documenting a fresh brand of dialectic, and by casting their facility in the "mere working out of consequences from data and general principles" as an anthropomorphized virtue machines can model for and perhaps teach us, he effectively rehabilitates computer-mediated algorithmic method as a creative and critical mode of performance. Recognition of the value of "working out . . . consequences" is as tangible a benefit, and perhaps as great a "surprise," as the mechanically generated results of any imaginable algorithm. Performance (including human performance of algorithmic action) is valued here over passive reception. Turing's surprises are provocations to further action, not those unpragmatic, theory-ridden "answers to enigmas in which we can rest" decried by William James. That is, we are sure from his description and subsequent proposals (indeed from the whole character of his project) that Turing means to take these dialogues further.

My own desire for an enhancement of the typical aesthetic provocation paradigm hinges—like Turing's observation and like OuLiPian practice generally—on the methodological uses of algorithmic constraint and calls for a new, more ludic and performative application of the notion of "aesthetic provocation."[43] The problem with a visualization (or any other last-step provocation to interpretation) generated algorithmically from previously encoded data is that pre-encoded data is pre-interpreted data. And programmed algorithms that are flatly, "automagically" applied to a dataset, not opening themselves up to examination and modification by a user, filter the object of interpretation even further. The user of such a system is not properly figured as a user at all, but rather becomes an audience to statements being made by the designers of the system's content model and visualization or other representational algorithms.

While these statements can constitute—in all fairness—remarkable critical moves on their own part, the culminant effect of an unbalanced use of this approach is to reinforce a mistaken notion that digitization (and the concomitant application of algorithmic process of any sort) is a precritical activity, the work of a service industry providing so-called content to scholars. As an interpreter of algorithmic statements, a scholar (the end-user) is of course enfranchised to respond critically or creatively in conventional ways: by writing, speaking, teaching, or even by answering visualizations in kind, responding with new images. All of these responses, however, typically take place outside the system that provokes them, and to date (despite the early promise of projects like *NINES* and the *Ivanhoe Game*), few scholarly systems have created meaningful opportunities for critical engagement on the part of users. Sadly, the scholar's interpretive act plays a distant second to the primary interpretation or algorithmic performance encoded by the creators of most allegedly "interactive" digital environments.

A more fruitful interest in algorithms and algorithmic processes—as first embodied in Llull's combinatoric wheels—lies in their design and our subjective experience in using them, rather than in their (oddly, at once) objective and Delphic output. A suggestion that digital humanists move beyond the conventional application of "aesthetic provocation" is by no means a denigration of the measured use of traditional information visualization—of the algorithmic "product." My own work, however, is much more invested in digitally or mechanically assisted algorithmic methodology as an interpretive strategy.[44] How are such provocative statements as those made by Fry's Valence produced? Can we insinuate ourselves (our subjective responses, interpretations, participatory acts) more deeply into their production? We may find that the greater understanding of algorithmic process we gain in dialogue and co-creation with our Turing machines leads to a deeper appreciation of the self-replicant, recombinant documentary world in which humanities scholars live and move and have their being. For even the most pedestrian algorithmic construct opens itself up as an interpretive field in productive ways. Our simple car-key algorithm, for example, could easily, in performance, become a synthetic, interpretive, and creative ludic exercise—a game.[45]

Even at its most basic level—setting aside the intimate manipulations of a designer or programmer—algorithmic performance by subjective agents is revelatory. Imagine actually going through the prescribed physical process of picking up every item in your house, individually, and examining it for car-key-ness or not-car-key-ness. You might well find your keys by the end of the algorithm—but, by that time, the "success" of the operation would certainly seem beside the point. Undertaking this structured, constraints-based activity as a thinking human being, either practically or imaginatively, means more than performing it mechanically with one end in sight (confirmation or disconfirmation of the presence of car keys). Instead, you would be prompted continually to interpret and reinterpret your environment, your goal, your scope of activity, and your very actions, simply because a constraining system was compelling you to think algorithmically. You would, in performance, act on and reinterpret the objects of your rule set and the rule set alike.

