Romantic Disciplinarity and the Rise of the Algorithm

Jeffrey M. Binder

Introduction

In the past decade, with the rise of social media, artificial intelligence, and new forms of automation, the word *algorithm* has rapidly ascended from an obscure technical term to a media buzzword. But algorithms themselves have existed since antiquity. As the *OED* puts it, an algorithm is "a procedure or set of rules used in calculation and problem-solving"; a familiar example is long division.[1] Commentators over the centuries were at times awed and at times disturbed by the fact that one could apparently produce real knowledge about the world by arranging symbols on a paper or slate according to mechanical rules. These changing attitudes toward algorithms were a bellwether for the broader epistemological shifts that intellectual historians, such as Michel Foucault in *The Order of Things*, have detected in the histories of scientific discourses.[2]

One thing the history of algorithms can tell us is why computation has become such a flashpoint for disciplinary conflicts. In a 2013 article, Alan Liu argues that literary scholars employing digital methods encounter a "meaning problem" due to the absence of a solid epistemological framework in which one can "take a signal discovered by machine and develop an interpretation leading to a humanly understandable concept."[3] Liu discerns a common perception among humanists that algorithmic methods exist in a different sphere from interpretation; Stanley Fish made one such complaint in a 2018 opinion piece.[4] Conversely, a number of media scholars, notably Friedrich Kittler, have questioned the adequacy of interpretive methods as means of studying computers, which one can only authentically understand, in their view, through mathematics.[5] Underlying both Liu's

Unless otherwise noted, all translations are my own.

1. *Oxford English Dictionary*, s.v. "algorithm." See also Donald E. Knuth, "Algorithmic Thinking and Mathematical Thinking," *The American Mathematical Monthly* 92 (Mar. 1985): 170–81.

2. See Michel Foucault, *The Order of Things: An Archaeology of the Human Sciences*, trans. pub. (New York, 1994).

3. Alan Liu, "The Meaning of the Digital Humanities," *PMLA* 128 (Mar. 2013): 414.

4. See Stanley Fish, "Stop Trying to Sell the Humanities," *The Chronicle of Higher Education*, 17 June 2018, www.chronicle.com/article/Stop-Trying-to-Sell-the/243643

5. See Friedrich Kittler, "There Is No Software," *CTHEORY*, 18 Oct. 1995, www.ctheory.net/articles.aspx?id=74. See also Wolfgang Ernst, *Digital Memory and the Archive*, ed. Jussi Parikka (Minneapolis, 2012).

Critical Inquiry 46 (Summer 2020)

Critical Inquiry 2020.46:813-834.

meaning problem and Kittler's antihermeneutic stance is an apparent disconnect between computation and what are typically thought of as cultural concerns, including aesthetics, affect, and meaning—in short, just those aspects of language that are most valued in literary studies.

This paper argues that that this disconnect results from a set of contingent decisions made in both humanistic and mathematical disciplines in the first half of the nineteenth century. The Romantic period has long been identified as a critical moment in the development of the humanities; the rubric of Romanticism is, Clifford Siskin writes, how literary studies makes sense of "the period of time in which it became a discipline."[6] But the period saw equally important changes in what we now think of as technical fields. At almost exactly the same time that Romantic poets and philologists were coming to view languages as organically developing beings, algebraists moved in a contrary direction, embracing methods that involved the mechanical manipulation of symbols.[7] My contention is that these simultaneous changes were parts of a single reconfiguration of the structure of disciplinarity that delineated, with implications that continue to resonate in the twenty-first century, which aspects of human activity would come to be formalized in algorithms and which would not.

The schism between algorithmic and interpretive methods followed a period of contention about the relation of mathematics to ordinary language. In the late eighteenth century, the majority of mathematicians viewed algebra

6. Clifford Siskin, "Mediated Enlightenment: The System of the World," in *This Is Enlightenment*, ed. Siskin and William Warner (Chicago, 2010), p. 172.

7. See Harvey W. Becher, "Radicals, Whigs and Conservatives: The Middle and Lower Classes in the Analytical Revolution at Cambridge in the Age of Aristocracy," *The British Journal for the History of Science* 28 (Dec. 1995): 405–26; Lorraine Daston, "Enlightenment Calculations," *Critical Inquiry* 21 (Autumn 1994): 182–202; Sloan Evans Despeaux, "'Very Full of Symbols': Duncan F. Gregory, the Calculus of Operations, and *the Cambridge Mathematical Journal*," in *Episodes in the History of Modern Algebra (1800–1950)*, ed. Jeremy J. Gray and Karen Hunger Parshall (Providence, R.I., 2007), pp. 49–72; and Kittler, "On the Take-off of Operators," trans. Kevin Repp, in *Inscribing Science: Scientific Texts and the Materiality of Communication*, ed. Timothy Lenoir (Stanford, Calif., 1998), pp. 70–77.

Jeffrey M. Binder is a junior visiting fellow at Pennsylvania State University's Center for Humanities and Information. A former computer programmer, he now specializes in humanistic approaches to technology, with a particular emphasis on the intersections of computation, language, and poetics. His work has been published in such journals as *Literary and Linguistic Computing*, *American Literature*, and *Media Culture and Society*. As a visiting fellow, he is working on a book about the history of algorithmic thinking from the seventeenth century to the nineteenth.

Critical Inquiry 2020.46:813-834.

as a means of representing the material world and only accepted the validity of symbolic methods that were backed up with clear physical interpretations.[8] This emphasis on conceptual clarity inspired endless debates about the status of algebraic entities whose relation to physical reality was difficult to articulate, such as negative and imaginary numbers.[9] Since the objective was to clarify meaning, these debates hinged on a question about the politics of language: whether one could define terms like *sum* and *quantity* in new ways that break with established usages, or whether one had to work in some way with conceptions received from tradition. The former position was associated with radical reform programs like those of the early French Revolution, as it suggested that received ways of thinking ought to be replaced with something more rational. For those who rejected the possibility of breaking with past usages, algorithms were only acceptable for instrumental purposes; within the realm of mathematical theory they seemed, at best, engines for producing unintelligible nonsense, and at worst, a tyrannical imposition of arbitrary rules onto natural reason.

Romantic thought, I show in this essay, provided nineteenth-century mathematicians with a way of sidestepping these thorny political questions. Responding to, among other factors, a disillusionment with the French Revolution and the popularization of Immanuel Kant's critical philosophy, Romantic thinkers argued that the analytical methods used in mathematics and natural science were inadequate in other areas of knowledge, such as aesthetics and morality. Although these arguments are sometimes read as early expressions of the hostility between the humanities and the sciences that C. P. Snow diagnosed in his well-known essay on the "two cultures," their effect in the early nineteenth century was less to stoke disciplinary antagonisms than to encourage scientific disciplines to clarify their boundaries by distinguishing matters of technical validity from the complex array of factors involved in "cultivating" human thought.[10] This distinction, I

8. G. W. Leibniz, on the other hand, did embrace the use of algorithms not backed up with concepts; see Hans Aarsleff, "The Eighteenth Century, Including Leibniz," in *Historiography of Linguistics*, vol. 13 of *Current Trends in Linguistics*, ed. Thomas A. Sebeok (The Hague, 1975), pp. 383–479; Marcelo Dascal, *Leibniz, Language, Signs, and Thought: A Collection of Essays* (Philadelphia, 1987); Olga Pombo, *Leibniz and the Problem of a Universal Language* (Münster, 1987); and Donald Rutherford, "Philosophy and Language in Leibniz," in *The Cambridge Companion to Leibniz*, ed. Nicholas Jolley (New York, 1995), pp. 224–69.

