Statecraft by Algorithms

*by Alma Steingart**

ABSTRACT

Throughout the 1920s Congress failed to pass an apportionment bill. Among the various reasons for the failure was Congress's inability to decide which method, or algorithm, should govern apportionment. Two competing methods, major fractions and equal proportions, rose to the top and the supporter of each claimed that his method offered the only "fair" and "unbiased" solution to the problem. Following this early debate, this chapter argues that contemporary concerns about algorithm fairness and equality do not emerge out of the nature of their complexity. Rather, they inhere in the incommensurability between mathematical and social rationales and the wide room for interpretation yawning between the two. Not only are definitions of "fairness" multiple but how algorithms are described, either through method or through principle, can lead to completely different results.

"May I ask you to read the enclosed three pages, and tell me in what respect you regard these mathematical results as lacking in 'elegance'?" Edward Huntington was upset.[1] He had just learned that George Birkhoff, his Harvard colleague and one of the most respected mathematicians of his generation, had criticized his mathematical solution to the problem of congressional apportionment. It was 1940; for two decades Huntington had been on a quest to convince the US Congress and the American people that his equal proportion method was the correct and only legitimate solution to the apportionment problem and had mobilized the mathematical community around him. To hear this criticism from such a close and respected colleague felt like a betrayal. "Don't you think I am entitled to a little more cooperation than that?" he asked Birkhoff. It was not just a question of personal insult; the issue was sensitive. Huntington worried that Birkhoff's criticism would negatively affect the standing of the entire mathematical community. Please, he implored Birkhoff, remain silent on the matter, for "you . . . have nothing to lose."[2]

Huntington was used to defending his method. Indeed, he spent much of the 1920s in a bitter fight with Walter Willcox, who advocated for a different solution to the apportionment problem, a method known as major fractions. The two men's dispute brought them to testify in front of Congress and spilled out onto the pages of *Science*

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[1] Edward V. Huntington to George Birkhoff, February 3, 1940, HUG4213.2, box 14, folder "B," Papers of George D. Birkhoff, 1902–1946, Harvard Univ., Cambridge, MA.

[2] Huntington to Birkhoff, February 3, 1940.

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and the *New York Times*.[3] Fundamentally, they disagreed on the method that statisticians in the Census Bureau needed to follow to solve the apportionment problem. They offered two competing algorithms. These algorithms were not computerized, but rather step-by-step instructions, rule-based calculations aimed at solving a particular problem—how seats in the House of Representatives should be allocated among the various states after each decennial census.

The story of Huntington and Willcox's fight is a useful one to consider in our time, which has been designated by some as the age of algorithms, a period in which almost every aspect of our daily lives is enmeshed, whether we know it or not, in complex logical circuits churning nonstop on computers around the world.[4] When scholars from a wide array of fields began turning their attention to the study of algorithms, one of the main issues that they quickly homed in on was fairness. How do users ensure that the algorithms they deploy are not biased toward one group or another? How should algorithm accountability be defined? And what are the limits of transparency? Some studies have focused on the data that feed into these algorithms, showing how data tend to perpetuate already existing inequalities, while others have emphasized the black-boxed nature of many of these algorithms.[5] These problems are often attributed to the complexity of many modern algorithms. Modern algorithms are based on massive amounts of data, require substantial computer power and memory, and involve convoluted statistical analyses, which are understood by only a select few.

The dispute between Huntington and Willcox shows that concerns about bias, transparency, and accountability are not rooted in the complexities of digital algorithms. Nor are they unfortunate artifacts of the inherently difficult and large-scale problems that contemporary algorithms address, be it in healthcare, education, or the insurance industry. Rather, these problems are due to the necessarily reductionist approach buttressing *any* attempt to reduce social or political problems to a set of clear rule-based procedures. They inhere in the incommensurability between mathematical and social rationales and the wide room for interpretation yawning between the two. To understand the

[3] Edward V. Huntington, "The Reapportionment Bill in Congress," *Science* 67, no. 1742 (1928): 509–10; Huntington, "The Report of the National Academy of Sciences on Reapportionment," *Science* 69, no. 1792 (1929): 471–73; Huntington, "Reply to Professor Willcox," *Science* 69, no. 1784 (1929): 272; Walter F. Willcox, "The Apportionment of Representatives," *Science* 67, no. 1745 (1928): 581–82; Willcox, "The Apportionment Situation in Congress," *Science* 69, no. 1780 (1929): 163–65; Willcox, "Professor Huntington's Method in Controversy," *Science* 69, no. 1787 (1929): 357–58.