Repositioning closed, mechanical, or computational operations as participatory, ludic algorithms requires acknowledgment of a primary definition, derived from the studies of the game theorist Martin Shubik, a figure sadly neglected in literary or new media game studies. He concludes a powerful survey of "the scope of gaming" with the simple statement that "all games call for an explicit consideration of the role of the rules."[46] Shubik means us to understand this "consideration" not only as adherence by players to a set of constraints, but also as appreciation of the impact of rules on the whole scope of play. The rule set or constraining algorithm in any ludic system becomes another player in the process and, as expert gamers often testify, can seem to open itself to interpretation and subjective response—in some cases, to real, iterative (which in this case is to say, turn-based) modification.[47] In our "consideration of the role of the rules" we must follow C. S. Peirce, and understand algorithmic rule sets "in the sense in which we speak of the 'rules' of algebra; that is, as a permission under strictly defined conditions" (4.361). The permission granted here is not only to perform but also to reimagine and reconfigure.

Llull in Application

"The Farmer and the Cowman Should Be Friends"

Algorithmic and ludic operations, however fundamental to artistic and scholarly activity, remain exotic concepts to most humanities researchers. Ramon Llull, our benchmark designer of the participatory, ludic algorithm, is more generally appreciated by academics in the historical context of *ars combinatoria,* a practice described by the installation artist Janet Zweig and others as rooted in mysticism and divination and leading up to the aleatory experimentation of the modern conceptual artists, musical composers, and mathematically inspired writers. *Ars combinatoria* have been called "the software of the baroque," with an output as rich as Bach's fugues, at once mechanical and occult.[48]

Anthony Bonner, in tracing the evolution of Llull's mechanical design from early forms more dependent on prose description, reference tables, and static figures, draws attention to the shift to *ars combinatoria* proper brought about with the introduction of the inter-rotating wheel:

> Initially it appears as a device to compensate for the loss of basic principles that formerly constituted the building blocks of the Art; but soon one sees that it is in fact the replacement of a vast sprawling structure, whose parts are loosely and often only implicitly (or analogically) interrelated, by a far more compact structure, whose parts are tightly and much more explicitly and mechanically interrelated.[49]

Not only does the device, first embodied as the Fourth Figure of the Ars Brevis, serve that work's aim of making plain the complexities of Llull's Ars Magna, it also demonstrates that the essence of a "vast sprawling" and analogical structure can be usefully condensed into a set of combinatorial relations—so long as the concretization and precision implied by the new form can be matched by flexibility in an open, interpretive rule set.

Unfortunately, the association of Llull's Great Art with *ars combinatoria* implies for some a focus that is either mystical (almost alchemical) or inextricably linked to an allegedly uncritical or pre-critical artistic value on "pure process and play."[50] What relevance can such flights of fancy have to serious scholarly issues of interpretation and analysis? We can begin to answer this question by contextualizing Llull's own design (though it is an answer best embodied in the design and production of new tools rather than simply explicated historically).

Llull's algorithmic and combinatorial device emerged not from mysticism or playful experimentation, but rather from a crisis in communication and interpretation. The Ars Magna was meant to serve as an aid to hermeneutic thought and cross-cultural understanding in light of seemingly insurmountable (and unassailably rigorous) problems of textual criticism and rescension. That they seem playful in use is a mere fringe benefit of the serious interpretive burden Llull meant his spinning wheels to bear.

Llull was born on Majorca, only a few years after the king of Aragon and Catalonia had retaken the island from its Islamic conquerors. In Llull's time, Majorca was a melting pot: at least one-third of the population was Muslim, there was a strong and influential Jewish minority in the economic and political center, and the rest of the island's inhabitants were Catholic. Künzel calls the Mediterranean of Llull's day "a kind of interface for three expanded cultural streams."[51] Llull recognized many elementary commonalities among the three combative monotheistic religions represented on Majorca, but despite the sharing of basic concepts and notions of divinity, cultural tensions grew and Llull became deeply committed to the cause of resolution and appeasement. We find it therefore "necessary to regard his invention as embedded within a special situation, i.e. embedded in a deep crisis of communication."[52] Admittedly, Llull saw himself as a Christian missionary and his tools as enabling devices for the conversion of the infidels—not by the sword, as the failed Crusades had attempted, but by logical reasoning facilitated through the innovative combination of familiar, shared ideas.