9. See Jean le Rond d'Alembert, "Négatif," in *Encyclopédie, Ou Dictionnaire Raisonné Des Sciences, Des Arts et Des Métiers*, ed. Denis Diderot and d'Alembert, 17 vols. (Paris, 1751–1772), 11:72–74; William Frend, *The Principles of Algebra* (London, 1796); and Francis Maseres, *Dissertation on the Use of the Negative Sign in Algebra* (London, 1758).

10. See C. P. Snow, *The Two Cultures* (New York, 2012). See also Jürgen Habermas, "Modernity: An Unfinished Project," trans. Nicholas Walker, in *Habermas and the Unfinished*

argue, facilitated the rise of algorithms by shuffling computation and meaning off into separate domains where each could have some degree of protection from the other—the first from the uncertainty of ordinary words and notions, the second from the possibility that the mechanical nature of mathematical methods would deprive human thought of the breathing room that, to the Romantic mindset, it needed to thrive.

This essay begins with a more detailed discussion of the attitudes toward algorithms that existed in the eighteenth century, with a particular focus on the French mathematician Nicolas de Condorcet. At the height of the 1789 Revolution, Condorcet attempted to create a universal language that would eliminate all traces of words from mathematical practice. This utopian scheme represents the culmination of an Enlightenment epistemology that made algorithms dependent on conceptual thought. Second, I discuss William Wordsworth's arguments about the relationship of poetry and science. While Wordsworth is sometimes viewed as a critic of science, I argue that his polemic is specifically targeted at highly politicized projects like Condorcet's that sought to supplant existing modes of thought with scientific rationality. Finally, I demonstrate the importance of Romantic thought for George Boole, the creator of the logic system that would eventually form the basis of digital electronics. The reason Boole was able to succeed where Condorcet had failed, I argue, was that Romantic notions of culture enabled him to reconcile a mechanical view of symbolic procedures with an organic view of the development of meaning—a dichotomy that remains a key assumption of computer interfaces in the twenty-first century.

Condorcet: The Enlightenment Reasoning Machine

In the winter of 1794, Condorcet knew that he would not live long. During the early years of the French Revolution, he was an enthusiastic participant, helping to draft the 1789 *Declaration of the Rights of Man and of the Citizen* and representing Paris in the Legislative Assembly of 1791–1792. But after the start of the Terror, his support for the moderate Girondin faction

Project of Modernity: Critical Essays on "*The Philosophical Discourse of Modernity*," ed. Maurizio Passerin d'Entrèves and Seyla Benhabib (Cambridge, Mass., 1997), pp. 38–55; Bruno Latour, *We Have Never Been Modern*, trans. Catherine Porter (Cambridge, Mass., 1993); *One Culture: Essays in Science and Literature*, ed. George Lewis Levine and Alan Rauch (Madison, Wis., 1987); Vincent Mosco, "Entanglements: Between Two Cultures and beyond Science Wars," *Science as Culture* 21 (Mar. 2012): 101–15; Roy Porter, "The Two Cultures Revisited," *boundary 2* 23 (Summer 1996): 1–17; Hans-Jörg Rheinberger, "Culture and Nature in the Prism of Knowledge," *History of Humanities* 1 (Spring 2016): 155–81; and Max Weber, "Religious Rejections of the World and Their Directions," in *From Max Weber: Essays in Sociology*, trans. and ed. H. H. Gerth and C. Wright Mills (1948; New York, 1991), pp. 323–59.

made him into an outlaw, and he was forced to flee from his home.[11] During his eight months in hiding, Condorcet passed the time by writing political texts that sketched a utopian plan for the future. In one of the fragments he wrote while a fugitive, soon published as *Outlines of an Historical View of the Progress of the Human Mind*, Condorcet suggests two means by which the improvement of the human race can be assured: first, the adoption of "technical methods," by which he means "the art of uniting a great number of objects in an arranged and systematic order"; and second, a "universal language" that "expresses by signs, either the direct objects, or those well-defined collections constituted of simple and general ideas, which are to be found or may be introduced equally in the understandings of all mankind."[12] Such a language, he writes, would not have "the inconvenience of a scientific idiom, different from the vernacular tongue"; it could be learned by all, as schoolchildren learn the language of algebra, providing universal access to the best scientific knowledge available and ensuring that there could be no disagreement about either the meaning of terms or the validity of arguments (*O*, pp. 239–40).

The algorithmic nature of Condorcet's proposed universal language has led some commentators—including Umberto Eco, Roger Chartier, and Keith Michael Baker—to liken his work to later developments in formal logic and even computer science.[13] Condorcet's scheme bears a particularly striking resemblance to Boolean logic. But Condorcet treated the relation of algorithm and meaning very differently from later practitioners of logic and computation. Rather than prescribing formal rules in the manner of Boole or Gottlob Frege, Condorcet envisioned his universal language in terms of the ordering device that is, for Foucault, distinctive of the Classical episteme: the taxonomy.[14] Unlike a modern programming language, Condorcet's system was meant not just to facilitate computation but also to provide a set of "tables" that classify all of the things in the world.[15] This utopian project rested on an assumption that was widespread among eighteenth-century mathematicians: that algorithms had to be founded on clear mental representations in order to be useful. For Condorcet and other political

11. See David Williams, *Condorcet and Modernity* (New York, 2004), p. 42.

12. Marie-Jean-Antoine-Nicolas Caritat, *Outlines of an Historical View of the Progress of the Human Mind*, trans. pub. (Baltimore, 1802), pp. 238, 239; hereafter abbreviated *O*.

13. See Keith Michael Baker, *Condorcet: From Natural Philosophy to Social Mathematics* (Chicago, 1975), p. 124; Roger Chartier, "Languages, Books, and Reading from the Printed Word to the Digital Text," trans. Teresa Lavender Fagen, *Critical Inquiry* 31 (Autumn 2004): 137; and Umberto Eco, *The Search for the Perfect Language*, trans. James Fentress (Malden, Mass., 1997), p. 283.

14. See Foucault, *The Order of Things*, pp. 71–76.

15. Baker, *Condorcet*, p. 124.

radicals who adhered to this view, reasoning could not be reduced to a mechanical process until all knowledge was rebuilt from the ground up on scientific principles—a dream that was inseparable from projects of political reform.