[4] James Evans and Adrian Johns, "The New Rules of Knowledge: An Introduction," *Critical Inquiry* 46, no. 4 (2020): 806–12; Serge Abiteboul and Giles Dowek, *The Age of Algorithms* (Cambridge: Cambridge Univ. Press, 2020); Navneet Alang, "Life in the Age of Algorithms," *New Republic*, May 13, 2016, https://newrepublic.com/article/133472/life-age-algorithms; Taina Bucher, *If . . . Then: Algorithmic Power and Politics* (New York: Oxford Univ. Press, 2018); Massimo Mazzotti, "Algorithmic Life," *LA Review of Books*, January 22, 2017, https://lareviewofbooks.org/article/algorithmic-life/; Christopher Steiner, *Automate This: How Algorithms Took Over Our Markets, Our Jobs, and the World* (New York: Penguin, 2012).

[5] For a selection, see Tarleton Gillespie, "The Relevance of Algorithms," in *Media Technologies: Essays on Communication, Materiality, and Society*, ed. Gillespie, Pablo J. Boczkowski, and Kirsten A. Foot (Cambridge: MIT Press, 2014), 167–94; Safiya Umoja Noble, *Algorithms of Oppression: How Search Engines Reinforce Racism* (New York: New York Univ. Press, 2018); Cathy O'Neil, *Weapons of Math Destruction: How Big Data Increases Inequality and Threatens Democracy* (New York: Crown, 2017); Frank Pasquale, *The Black Box Society: The Secret Algorithms That Control Money and Information* (Cambridge, MA: Harvard Univ. Press, 2015); Brent Daniel Mittelstadt et al., "The Ethics of Algorithms: Mapping the Debate," *Big Data & Society* 3, no. 2 (2016); Malte Ziewitz, "Governing Algorithms: Myth, Mess, and Methods," *Science, Technology, & Human Values* 41, no. 1 (2016): 3–16.

problem of apportionment requires no more than basic arithmetic. And yet the fight over apportionment in the 1920s demonstrates that even relatively simple algorithms are open to multiple explications and cannot be understood outside of the social and political realities to which they speak.

Not only are definitions of "fairness" multiple but how algorithms are described can lead to radically different results. When testifying in Congress or arguing in public, Huntington and Willcox recognized that describing the principles underlying their algorithms and accounting for the step-by-step computational processes that were derived from them could lead to myriad responses. While Huntington focused his effort on convincing others that the underlying principles of his method were correct even if the process itself was unintelligible, Willcox took the opposite approach, focusing his persuasive efforts on rendering the process more intelligible rather than clarifying the underlying mathematical principles. To some degree, the controversy between the two was rooted in this fundamental disagreement.

A large body of literature on science, policy, and the law has investigated the relation of science to social order, in issues ranging from intellectual property to scientific expert witnesses and evidence to environmental protection. Such literature has demonstrated the coproduction of scientific and legal "facts," revealed divergences between legal rationales and scientific authority, and offered new methodologies to both science and technology studies and legal scholars.[6] Furthermore, much attention in history of science has been directed at the role of quantification in the basic functions of governance.[7] As Michel Foucault argued, numbers are key elements in regimes of power and knowledge in civil society. The population as a unit of control and surveillance can be managed as an object of discipline only if it is first *counted*, and herein the power of numbers is embedded in, and used as a tool by, regimes of biopower.[8]

To the best of my knowledge, the case below represents the first forays of the mathematical community in the United States into the electoral process.[9] In the following century mathematical and statistical expertise would become indispensable to how

[6] See, for example: Simon A. Cole, "Where the Rubber Meets the Road: Thinking about Expert Evidence as Expert Testimony," *Villanova Law Review* 52 (2007): 803–42; Harry Collins and Robert Evans, *Rethinking Expertise* (Chicago: Univ. of Chicago Press, 2008); Sheila Jasanoff, *Science at the Bar: Law, Science, and Technology in America* (Cambridge, MA: Harvard Univ. Press, 1995); Michael Lynch et al., *Truth Machine: The Contentious History of DNA Fingerprinting* (Chicago: Univ. of Chicago Press, 2010); Stephen Turner, "What Is the Problem with Experts?," *Social Studies of Science* 31, no. 1 (2001): 123–49.