Earlier attempts at peacefully convincing unbelievers, Llull recognized, had failed because of problems of bibliographical analysis and textual criticism: theologians from the various camps had "based their arguments on sacred texts" (trying to point out errors in the Koran, the Talmud, or the Bible)—a practice that "invariably became bogged down in arguments as to which texts were acceptable to whom and how to interpret them."[53] A passage from Llull's *Book of the Gentile and the Three Wise Men*—written ca. 1275 as a popular companion to the Ars Magna, in which the complex operands of that method are softened through presentation as the flowers and leaves of a tree—demonstrates the author's consciousness of the text-critical nature of religious problems of his day:

> "I am quite satisfied," said the Gentile to the Jew, "with what you have told me; but please tell me the truth: do Christians and Saracens both believe in the Law you mention?" The Jew replied: "We and the Christians agree on the text of the Law, but we disagree in interpretation and commentaries, where we reach contrary conclusions. Therefore we cannot reach agreement based on authorities and must seek necessary arguments by which we can agree. The Saracens agree with us partly over the text, and partly not; this is why they say we have changed the text of the Law, and we say they use a text contrary to ours."[54]

The innovation of the Ars Magna was to abstract philosophical concepts in play from their textual condition, by identifying notions common to the documentary sources of all three major religions and offering a combinatorial method for fusing them together and analyzing their relations. Llull's hope was that Christian arguments inspired by the Ars Magna would be satisfactory to Muslims and Jews, stemming as they did from logical combinations of their own basic beliefs. There is, however, no quality or assumption inherent in the Llullian method to enforce a certain interpretive slant. It is just as easy to use Llull's wheels to formulate arguments that favor Judaism or Islam. All the interpretive impetus is placed on the *artista*, the human user of the Ars Magna.[55]

Dynamic Diagrams

Llull's method was not only notable for being clearly delineated; it was also self-testing, in the sense that the execution of iterative combinatorial motions was only carried out until contradictions or obvious untruths emerged. These untruths, naturally, would not appear as a parsing error or blue-screen breakdown in any material system at hand (the wheels, the diagrams), but rather in the conceptual system taking shape over the course of interaction with the Ars Magna in the mind of its user. At that point, the wheels themselves (and therefore all the marked primitives and practiced algorithms in play) could be examined and reconfigured. In this way, Llull's Great Art was both a generative and autopoietic mechanism, through which new posited truths and refined combinatorial and analytic methods could emerge.

Emergence, rather than derivation, is in fact the hallmark of Llullian method. The diagrams generated by Llull's wheels operate on principles of equivalency, not cause and effect, generating statements "*per aequiparantium,* or by means of equivalent relations," in which ideas are not chained causally (the primary method for deriving logical and predictive relations), but are instead traced "back to a common origin."[56] In the same way, Llull's idea of an *ars combinatoria* is not flatly combinatoric, but also fundamentally relational in structure and scope, in the manner of proof-theoretical semantic tableaux.[57] Even better, for Llull's uses, is that inherent value placed on human associations and the interpretive interplay of concepts ensures Laputian "wisdom" or random nonsense can be rejected. We must, in looking at Llull's diagrams, appreciate his attitude toward their primary elements, the "constants" represented by an alphabetic notation.[58] In Llull's estimation, nothing in the world is inactive. Nothing simply is; rather, everything performs whatever its nature dictates. So Llull's emergent definitions (for example, the wheels may be spun to generate the simple statement "Goodness is great"), which "to some commentators have seemed simply tautological, in fact imply a dynamic reality articulated in a large web of interactions."[59] Llull's definitions for alphabetic ciphers are "purely functional," after the style of "modern mathematicians, who do not say what a thing is, but only what it does."[60] This dynamism provokes computer scientists like Ton Sales to argue that Llull invented the graph.