Condorcet did not live to see his remarks about the universal language published. On 27 March 1794, he was arrested while attempting to flee the house where he was hiding, and two days later he died in his cell of unknown causes. Along with the manuscript for *Outlines of an Historical View of the Progress of the Human Mind*, which was published the following year, he left behind an unfinished plan for the universal language he describes.[16] Over the course of about ninety handwritten pages, Condorcet shows how the symbolic language of algebra can be made to subsist on its own, without the need for French or English words explaining how different equations relate to each other. While Condorcet begins with algebra, his goal is to extend this symbolization beyond mathematics to "all kinds" of knowledge.[17] One could, to use his example, have the number 145702342 designate a particular plant, with 145 representing the class, 70 the genus, 23 the species, and 42 the individual (see "L," p. 217). Just before the manuscript cuts off, he promises to create comprehensive catalogues of such symbols for use in the realms of metaphysics, linguistics, morals, and politics (see "L," p. 219).

Even before Condorcet begins to move beyond mathematics, however, he begins to show some anxiety about the possibility of natural language finding its way back in. Before the universal algebra can be put to use in a particular case, it is necessary to establish the meanings of the symbols, and it was not apparent that this could be done without some recourse to words. Condorcet considers this a flaw in his scheme, although not a fatal one:

> We will observe first that if, in a rare circumstance, it were impossible to make understood an absolutely new theory, to designate an object which had not yet been considered, to develop an operation of which one has not yet formed any idea, without having recourse to some verbal explications, the language would not on that account merit less the name of universal, would not on that account be less useful. It would happen then, but in an opposite sense, what happens in spoken language, when sometimes one is obliged to show the

16. See Frank E. Manuel, *The Prophets of Paris, and Comte* (Cambridge, Mass., 1962), p. 59.

17. G. G. Granger, "Langue Universelle et Formalisation Des Sciences. Un Fragment Inédit de Condorcet," *Revue d'histoire Des Sciences et Leurs Applications* 7 (1954): 204; hereafter abbreviated "L."

> object itself or its representation, because of a lack of having the expressions to describe it. One would need one language to supplement [*suppléer*] the other. One might believe that this defect will not be encountered but very rarely in the language of universal algebra. ["L," p. 213]

To make theories understood, to designate objects, to form ideas of operations—these are all matters of mediating between the symbols and a person's mental conceptions of the world. When an adjustment has to be made to the alignment between symbols and ideas, "verbal explications" must intervene. This is a problem that Joseph Marie de Gérando would judge, a few years later, to be fatal to the idea of a philosophical language: one would have to explain the meanings of the newly minted symbols in an existing, presumably imperfect language, thus tainting the new one.[18] Yet Condorcet is confident that it will not be a problem in the majority of cases. One can mostly avoid the taint of words, he thinks, by taking care always to proceed "from known to unknown" and by expressing new ideas as "generalizations" or "restrictions" of existing ones ("L," p. 213). In this way, the algebraic system can be made as self-contained as possible, and the French language can, for the most part, be held at bay outside the walls.

While Condorcet's universal language scheme can be assigned little direct influence, his apparent aversion to words—the fact that he saw the occasional need for a French definition as a "defect" of his plan—stemmed from an epistemological problem that faced all disciplines that employed algorithms in the eighteenth century, including algebra itself. This problem had been heartily debated for decades. In 1759, Condorcet's mentor Jean le Rond d'Alembert had questioned why algebra, in spite of the certainty of its principles and inferences, "is not yet entirely exempt from obscurity in certain regards."[19] As a specific example, d'Alembert offers negative numbers, of which, he writes, he does not know a single work to provide a clear theory.[20] As Antoine Arnauld had pointed out in a 1667 geometry text, the proportion of a larger number to a smaller one should, intuitively, be larger than the reverse, yet this is not the case with negative numbers, at least in

18. See Joseph-Marie de Gérando, *Des Signes et de l'art de penser considérés dans leurs rapports mutuels*, 4 vols. (Paris, 1799), 1:xxi. See also James Knowlson, *Universal Language Schemes in England and France, 1600–1800* (Toronto, 1975), p. 200.

19. D'Alembert, "Essai sur les élémens de philosophie, ou sur les principes des connaissances humaines, avec les éclaircissemens," in *Oeuvres de D'Alembert*, 5 vols. (Paris, 1821–22), 1:261.

20. See ibid., p. 261n.

modern symbolic algebra: $1/-1 = -1/1$.[21] As an explanation of this seeming paradox, d'Alembert concludes that algebra is "a kind of language which has, like the others, its metaphysics."[22] In order to genuinely understand the results of algebra, one must learn to think within this particular metaphysics. If, instead, one lets the vulgar conceptions of ordinary language seep into one's mathematical reasoning, one will only end up confused.

These concerns were not merely theoretical. The development of the infinitesimal calculus by Isaac Newton and Gottfried Wilhelm Leibniz in the late seventeenth century had opened new vistas in mathematics and physics, but it also raised troubling questions. The Leibnizian version of the calculus, which was based on the celebrated symbols dx and $\int dx$, provided a set of algorithms for two operations—differentiation and integration—that enabled people to produce correct results even in cases so complex as to be virtually impossible to reason about without symbolic notation. Yet Leibniz's methods could also, if used incautiously, produce results that were evidently false. If one supposes, for instance, that $\frac{dy}{dx}dx = dy$—something that would be valid for ordinary, nonzero numbers—then one can easily use the calculus to prove that $1 = 2$. A fully rigorous theoretical foundation for Leibniz's methods did not exist until the nineteenth century, when Bernard Bolzano and Augustin-Louis Cauchy devised the epsilon-delta definition that is now taught in mathematics textbooks.[23] In Condorcet's time, there were several competing explanations of why Gottfried Wilhelm Leibniz's methods worked that all had unresolved difficulties. What was missing, to the eighteenth-century mind, was not a set of formal rules, but rather a metaphysics that would determine, once and for all, the meanings of all the symbols involved in the science.

Condorcet's attempt to expel words from algebra was an extreme response to this problem. Most of his contemporaries took more moderate positions. Étienne Bonnot de Condillac, for instance, asserted in his 1780 book *Logic* that (contra d'Alembert) mathematics is no different from other sorts of reasoning and that one could accordingly do algebra equally well with symbols or with words.[24] But the d'Alembert and Condillac factions shared the assumption that mathematics was, fundamentally, a way of

21. See Albrecht Heeffer, "On the Nature and Origin of Algebraic Symbolism," in *New Perspectives on Mathematical Practices: Essays in Philosophy and History of Mathematics*, ed. Bart Van Kerkhove (Hackensack, N.J., 2009), p. 13.

22. D'Alembert, "Essai," p. 262.

23. See Judith V. Grabiner, "Who Gave You the Epsilon? Cauchy and the Origins of Rigorous Calculus," *The American Mathematical Monthly* 90 (Mar. 1983): 185–94.