[7] Theodore M. Porter, *Trust in Numbers: The Pursuit of Objectivity in Science and Public Life* (Princeton, NJ: Princeton Univ. Press, 1996); Alain Desrosières, *The Politics of Large Numbers: A History of Statistical Reasoning* (Cambridge, MA: Harvard Univ. Press, 1998); William Alonso and Paul Starr, eds., *The Politics of Numbers* (New York: Russell Sage Foundation, 1987); Dan Bouk, *How Our Days Became Numbered: Risk and the Rise of the Statistical Individual* (Chicago: Univ. of Chicago Press, 2015).

[8] Graham Burchell, Colin Gordon, and Peter Miller, eds., *The Foucault Effect: Studies in Governmentality* (Chicago: Univ. of Chicago Press, 1991); Foucault, *Security, Territory, Population: Lectures at the Collège de France, 1977–1978*, ed. Michel Senellart (New York: Macmillan, 2009), 87–114; Nikolas Rose, *Powers of Freedom: Reframing Political Thought* (Cambridge: Cambridge Univ. Press, 1999).

[9] This is not to say that mathematicians did not seek to use their expertise to devise electoral systems earlier. Many Enlightenment thinkers lent their hands to that effort. Rather, my claim is that in the United States, the apportionment fight represents the first time a self-identified professional mathematician sought to use his academic standing to intervene within an ongoing debate about the meaning of fair representation. For earlier examples, see Alfred De Grazia, "Mathematical Derivation of an Election System," *Isis* 44, no. 1–2 (1953): 42–51.

Americans elect their representatives, but at the beginning of the twentieth century the mathematical community was coming into its own.[10] This case thus sets the stage for the birth of a new American mathematical expertise, its limits and its strengths. Mathematicians' claim to expertise was based on the notion of mathematical proof, and how it might be leveraged to interpret constitutional fairness. Mathematicians' ability to call upon proof is predicated on their ability to treat underlying questions in the abstract. Only once all the necessary conclusions are logically deduced does it become meaningful to articulate how the results apply to a specific case. This impetus places mathematicians in direct conflict with political (and legal) sensibilities that seek to address matters "on the ground." In other words, mathematicians' claim to authority, the source of their expertise, necessitates the separation of mathematical analysis from the lived world. However, this imperative is exactly what makes mathematical analysis problematic when it intersects with political and legal doctrines, which are often more interested in the here and now than in logical coherence. Thus, mathematics' greatest strength is also its greatest weakness when it interfaces with American democracy.

But how can ideas such as fairness and bias be defined mathematically? And what are the relations among mathematical, political, and legal conceptions of fairness? As the debates on apportionment method raged during the 1920s, it became clear that it was extremely difficult, if not impossible, to arrive at any narrow mathematical definition of fairness. In particular, three overlapping meanings of fairness arose: an *abstract* one that sought to determine a clear criterion by which different methods can be judged in relation to one another and that focused on an interpretation of the Constitution, a *pragmatic* one that revolved around the potential political impact of using each method, and a *procedural* one having to do with the relative comprehensibility (or lack thereof) of the underlying methodology. As the debates make readily apparent, in each of these definitions of fairness—the abstract, the pragmatic, and the procedural—no fine line distinguished political from technical content.

THE APPORTIONMENT PROBLEM

While the Constitution is clear about the proportional composition of the House of Representatives, stating that "Representatives . . . shall be apportioned among the several States . . . according to their respective Number," it is not explicit about the method by which this proportional allocation is to be computed.[11] It is this ambiguity that gave rise to the problem of remainders.[12] To get a sense of the nature of the problem, it is beneficial to try to compute an apportionment. When the 1910 decennial census was complete, the total population of the United States was 91,072,117 and the size of the House was 433 members. To determine how many representatives each state was entitled to,

[10] The increasing influence of mathematicians, statisticians, and later computer scientists on the American electoral system during the twentieth century is the topic of a book project from which this article emerged.

[11] The provision in the Constitution set a minimum proportion of population to each House member. There was to be no more than one representative for every thirty thousand people of the "representative population." However, it said nothing more on how the calculation should be done. Up until the passing of the Fourteenth Amendment in 1868, the original apportionment clause in the Constitution included the infamous three-fifths compromise.