It is clear that "concept-structuring or taxonomic" graphical designs—such as tree structures—predate Llull.[61] Llull's typical graph was not built on a static, taxonomic model, however, but "conceived rather as a present-day's 'semantic network' and intended to be 'followed,' i.e. dynamically executed as though it were truly a fact-finding 'program' or a decision tree" as used in AI decision procedures."[62] Such an image was not a chart or illustration, but instead an "actual net of links that allowed the user to explore in a combinatorial fashion the relations that existed among the currently manipulated concepts."[63] In this way, Llull's designs resembled or prefigured modern conceptual graphs and semantic networks, as they "presupposed a dynamic interpretation" in which to know the concepts at hand meant to follow and explore their consequences and associations, to participate actively in the manufacture and representation of knowledge.[64]

Dark, Satanic Millstones?

Perhaps the finest quality of Llull's now-neglected system is that it assumes activity at all its levels. It works at once mechanically and graphically, and it offers a method by which its users may respond interpretively, interactively, and iteratively to its combinatoric output. Here, we are not asked to feed data into a closed system (the algorithms of which were perhaps fashioned by others, necessarily for other purposes and materials than our own) and wait passively for a visualization or tabular report. We are instead meant to create, mark, and manipulate a wheel; to record its statements diagrammatically; and to follow and explore those resultant diagrams as a means of formulating, testing, and refining both ideas and rules, or algorithmic and combinatorial systems of interpretive constraint. No satanic mill, Llull's open-ended mechanical model instead follows William Blake's imperative: "I must create my own System, or be enslaved by another Man's." For no matter how benign and even profitable the typical enslavement to after-the-fact "aesthetic provocation" in humanities computing tools may be, algorithmic instruments that do not work on Llull's principle can only deliver us "answers" that are either pre-known or inaccessibly random—that is, either derivative from algorithms and content models that express deep-seated, framing preconceptions about our field of study (as in typical, last-stage "aesthetic provocation"), or derivative of deformative and aleatory automations that too often do not open themselves adequately to the participation of a subjective agent during their operation.[65]

Janet Zweig, in her overview of ancient and modern *ars combinatoria,* asks a fundamental question, relevant to appreciating Ramon Llull and his Great Art in the context of digital scholarship and computer-assisted hermeneutics: “What is the qualitative difference between permutational systems that are intentionally driven and those systems that are manipulated with chance operations?”[66] It is important to understand—as Llull’s critics and the slow forces that have driven him into obscurity did not—that the Ars Magna is not a game of highfalutin, theological *Twister:* a governing, user-manipulating system of chance operations and random (or worse—insidiously circular) output.

Zweig’s question about the qualitative difference between aleatory and intentionally driven mechanisms implies its own answer: the differences are qualitative, embedded in, and emergent from our familiar world of humanistic interpretation. We are not meant merely to get output from Llull’s wheels. They are designed to generate insight into their own semi-mechanical processes and into our rhetorical and hermeneutic methodologies of use. Like so many (often misunderstood) humanities computing projects, Llull’s wheels assert that interpretation is merely aided by mechanism, not produced mathematically or mechanically. That this assertion is sometimes lost on the general academic community is not simply a failure of the devices scholar-technologists produce (although, as this chapter has sought to suggest, we can do a better job of anticipating and incorporating patently interpretive forms of interaction on the part of our users into the systems we create for them). Instead, it displays our failure to articulate the humanistic and hermeneutic basis of our algorithmic work to a lay audience. Further, it reveals the rampant under-appreciation among scholars of the algorithmic nature of an over-familiar machine on which all our work is predicated: the book.

When I began to examine Ramon Llull, I anticipated closing a description of the Ars Magna with some examples of how computing humanists or digital historians and literary scholars might use his wheels to analyze and reconfigure combinatorially the hidden rules and assumptions that drive our own practice. Instead, I am inclined to argue that the best new use for Llull’s old machines might be as defamiliarizing devices, modeling—for a larger and often skeptical or indifferent academic community—the application of mechanical or algorithmic systems to problems of interpretation with which scholars engage on a day-to-day basis. A dearth of clear and compelling demonstrations of this applicability to the interests of the academy is the central problem facing the digital humanities today. It is the reason our work, like the allegedly “pre-critical” activity of bibliographers and textual critics before us, remains insular.[67]

Llull tells us that he chose a graphical and mechanical art partly through inspiration (the Ars Magna was revealed in fiery letters on the manipulable and discrete leaves of the lentiscus plants on Majorca's highest peak)—and partly out of a recognition that the elements of interpretation should be finite in number, explicit in definition and methodological use, and visually memorable. Seen in this (divine?) light, interpretation lends itself easily to algorithm and apparatus. Why should any of us feel fettered? Let us build enabling devices for scholars—digital environments that marry methodological openness and mechanical clarity to the practice of humanities interpretation.