24. See Étienne Bonnot de Condillac, "Logic, or the First Developments of the Art of Thinking," in *Philosophical Writings of Etienne Bonnot, Abbé de Condillac*, trans. and ed. Frank Philip and Harlan Lane, 2 vols. (New York, 2014), 1:413.

understanding the world.[25] The Enlightenment project, broadly considered, was less concerned with creating knowledge for its own sake than with improving the way people think in practical circumstances. Inspired in part by Jean-Jacques Rousseau's infamous argument that scientific progress degraded the morals of society, Enlightenment thinkers sought to make their work socially useful as well as true.[26] This practicality was manifest in Enlightenment logic texts like Condillac's, which, on the advice of Francis Bacon and John Locke, de-emphasized formal rules in favor of informal advice about how to reason well.[27] The goal of advancing scientific knowledge was, in this moment, inseparable from the practical business of making people more rational—from "the real improvement of man," as Condorcet put it (*O*, p. 209).

This emphasis on improving people entangled algorithms inexorably with programs of education and social reform. Unless they were accompanied by a real change in the way people thought, the symbolic methods of algebra would be, like the syllogisms of the Scholastics, mere academic games devoid of any real utility. "Every abstract science," wrote Denis Diderot, "is simply juggling with symbols. The exact picture was dropped when the symbol was separated from the physical object, and it is only when the symbol and the physical object are brought together again that the science once again becomes a matter of real things."[28] This return to reality depended on something happening in the mind: mathematicians had to attach the symbols to clear mental pictures of the world. The enemies of this clarity were the enemies of the Enlightenment—old errors and prejudices received from tradition and the recurrence of barbarism. Because his Cartesian epistemology made mathematics dependent on how people think, Condorcet's mechanical system of reasoning could only come into being in what he called the "tenth epoch," the final stage of history in which everyone is enlightened (*O*, p. 209).[29]

25. On the Enlightenment view of mathematics as a means of understanding physical reality, see Amir Alexander, *Duel at Dawn: Heroes, Martyrs, and the Rise of Modern Mathematics* (Cambridge, Mass., 2010), p. 8.

26. See Jean-Jacques Rousseau, "Discourse on the Arts and Sciences or First Discourse," in *The Discourses and Other Early Political Writings*, trans. and ed. Victor Gourevitch (New York, 1997), pp. 1–28.

27. See Francis Bacon, *The Advancement of Learning*, ed. Joseph Devey (New York, 1901), pp. 21–22, and John Locke, *An Essay Concerning Human Understanding*, ed. R. S. Woolhouse (New York, 1997), p. 600. British logic texts took a similar approach in the eighteenth century; see Wilbur Samuel Howell, *Eighteenth-Century British Logic and Rhetoric* (Princeton, N.J., 1971).

28. Denis Diderot, *D'Alembert's Dream*, in "*Rameau's Nephew*" *and* "*D'Alembert's Dream*," trans. Leonard Tancock (New York, 1966), pp. 221–22.

29. See Baker, "On Condorcet's 'Sketch,'" *Daedalus* 133 (Summer 2004): 56–64.

The dependence of algorithms on human thought was even more pronounced in eighteenth-century Britain. British mathematicians were strongly under the sway of Newton, who preferred geometric modes of demonstration to algebraic ones and was skeptical of Leibniz's symbolic notations.[30] In a 1715 *Philosophical Transactions* article discussing his priority dispute with Leibniz, Newton wrote in the third person that "Mr. Newton doth not place his Method in Forms of Symbols," indicating that he had little use for methods that involved shuffling around *dx*s and *dy*s on a page.[31] The standard view is that, because of this rejection of Leibniz's useful notation, British mathematics lagged behind that of Continental Europe until the early nineteenth century, when young mathematicians such as Charles Babbage, John Herschel, and George Peacock introduced the French analytical approach to Cambridge.[32] But compared to their French forebears, the British algebraists of the nineteenth century worried far less about whether the imperfections of ordinary language would compromise the purity of mathematical reasoning. One critical difference, I contend, was that the nineteenth-century British tradition eschewed the universalizing reform projects of the Enlightenment in favor of the Romantic idea that scientific methods must work together with the organically developing culture of a people. This dualism provided mathematicians with a new way of understanding the relationship of symbolic algebra to human thought that would ultimately prove far more conducive to mechanization than Condorcet's Enlightenment philosophy.

William Wordsworth: A Wholesome Separation

The popular version of literary history has assimilated Wordsworth to the view of Romanticism as a reaction against science. This reading is reinforced by his 1798 poem "The Tables Turned," which contains the famous statement that "Our meddling intellect / Mis-shapes the beauteous forms of things; / — We murder to dissect."[33] But Wordsworth's critiques of science have more

30. See Niccolò Guicciardini, "Dot-Age: Newton's Mathematical Legacy in the Eighteenth Century," *Early Science and Medicine* 9, no. 3 (2004): 218–56, and Joan L. Richards, "Rigor and Clarity: Foundations of Mathematics in France and England, 1800–1840," *Science in Context* 4 (Autumn 1991): 297–319.

31. Quoted in Florian Cajori, *Notations Mainly in Higher Mathematics*, in *A History of Mathematical Notations* (Mineola, N.Y., 2012), p. 200.

32. See Menachem Fisch, "The Making of Peacock's Treatise on Algebra: A Case of Creative Indecision," *Archive for History of Exact Sciences* 54 (June 1999): 137–79; I. Grattan-Guinness, "Charles Babbage as an Algorithmic Thinker," *IEEE Annals of the History of Computing* 14, no. 3 (1992): 34–48; Kevin Lambert, "A Natural History of Mathematics: George Peacock and the Making of English Algebra" *Isis* 104 (June 2013): 278–302.

33. William Wordsworth and Samuel Taylor Coleridge, "The Tables Turned," *Lyrical Ballads 1798*, ed. W. J. B. Owen (New York, 1969), p. 105. See James H. Averill, "Wordsworth and

equivocal implications if considered in the context of eighteenth-century thinkers like Condorcet, for whom scientific inquiry was part of a revolutionary project of improving people. Wordsworth's quarrel, I argue, was less with science *per se* than with such attempts to replace existing modes of thinking with scientific rationality. While it was not exactly Wordsworth's intention, this critique ultimately contributed, as the eighteenth century gave way to the nineteenth, to the establishment of a sharper distinction between disciplinary standards of scientific truth and the cultural factors involved in fostering human thought.

One of Wordsworth's most direct statements of his views on science appears in the preface to *Lyrical Ballads*, the 1798 collection he coauthored with Samuel Taylor Coleridge; the preface first appeared in the 1800 edition of the book and was revised and expanded for the 1802 edition. In a footnote, he rejects the "contradistinction of Poetry and Prose" in favor of "the more philosophical one of Poetry and Science," meaning, as he clarifies in the revised version, a distinction between language that deals with feeling and language that deals with facts.[34] The best poetic language, he argues throughout the preface, draws on the "real language of men" and, in particular, on the language of rustic life ("P," p. 153). The advantage of rustic language for expressing feelings is that it has a deep connection to the "durable" experiences of the natural world; it thus provides "a more permanent and a far more philosophical language" than that of John Dryden and Alexander Pope, whose poetry is hobbled by "false refinement or arbitrary innovation" ("P," pp. 156, 157).

While Wordsworth's immediate target in the preface is the highly formal poetic diction of the Augustans, his use of the word *arbitrary* here inculcates him in a broader eighteenth-century debate about the nature of language. A number of Enlightenment thinkers, Condorcet among them, endorsed what Tristram Wolff has called *linguistic voluntarism*—the idea that, since the meanings of signs are arbitrary, those meanings can and should be altered to better suit the natures of things.[35] For the voluntarists, changing the meaning of a word was much like altering the definition of a mathematical function: one need only write $y = x^2 + 1$, and that is what y

'Natural Science': The Poetry of 1798," *The Journal of English and Germanic Philology* 77 (Apr. 1978): 232–46; Daniel Brown, "William Rowan Hamilton and William Wordsworth: The Poetry of Science," *Studies in Romanticism* 51 (Winter 2012): 475–501; Geoffrey Durrant, *Wordsworth and the Great System: A Study of Wordsworth's Poetic Universe* (New York, 1970); John Turner, "Wordsworth and Science," *Critical Survey* 2, no. 1 (1990): 21–28.

34. Wordsworth and Coleridge, "Wordsworth's Preface of 1800, with a Collation of the Enlarged Preface of 1802," *Lyrical Ballads 1798*, p. 164n; hereafter abbreviated "P."

35. See Tristram Wolff, "Arbitrary, Natural, Other: J. G. Herder and Ideologies of Linguistic Will," *European Romantic Review* 27 (Mar. 2016): 259–80.

Critical Inquiry 2020.46:813-834.

will mean. Voluntarism is a critical assumption of Condorcet's universal language project. The problem with such "arbitrary innovation," from Wordsworth's perspective, is that its results lack the emotional resonances of natural languages like English, which are deeply intertwined with the lives of human communities and laden with centuries of history. One might be able to conduct a scientific inquiry using algebraic symbols, but one could not write genuinely moving poetry with them.

Wordsworth addresses a voluntarist project directly in the 1805 version of his long, autobiographical poem *The Prelude*. In the "Books" section, he describes a young boy corrupted by the utilitarian educational system of England circa 1800, his discourse "Tremendously embossed with terms of art. / Rank growth of propositions overruns / The stripling's brain; the path in which he treads / Is choked with grammars."[36] As the editors of the Norton Critical Edition of *The Prelude* point out, a likely target for Wordsworth's polemic is Maria Edgeworth's 1798 book *Practical Education*, which includes a few chapters written by her father, Richard Lovell Edgeworth (see *TP*, p. 162n). Edgeworth advocated exposing children to the "technical terms" of chemistry and other scientific fields from a young age, a practice that was meant to enact, albeit in a subtler way, the same sort of rationalization that Condorcet had attempted with his universal language.[37] "There is no occasion," Edgeworth writes, "to make any sudden or violent alteration in language; but a man who attempts to teach, will find it necessary to select his terms with care, to define them with accuracy, and to abide by them with steadiness; thus he will make a philosophical vocabulary for himself."[38] While Edgeworth rejects "sudden or violent" approaches to linguistic reform, her educational program is ultimately directed toward remaking language from the ground up.

Wordsworth's *The Prelude* as a whole can be taken as a demonstration of the inadequacy of such analytical languages to account for the complexities of actual human experience. In a passage that is sometimes read as his statement of intent in the poem, Wordsworth notes the impossibility of ever reaching a definitive analysis of one's own mind:

> Hard task to analyse a soul, in which
> Not only general habits and desires,
> But each most obvious and particular thought—
> Not in a mystical and idle sense,

36. Wordsworth, *The Prelude, 1799, 1805, 1850*, ed. Jonathan Wordsworth, M. H. Abrams, and Stephen Gill (New York, 1979), p. 168; hereafter abbreviated *TP*.

37. Maria Edgeworth and Richard Lovell Edgeworth, "On Attention," *Practical Education* (New York, 1801), p. iv.

38. Ibid., p. 67.

But in the words of reason deeply weighed—
Hath no beginning. [*TP*, p. 76]

From the perspective of Enlightenment linguistic thought, the consequences of this statement are large. By denying that one can ever determine the origins of one's "habits and desires," Wordsworth also denies the possibility of rebuilding language from first principles, as voluntarists like Condorcet and Edgeworth had attempted to do. However useful the analytical method may be in developing better scientific terminologies and nomenclatures, it cannot compete with the organically developing languages of human communities as means of regulating the emotional attachments that motivate people to behave morally in practice.

Some scholars, such as Siskin and Robin Valenza, have interpreted Wordsworth's poetic project as an attempt to carve out a role for poets in the emerging disciplinary system; it is the poet, Wordsworth suggests, who is best able to take stewardship over the moral aspects of society that science cannot handle.[39] But Wordsworth's repudiation of voluntarism had implications for the "man of science" as much as for the poet. These implications become clear in the several passages on mathematics in *The Prelude.* In stark contrast to d'Alembert's view of mathematics as a means of representing the world, Wordsworth characterizes geometry as "an independent world / Created out of pure intelligence" (*TP*, p. 194). He treats this "independent world" as an escape from both morality and politics; having become disillusioned first with the French Revolution and then with Godwinian radicalism, Wordsworth "Yielded up moral questions in despair, / And for my future studies, as the sole / Employment of the enquiring faculty, / Turned toward mathematics, and their clear / And solid evidence" (*TP*, pp. 406–08). There is arguably a biographical parallel between Wordsworth and Condorcet here, as both sought comfort in mathematics during the political turmoil of the mid-1790s. But Condorcet certainly had not "Yielded up moral questions"—instead, he had viewed mathematics as a means of pinning morality down. Wordsworth narrates his disillusionment with such incursions of science into the moral realm in the later books of *The Prelude*, finally resolving "to keep / In wholesome separation the two natures— / The one that feels, the other that observes" (*TP*, p. 476).

These were, of course, contentious statements. The idea of the poet as a moral authority was certainly not universally accepted in nineteenth-century Britain, and utilitarianism would remain an important intellectual

39. See Siskin, "Mediated Enlightenment," p. 170, and Robin Valenza, *Literature, Language, and the Rise of the Intellectual Disciplines in Britain, 1680–1820* (New York, 2009), p. 144.

force for decades. But the dualistic view of culture that Wordsworth promoted—the idea that science deals only with matters of fact, whereas poetry deals with feeling—had adherents among mathematicians and logicians as well as among poets. The narrowing of the scope of science to matters of fact is apparent in the early-nineteenth-century logic texts of Richard Whately and John Stuart Mill, who both differ from their Enlightenment predecessors in insisting that their science is concerned only with specifying formal criteria for validity, not with the practicalities of making people reason better.[40] The extent of Wordsworth's direct influence on these developments is debatable, but the outcome is broadly in line with the arguments he makes in the 1802 preface and in *The Prelude*. Via the work of Boole, this intellectual turn would prove to have crucial significance in the history of computation.