NOTES

1. Jonathan Swift, *Gulliver's Travels*, ed. A. J. Rivero (New York: W. W. Norton, 2001), part III, chapter 5.

2. Swift, part III, chapter 5.

3. See John Unsworth, "'Scholarly Primitives': What Methods Do Humanities Researchers Have in Common, and How Might Our Tools Reflect This?" paper presented at "Humanities Computing: Formal Methods, Experimental Practice," King's College, London, 2000, accessed July 31, 2012, http://bit.ly/p8O0i.

4. Ton Sales, "Llull as Computer Scientist, or Why Llull Was One of Us," Instituto Brasiliero de Filosofia e Ciencia Raimundo Lulio 2.3, *ARTS '97 Proceedings of the 4th International AMAST Workshop on Real-Time Systems and Concurrent and Distributed Software: Transformation-Based Reactive Systems Development*.

5. Some seventy medieval manuscripts of the Ars Brevis alone (a shortened expression of Llull's tools and methods) survive, and Anthony Bonner records twenty-four Renaissance editions of this popular work. For a succinct reception history, see Bonner's introductions to "Llull's Thought" and "Llull's Influence," in *Selected Works of Ramon Llull (1232–1316),* trans. Anthony Bonner (Princeton, N.J.: Princeton University Press, 1985), 577.

6. François Rabelais, *Gargantua and Pantagruel*, trans. Sir Thomas Urquhart and Peter Antony Motteux (London: David Nutt, 1900), 231.

7. Francis Bacon, *De Augmentis Scientiarum. Of the Advancement and Proficience of Learning; or, The Partitions of Sciences*, trans. Gilbert Wats (Oxford: Litchfield, 1640), VI.2.

8. Martin Gardner, "The Ars Magna of Ramon Lull," in *Logic Machines and Diagrams* (Chicago: University of Chicago Press, 1982), 19.

9. Gardner, 18.

10. Peter Bexte and Werner Künzel, *Allwissen und Absturz: der Ursprung des Computers* (Frankfurt am Main: Insel Verlag, 1993), introduction.

11. Werner Künzel, *The Birth of the Machine: Raymundus Lullus and His Invention*, accessed July 31, 2012, http://www.c3.hu/scca/butterfly/Kunzel/synopsis.html.

12. Künzel.

13. All thumbnail images of Llull's figures and mechanisms presented here are taken from Bonner's reproduction of the Ars Brevis (Escorial, MS f-IV-12, folios 3, 4, 6, and 7) in the *Selected Works*.

14. Anthony Bonner, "What Was Llull Up To?" Instituto Brasiliero de Filosofia e Ciencia Raimundo Lulio, accessed July 31, 2012, http://bit.ly/i4wocZ.

15. Stephen J. Ramsay, *Algorithmic Criticism* (Ph.D. dissertation, University of Virginia, 2003), 15ff.

16. Anthony Bonner, *Doctor Illuminatus: A Ramon Llull Reader* (Princeton, N.J.: Princeton University Press, 1993), 294.

17. Gardner, 1.

18. Gardner, 14–15.

19. Quoted in Janet Zweig, "Ars Combinatoria: Mystical Systems, Procedural Art, and the Computer," *Art Journal* 56, no. 3 (1997): 22.

20. Sales, 2.3.

21. Frances Yates, *The Art of Memory* (London: Routledge, 1999), 306.

22. Sales, 2.1.

23. Sales, 3.

24. Countess of Lovelace, "Sketch of the Analytical Engine invented by Charles Babbage, Esq. By L. F. MENABREA, of Turin, Officer of the Military Engineers," trans. Augusta Ada Byron King, *Scientific Memoirs* 3 (1843): 666–731. See "Note G."