George Boole: A Language Without Things

Although some readers may have only encountered Boolean logic in the search strings used in library databases, such as "poetry AND (mathematics OR algebra)," the system of *and*s, *or*s, ones, and zeroes that Boole created plays a pervasive role in electronic computers. In the 1847 book in which he first introduced it, Boole claimed that this system would provide "a step toward a philosophical language," echoing the claims Condorcet had made half a century before.[41] But there is a major difference in the way the two systems work. Condorcet had intended his universal algebra to incorporate an encyclopedic catalogue of things, thus enabling it to constitute, in itself, a unified body of knowledge that could be used to settle disputes in any area of life. Boole, by contrast, excludes questions of meaning from the scope of his system; his logical calculus is meant to work together with, rather than replace, the bodies of linguistic and conceptual knowledge that already exist in other spheres of the academy and of society more broadly. This compartmentalized view of knowledge freed symbolic logic from the conceptual issues that had confounded Condorcet's project and, by doing so, opened the possibility for algorithms to take a newly central role in the production of knowledge.

Boolean logic may seem antithetical to Romantic thought because, in its modern form, it is an entirely instrumental system that reduces the world

40. See John Stuart Mill, *A System of Logic, Ratiocinative and Inductive*, 2 vols. (London, 1843), 1:439, 2:201–02, and Richard Whately, *Elements of Logic* (Boston, 1859), p. 10.

41. George Boole, *The Mathematical Analysis of Logic* (London, 1847), p. 5; hereafter abbreviated *M*.

Critical Inquiry 2020.46:813-834.

to ones and zeroes rather than making room for intuition.[42] Yet Boole himself was far from a utilitarian. Like other Victorian practitioners of pure mathematics, he viewed his work as a contemplative practice detached from practical affairs.[43] At the same time that he was formulating his logic system, he wrote a large volume of verse in a style influenced by Dante Alighieri, John Milton, and Wordsworth; a "real mathematician," he reportedly said, "must be something more than a *mere* mathematician, he must be also something of a poet."[44] Boole's views on poetry were rather different from Wordsworth's, but the two were alike in their insistence that scientific methods of analysis must not overstep their bounds into the areas of human life that are properly governed by feeling. This dualism, I argue, enabled Boole to make sense of a disconnect that arose in his work between the algorithmic processes of algebra and the actualities of human thought; yet it came at the cost of opening an epistemological divide between algorithmic methods and the newly established domain of culture.

Boole's logical system, which he first published in the hastily written 1847 book *The Mathematical Analysis of Logic* and presented in a more refined form in *An Investigation of the Laws of Thought* (1854), is based on the insight that the logical connectives *and* and *or* operate analogously to algebraic operators. In Boole's system, multiplication represents *and*, addition represents (exclusive) *or*, and subtraction represents *not*; 1 represents everything in the universe of discourse and 0 represents nothing. To adapt one of his examples, one could translate the statement "Every poet is a man of genius" into the equation $p(1 - g) = 0$, which means, more literally interpreted, that the category of entities that are poets (p) and not men of genius ($1 - g$) is empty (0) (*M*, p. 26).[45] On the basis of this symbolic representation, Boole develops what he calls "a directive method" for answering logical questions—that is, not just a set of criteria for determining

42. See Max Horkheimer and Theodor W. Adorno, *Dialectic of Enlightenment*, trans. Edmund Jephcott, ed. Gunzelin Schmid Noerr (Stanford, Calif., 2002), p. 23.

43. Victorians distinguished pure mathematics, which dealt only with abstractions, from mixed mathematics, which emphasized applicability to physics and engineering; see Alexander, *Duel at Dawn*, and Daniel J. Cohen, *Equations from God: Pure Mathematics and Victorian Faith* (Baltimore, 2007). For a very different perspective on the relation of formal logic to the *vita activa*, see Paul Livingston, *The Politics of Logic: Badiou, Wittgenstein, and the Consequences of Formalism* (New York, 2014).

44. Mary Everest Boole, "Home-Side of a Scientific Mind," *The Dublin University Magazine: A Literary and Political Journal* 91 (Jan. 1878): 106; hereafter abbreviated "H." On Boole's poetry, see Desmond MacHale, *The Life and Work of George Boole: A Prelude to the Digital Age* (Cork, 2014).

45. See Theodore Hailperin, *Boole's Logic and Probability: A Critical Exposition from the Standpoint of Contemporary Algebra, Logic and Probability Theory* (New York, 1986).

whether a deduction is correct, but also a rigorously defined algorithm for deciding which deductions to make.[46]

A key inspiration for this system was the then-recent symbolic turn in British algebra, which Boole summarizes at the beginning of *Mathematical Analysis*: "They who are acquainted with the present state of the theory of Symbolical Algebra, are aware, that the validity of the process of analysis does not depend upon the interpretation of the symbols which are employed, but solely upon the laws of their combination" (*M*, p. 3). Whereas Enlightenment mathematicians had attempted to found algorithms on concepts, nineteenth-century algebraists such as Boole's mentor Duncan F. Gregory reversed the order; we begin by letting the symbols "reason for us," as William Whewell put it, and work out what it all means afterward.[47] Boole drew out the implications of this reversal with a boldness that was uncommon in his time. Whereas Gregory and Peacock stopped short of treating algebra as an entirely formal system, insisting that one must eventually devise a geometric interpretation in order for the results to have scientific value, Boole accepted the validity of symbolic methods even in cases when no interpretation was possible. In doing so, he encountered what might be seen as an early instance of Liu's "meaning problem"—a rift between the algorithmic processes of symbolic logic and the conceptual resources by which people understand the meanings of the symbols.

Boole addresses this rift directly in one of the most notorious passages in *An Investigation of the Laws of Thought*. One of the prime dangers of employing symbolic methods, Boole writes, is that such methods can produce expressions that are "uninterpretable in that sphere of thought which they are designed to aid" (*I*, p. 67). Such uninterpretable statements occur frequently in Boole's text; his algorithm sometimes produces equations that contain division, which, unlike multiplication, addition, and subtraction, has no logical meaning that can be translated into English. This phenomenon, Boole writes, is specific to symbolic methods, as "this apparent failure of correspondency between process and interpretation does not manifest itself in the *ordinary* applications of human reason" (*I*, p. 67). Boole's response to this potential objection is that, as long as the method is correct and one can interpret the input and output of the process, the incomprehensibility of what happens in between is irrelevant. In effect,

46. Boole, *An Investigation of the Laws of Thought: On Which Are Founded the Mathematical Theories of Logic and Probabilities* (London, 1854), p. 11; hereafter abbreviated *I*.

47. William Whewell, *The Philosophy of the Inductive Sciences: Founded upon Their History*, 2 vols. (London, 1840), 1:143. See also Gregory, "On the Real Nature of Symbolical Algebra," *Transactions of the Royal Society of Edinburgh* 14 (1840): 208–16, and George Peacock, *A Treatise on Algebra* (London, 1830), p. xiv.

Boole's system turns deductive reasoning into a black box inside of which interpretation is needless and, in the case of expressions involving division, futile.

The use of uninterpretable expressions has never been widely accepted among logicians. One of Boole's early champions, William Stanley Jevons, criticized Boole for employing "dark and symbolic processes," and later practitioners of symbolic logic mostly attempted to ensure that one could always, at least in theory, understand the meanings of the symbols.[48] But uninterpretability is worth taking seriously as a side effect of the adoption of algorithmic methods. As an example that, in Boole's view, proves the legitimacy of the practice, "the uninterpretable symbol √-1," although devoid of any sensible meaning, may be used "in the intermediate processes of trigonometry" (*I*, p. 69). While one might question whether imaginary numbers like $\sqrt{-1}$ are really "uninterpretable" in an absolute sense, it is true that they cannot be interpreted in terms of ordinary notions of quantity or distance. Yet, as Gerolamo Cardano discovered in the sixteenth century, they can nonetheless be used in algorithms that produce verifiably correct results about quantities.[49] Most mathematicians from Cardano's time down to the Enlightenment were suspicious of such methods, since they seemed to lack an adequate conceptual foundation. For Boole, however, the apparent incomprehensibility of imaginary numbers has no bearing on their legitimacy as instruments of computation; all that matters, for the purposes of mathematical validity, is that one follows the rules.

This disarticulation of algorithms from conceptual thought marks a definitive break from Enlightenment conceptions of the nature of mathematics. For Condorcet, symbolic methods could only be applied to a given domain of knowledge after that domain has been reduced to mathematically precise concepts. Boole's algebraic system, by contrast, provides entirely separate rules for computing results—in Boole's terms, *process*—and for translating those results into the languages of other disciplines—*interpretation.* Employing algorithms, in this system, does not require rebuilding knowledge of one's subject matter from the ground up. Instead, Boole's

48. W. Stanley Jevons, *Pure Logic and Other Minor Works*, ed. Robert Adamson and Harriet A. Jevons (New York, 1890), p. 67. See also Frank Markham Brown, "George Boole's Deductive System," *Notre Dame Journal of Formal Logic* 50, no. 3 (2009): 303–30; Witold Marciszewski and Roman Murawski, *Mechanization of Reasoning in a Historical Perspective* (Atlanta, Ga., 1995), pp. 146–47. Boole's use of uninterpretable statements is defended in J. W. Van Evra, "A Reassessment of George Boole's Theory of Logic," in *A Boole Anthology: Recent and Classical Studies in the Logic of George Boole* (Boston, 2000), pp. 87–99.

49. See Helena M. Pycior, *Symbols, Impossible Numbers, and Geometric Entanglements: British Algebra through the Commentaries on Newton's "Universal Arithmetick"* (New York, 2006), p. 23.

method simply produces answers that one may interpret, as he puts it in his first book, "in the spirit of" the existing methods of one's discipline (*M*, p. 10).

What enabled Boole to disentangle algorithms from meaning where Condorcet could not, I would like to suggest, was the reconceptualization of the purpose of science that occurred in the Romantic period. Like Wordsworth, Boole treated science as concerned primarily with matters of fact, not with the sort of all-encompassing social reform that Condorcet had envisioned. In the final paragraph of *An Investigation of the Laws of Thought*, Boole draws the bounds of his discipline in terms quite in line with Wordsworth's dichotomy between science and feeling:

> If the mind, in its capacity of formal reasoning, obeys, whether consciously or unconsciously, mathematical laws, it claims through its other capacities of sentiment and action, through its perceptions of beauty and of moral fitness, through its deep springs of emotion and affection, to hold relation to a different order of things. . . . As truly, therefore, as the cultivation of the mathematical or deductive faculty is a part of intellectual discipline, so truly is it only a part. [*I*, p. 423]

The pairing of "sentiment and action" here is especially telling. Boole's anatomy of the mind effectively drains mathematics of the overt political content that it had had for the French analysts, slotting it away as one discipline among many and distinguishing it, in particular, from the emotional factors that motivate actual human behavior.

While this passage might be taken as a mere nod to traditional pieties, Boole's published lectures suggest that he was sincere in his adherence to Romantic notions of culture. In an 1847 address, he criticizes those who believe that the physical sciences are fit "to effect a species of intellectual regeneration in society" and recommends, using quite Wordsworthian language, "cultivating the love of Nature" as a means of developing moral sentiments.[50] Elsewhere, he maintains, echoing an earlier argument by Coleridge, that empirical methods can only produce "a mere collection of facts" unless they are guided by a moral purpose.[51] In a later speech entitled "The Social Aspect of Intellectual Culture," Boole argues, drawing on William Whewell's historiography, that progress is driven by "the slow but combined action of the social state," each new advance depending on everything that has been achieved in the past in both the sciences and the

50. Boole, *The Right Use of Leisure: An Address, Delivered Before the Members of the Lincoln Early Closing Association, February 9th, 1847* (London, 1847), pp. 14, 23.

51. Quoted in MacHale, *The Life and Work of George Boole*, p. 111.

arts.[52] Whereas Condorcet had located his universal algebra in the final, enlightened epoch of history in which it would supersede all other forms of knowledge, Boole's narrative of progress positions the "laws of thought" governing algebra and logic outside the history of human society, whose development could be guided, just as Wordsworth suggested, by feeling (see *I*).

Given this organic view of human life, it may seem ironic that Boole's work would ultimately enable logic to become embodied in machinery. Boole's early followers, starting with Jevons, wasted no time in exploring the possibilities his system opened for mechanization, and starting in the 1930s, Boolean logic would play a central role in the design of digital electronics.[53] While Boole himself showed little interest in computing machines, the amenability of his system to mechanization does become apparent in his approach to pedagogy. According to a biographical essay that his wife, Mary Everest Boole, published in 1878, he thought it important that children "should spend a great deal of time over some mechanical work which could be done without the presence of a teacher, and which they must concentrate their whole energies upon, and do with perfect accuracy" ("H," p. 109).[54] He maintained, she writes, that students must be taught how to work a sum before learning the reasoning behind the procedure; they are "to *obey* first and *understand* afterwards" ("H," p. 109). This statement exemplifies the reversal of the relationship between algorithm and meaning that occurred between the eighteenth and nineteenth centuries. After algorithms were freed from their dependence on concepts, mathematical and logical validity came to have less to do with how one thinks than with what one does. It is only a short leap from this "directive method" to the literal mechanization of logical reasoning.

To understand how this emphasis on "mechanical work" could coexist with the idealism of Boole's lectures, it is critical to recognize that the symbolic turn in algebra was not based on an all-encompassing mechanical view of the world. Boole's statement about mathematicians and poets

52. Boole, *The Social Aspect of Intellectual Culture. An Address Delivered in the Cork Athenæum, May 29th, 1855, at the Soiree of the Cuvierian Society* (Cork, 1855), p. 11. See also Whewell, *History of the Inductive Sciences: From the Earliest to the Present Times*, 3 vols. (London, 1837).