25. Gardner, 18.

26. Lovelace, "Note G."

27. Johanna Drucker and Bethany Nowviskie, "Speculative Computing: Aesthetic Provocations in Humanities Computing," in *A Companion to Digital Humanities*, ed. John Unsworth, Ray Siemens, and Susan Schreibman (Oxford: Blackwell, 2004).

28. Alan Turing, "Computing Machines and Intelligence," *MIND, A Quarterly Review of Psychology and Philosophy* 59, no. 236 (October 1950): 433–60. See 000–000.

29. Algorithmic text analysis tools such as those designed by Stephan Sinclair in an OuLiPian mode have been aggregated (among less consciously ludic applications) at TAPoR, the Canadian Text Analysis Portal for Research, directed by Geoffrey Rockwell. See TAPoR, accessed July 31, 2012, http://portal.tapor.ca/. Ben Fry's work at the MIT Media Lab and elsewhere is available, accessed July 31, 2012, at http://benfry.com/. See especially his genomic cartography, "Favoured Traces," and organic information design projects, all of which have been applied to text analysis (but only in art installation contexts unhappily ignored by textual scholars).

30. See Colin Symes, "Writing by Numbers: Oulipo and the Creativity of Constraints," *Mosaic* 32, no. 3 (1999): 87. Interestingly, Florian Cramer points out that Friedrich Schlegel, in the 1790s, defined Romanticism in terms of recursion and formal self-reflexivity—the same terms under which contemporary algorithmic and combinatorial digital art (of which Cramer himself is a Lullian practitioner) takes shape. See Cramer's Tate Modern talk, "On Literature and Systems Theory," of April 2001, versions of which remain at the Internet Archive, accessed July 31, 2012, http://userpage.fu-berlin.de/~cantsin/homepage/#theory.

31. Jon Elster, "Conventions, Creativity, and Originality," in *Rules and Conventions: Literature , Philosophy, Social Theory*, ed. Mette Hjort (Baltimore: Johns Hopkins University Press, 1992). See discussion in chapter 1 of Alan M. MacEachren's 1994 *How Maps Work: Representation, Visualization, and Design*. And it is no new notion; see the discussion of constraint in the work of Dante Alighieri in Jerome McGann and Lisa Samuels's seminal essay, "Deformance and Interpretation," accessed July 31, 2012, http://www2.iath.virginia.edu/jjm2f/old/deform.html.

32. Symes, 88.

33. Symes, 88.

34. Symes, 90.

35. This idea is closely tied to the biology of autopoiesis as articulated by Francisco Varela and Humberto Maturana. See their *Autopoiesis and Cognition: The Realization of the Living* (Dordrecht: Reidel, 1980).

36. Symes, 89.

37. Elster, "Fullness and Parsimony," in *Explanation and Value in the Arts*, ed. Ivan Gaskell and Salim Kemal (New York: Cambridge University Press, 1993), 164.

38. Robert de Beaugrande, "Writing and Meaning: Contexts of Research," in *Writing in Real Time: Modelling Production Processes*, ed. A. Matsuhashi (Norwood, N.J.: Ablex, 1987).

39. The difficulties involved in rigorous analysis of this quality of poetic production have been framed as a "problem of overlapping hierarchies" by the humanities and linguistic computing communities. Trace the discussion to Michael Sperberg-McQueen's comments at the Extreme Markup Conference 2002 ("What Matters?" accessed July 31, 2012, http://www.w3.org/People/cmsmcq/2002/whatmatters.html) and debate by Alan Renear and Jerome McGann at the 1999 joint conference of the Association for Computers and the Humanities and Association for Literary and Linguistic Computing ("What is Text?").

40. On the relation between hermeneutics and design, a developing interest in the architectural community, see especially D. Schön, "Designing as a Reflective Conversation with the Materials of a Design Situation," *Research in Engineering Design* 3 (1992): 131–47; Adrian Snodgrass and Richard Coyne, "Is Designing Hermeneutical?" *Architectural Theory Review* 1, no. 1 (1997): 65–97; Richard Coyne, *Designing Information Technology in the Postmodern Age: From Method to Metaphor* (Cambridge, Mass.: MIT Press, 1995). See also Nigel Cross's "Designerly Ways of Knowing," *Design Studies* 3, no. 4 (1984): 221–27; and Terry Winograd and Carlos F. Flores, *Understanding Computers and Cognition: A New Foundation for Design. Language and Being* (Norwood, N.J.: Ablex, 1986), 12: "We also consider design in relation to systematic domains of human activity, where the objects of concern are formal structures and the rules for manipulating them. The challenge posed here for design is not simply to create tools that accurately reflect existing domains, but to provide for the creation of new domains. Design serves simultaneously to bring forth and to transform the objects, relations, and regularities of the world of our concerns."

41. Loosely, "rats who build the very maze they propose to quit." Quoted in Symes, 43.

42. See Turing, 000–000.

43. This is an enhancement I embodied in the design of the Temporal Modelling PlaySpace environment, ca. 2001–2, and described, with Johanna Drucker, in Blackwell's *Companion to Digital Humanities*, 2004.

44. See, most recently, Neatline, a National Endowment for the Humanities Start-Up and Library of Congress-funded project for "geospatial and temporal interpretation of archival collections," undertaken by the Scholars' Lab at the University of Virginia Library, accessed July 31, 2012, http://neatline.org/.

45. Chris Crawford, author of the first major handbook for computer game design, contends that all great designers must think algorithmically, concentrating on process over fact and on trend over instance. The antithesis of "algorithmic thinking," he writes, is "instantial thinking," which always leads to poor interactive designs. The

instantial thinker "comes up with great cut scenes," the passive, movie-like animations that close chapters or levels in many digital action games, "but lousy interactions," which are the heart of gameplay, and "when he designs an adventure game, [the instantial thinker] loves to cook up strange dilemmas in which to place the player, but the idea of a dilemma-generating algorithm is lost on him." See Crawford, *The Art of Computer Game Design* (New York: Macmillan-McGraw-Hill, 1984).

46. Martin Shubik, "On the Scope of Gaming," *Management Science* 18, no. 5 (1972): 34.

47. See, for instance, Peter Suber's "Nomic," and *Imaginary Solution #1: Dr. Kremlin's Disc,* a game described in my unpublished dissertation, executed as a hands-on activity at the 2010 "Playing with Technology in History" symposium, accessed July 31, 2012, http://www.playingwithhistory.com/wp-content/uploads/2010/02/nowviskie-game.pdf.

48. Bexte and Künzel.

49. Bonner, *Selected Works,* 573.

50. Zweig, 23.

51. Künzel.

52. Künzel.

53. Bonner, "What Was Llull Up To?"

54. Llull, book II.3.6, trans. Bonner.

55. Bonner points out that the word "art" was the "usual scholastic translation" for the Greek τεχνη (*technē*). Llull's work is best understood as a "technique; it was not a body of doctrine, but a system. Or to put it in contemporary terms, it was a structure." *Selected Works,* 62.

56. Gardner, 13.

57. Sales, 2.4.

58. Anthony Bonner suggests that Llullian alphabetic ciphers are constants rather than variables ("What Was Llull Up To?"). Clearly, the wheels and their primitives open themselves to adjustment by a human user, or *artista*. I therefore take this assertion to mean that the letters, once placed in the practical matrix of Llull's wheels and charts, are best understood as having a one-to-one relationship with the objects or ideas they represent, the better to enable the sort of dynamic, performative interaction of an *artista* with a diagram Llull favored.

59. Bonner, "What Was Llull Up To?"

60. Bonner, *Selected Works*, 573.

61. Bonner, "What Was Llull Up To?"

62. Sales, 2.7.

63. Sales, 2.9.

64. Sales, 2.9.

65. It is for this reason that I prefer the terms "environment," "instrument," and "mechanism" to "tool" when designing mechanical or algorithmic aids to humanities interpretation. An "environment" is by definition an inhabitable space. An "instrument" is played as well as used, and a "mechanism" is a system that can be opened up for analysis and adjustment. "Tool," on the other hand, implies self-containment and inviolability.

66. Zweig, 20.

67. A notable exception to this older trend is the work of maverick analytical bibliographer Randall McLeod, who comfortably straddles empirical and interpretive genres in the same way that writers like Susan Howe blend poetic practice and criticism.