53. See Lindsay Barrett and Matthew Connell, "Jevons and the Logic 'Piano,'" *The Rutherford Journal* 1 (2005–2006), www.rutherfordjournal.org/article010103.html, and Claude Elwood Shannon, "A Symbolic Analysis of Relay and Switching Circuits" (master's thesis, Massachusetts Institute of Technology, 1940).

54. On the reliability of Mary Everest Boole's account of her husband's views, see Luis M. Laita, "Boolean Algebra and Its Extra-Logical Sources: The Testimony of Mary Everest Boole," *History and Philosophy of Logic* 1, nos. 1–2 (1980): 37–60.

suggests a hierarchy—one can only be a "real" mathematician if one can go beyond mechanically following the rules and perceive the poetry of the practice. This value judgment was not specific to Boole; the symbolic turn inspired numerous complaints that it would reduce mathematics to the "manipulation of symbols," a phrase with the class-based connotation of manual rather than intellectual labor.[55] What saved mathematics from a social fall was that the nineteenth-century disciplinary system distinguished the algorithmic aspects of the practice from the "cultivation" of a mathematician's mental faculties, which could be governed by the organic regime that Boole recommends in his lectures. However mechanical algebra might become in practice, critics could be assured, it would not impose that mechanical order upon people's minds—or at least not upon the minds of the highly "cultured."

While both the humanities and the sciences have long since moved on from Romantic attitudes, the distinction underlying this compromise—between matters of technical validity, which may be subject to rigorous formal rules, and cultural factors, which must be handled with more delicacy—continues to inform attitudes toward algorithms in the present day. The distinction between technical and cultural matters persists, among other places, in the design of computer interfaces. Computer screens are festooned with words—*save*, *submit*, *like*—that serve to mediate between the logic of the software and culturally transmitted systems of meaning.[56] While this specific semiotic practice arose in the twentieth century, it works within categories that were established in the Romantic period. It was Romantic thinkers like Wordsworth, Coleridge, and Edmund Burke who first delineated the modern category of culture, which captured those aspects of human thought that must be permitted to develop freely rather than being scientifically designed; and it was just those "cultural" aspects of thought that Boole and other nineteenth-century algebraists expelled from the scope of their science. This division places an epistemological barrier between algorithmic and interpretive methods, which now had to answer to different and potentially conflicting standards.

55. James Booth, "On Tangential Coordinates," *Proceedings of the Royal Society of London* 9 (1857–1859): 176. See also John Venn, *The Logic of Chance: An Essay on the Foundations and Province of the Theory of Probability* (London, 1866), p. 164; Becher, "Radicals, Whigs and Conservatives," pp. 413–14; Daston, "Enlightenment Calculations," pp. 185–86; Lambert, "A Natural History of Mathematics," p. 289; and Joan L. Richards, *Mathematical Visions: The Pursuit of Geometry in Victorian England* (Boston, 1988), pp. 39–50.

56. See Peter Bøgh Andersen, *A Theory of Computer Semiotics: Semiotic Approaches to Construction and Assessment of Computer Systems* (New York, 1997), p. 13.

A clear instance of this disconnect has occurred recently in the digital humanities. In his article on the meaning problem, Liu discusses a text-analysis technique known as *topic modeling*, which identifies clusters of words that sometimes, although not always, correlate roughly with what a human being would recognize as the *topic* of a piece of writing.[57] The creators of a popular variant of topic modeling known as latent Dirichlet allocation (LDA) make it clear, in their technical paper, that one should not read too much into the word *topic*: "We refer to the latent multinomial variables in the LDA model as topics, so as to exploit text-oriented intuitions, but we make no epistemological claims regarding these latent variables beyond their utility in representing probability distributions on sets of words."[58] This explanation rests on much the same dualism that I have identified as a product of Romanticism: the English word *topic* facilitates thought by bringing in a reservoir of intuitions drawn from culture, whereas the logic of the system provides a more scientifically precise definition of the variable. This subordination of meaning to algorithm presents a roadblock for disciplines that give primacy to the culturally determined meaning of words, as the scientific and cultural definitions of *topic* cannot be guaranteed to align.

In spite of its seeming inevitability, this epistemological gap is not inherent in the nature of algorithms. On the basis of Condorcet's Enlightenment project, one could imagine an alternative history of computation that relates algorithm to meaning in an entirely different way. Condorcet would have viewed the presence of words in user interfaces with skepticism, as they could potentially introduce unclear concepts into one's understanding of the system; he would have preferred to use numerical codes representing positions within a universal taxonomy of things. The goal in this choice of signifiers would not be to tailor the system to work well with people's existing intuitions, as user-interface designers do today, but rather to replace people's intuitive concepts with something better. Such a reform could only be justified morally on the grounds that the algorithms are founded on the universal teachings of reason. Without such a foundation, to claim that a statistical model has any right to tell us how we should understand the word *topic* would be, from an Enlightenment perspective, tyranny.

While Condorcet's Enlightenment optimism is not coming back, there is still room for revision in the present arrangement. The reigning paradigm of human-computer interaction is founded on an unsteady truce between two incompatible views of language: involuntarism and voluntarism. In

57. See Liu, "The Meaning of the Digital Humanities," p. 414.

58. David M. Blei, Andrew Y. Ng, and Michael I. Jordan, "Latent Dirichlet Allocation," *Journal of Machine Learning Research* 3 (2003): 996 n. 1.

regard to cultural factors, Wordsworth's side won out; the founders of modern linguistics, Wilhelm von Humboldt and Ferdinand de Saussure, both stridently deny that one can alter the meanings of words at will, figuring language as (Humboldt writes) "an involuntary emanation of the mind" that individuals and institutions can only influence in partial, uncertain ways.[59] But engineers happily change the technical definitions of words as they see fit. While linguists rejected voluntarism for good reason, the exact nature of the boundary between those aspects of computer systems that can be changed at will and those that must answer to collectively established conventions is hardly a settled matter. The prospects for rethinking this boundary are strong at present in digital humanities, which deals explicitly with intersections of computation and hermeneutics, as well as in artificial intelligence, in which a new debate has arisen over whether the workings of computational systems need always be "interpretable."[60] Participants in these discussions would do well to pay attention to the ways people thought about algorithms prior to the twentieth century, when fundamental assumptions about how mechanical processes related to human thought were still in flux, and other possibilities were visible.

59. Wilhelm von Humboldt, *On Language: On the Diversity of Human Language Construction and Its Influence on the Mental Development of the Human Species*, trans. Peter Heath, ed. Michael Losonsky (New York, 1999), p. 24. See also Ferdinand de Saussure, *A Course in General Linguistics*, trans. and ed. Roy Harris (Peru, Ill., 1986), pp. 68–74.

60. See Shane Barratt, "InterpNET: Neural Introspection for Interpretable Deep Learning," *Arxiv*, 25 Oct. 2017, arxiv.org/abs/1710.09511. See also Leo Breiman, "Statistical Modeling: The Two Cultures," *Statistical Science* 16, no. 3 (2001): 199–215, and Stephen Cass, "Unthinking Machines," *MIT Technology Review*, 4 May 2011, www.technologyreview.com/s/423917/unthinking-machines/