[12] Michel L. Balinski and H. Peyton Young, *Fair Representation: Meeting the Ideal of One Man, One Vote* (New Haven, CT: Yale Univ. Press, 1982).

the first step was to divide the total population by the number of seats in the House to obtain what is called an exact divisor. In 1910, the exact divisor was 210,320. The next step was to divide the population of each state by the divisor to arrive at that state's quota. Massachusetts's population was 3,366,416; thus the state's quota was 16.006. By the same procedure, Texas's quota was 18.526. A quota was similarly computed for each state. Now the question remained—and this is the crux of the problem—what do you do with these remainders? If you try simply ignoring the remainders, you will end up with a House smaller than 433. If, on the other hand, you decide to round up or down depending on whether the fraction is larger or smaller than half, you will most likely end up with a number that is either too big or too small.

The problem of method was already apparent after the first census was completed in 1791.[13] Opinions as to which method was most just surfaced repeatedly, and many American thinkers lent their time to the problem. Thomas Jefferson, Alexander Hamilton, Daniel Webster, and John Adams were among those who tried to tackle the problem and offer a methodology over the years. By 1850 Congress settled on the method known as the Hamiltonian method. According to this method, once you allocate all the whole numbers to the states, you simply order all the states from largest to smallest fraction and begin allocating the remaining seats in order until you reach the desired size of the House.[14]

This method would probably have remained in effect and the entire debate would have been avoided if not for the curious anomalies statisticians began to notice toward the end of the century. The most peculiar of all was named the Alabama Paradox: after the 1880 census, if the Census Bureau's statisticians were to use the Hamiltonian method, Alabama would have 8 representatives if the House size were 299, but 7 if there were 300 representatives. That is, *adding* a seat to the House would *decrease* the number of representatives to which the state was entitled. Similarly, after the 1900 census, Maine would receive 4 representatives if the size of the House were 383, 384, or 385. However, if it were increased to 386, then Maine would have only 3 representatives.[15] At the time, Congress was regularly increasing the size of the House to accommodate the changing demographics. Therefore, these mathematical mysteries remained just that—mysteries, but not political crises.

The Alabama Paradox did, however, encourage statisticians at the Bureau of the Census to study the problem in greater detail, and it is here that Huntington enters the story. During the first two decades of the twentieth century the problem was first tackled by two statisticians working at the bureau. The first, Walter Willcox, was the president of the American Statistical Society from 1911 until 1912. He became the main advocate of the major fraction method and fought for it in Congress throughout the 1920s.[16] The second, Joseph Hill, began working at the Census Bureau in 1898 and rose through the ranks until he became assistant director in 1921. It was he who enlisted Huntington's help

[13] Margo J. Anderson, *The American Census: A Social History*, 2nd ed. (New Haven, CT: Yale Univ. Press, 2015), ch. 1; Charles W. Eagles, *Democracy Delayed: Congressional Reapportionment and Urban-Rural Conflict in the 1920s* (Athens: Univ. of Georgia Press, 2010), ch. 2.

[14] For a thorough overview of each of these methods, see Balinski and Young, *Fair Representation*.

[15] See, for example, Joseph Hill, "Apportionment Methods Described," *Congressional Digest*, February 1929.

[16] William R. Leonard, "Walter F. Willcox: Statist," *American Statistician* 15, no. 1 (1961): 16–19; Margo J. Anderson, "Walter Francis Willcox," in *Statisticians of the Centuries*, ed. C. C. Heyde and E. Seneta (New York: Springer Science & Business Media, 2001), 265–67.

in studying the problem. In the process, Huntington adopted Hill's method, changed it slightly, renamed it the method of equal proportions, and became its fiercest advocate during the ensuing debate.

The fight over method began in earnest after the 1920 census when Congress failed to pass an apportionment bill.[17] The preceding decades had witnessed large demographic changes as the balance between the rural and the urban population shifted radically. Agricultural states that were bound to lose their relative representation in the House were eager to do anything they could to maintain their power despite a dwindling citizenry. This political calculation, as well as simple self-preservation by some congressmen, explains the fervor behind the apportionment legislation and Congress's inability to pass a bill throughout the entire decade. Congressmen's objections to a new apportionment varied. Some questioned the results of the census. World War I, they argued, created artificial and temporary conditions as soldiers returned from war, which did not reflect the current demographic distribution of the country. They insisted that it would thus be unfair to apportion Congress based on faulty and outdated numbers.[18] Others argued that only citizens should be counted for apportionment purposes, ignoring the large number of immigrants.[19] Finally, Republican representative George H. Tinkham of Massachusetts tried to convince his colleagues that Congress must consider the Fourteenth Amendment and reduce the representation of any state that disenfranchised African Americans.[20]

However, the most contested aspect of the apportionment legislation and the one that made the problem of method increasingly important was whether to increase the size of the House.[21] Some members of Congress insisted that the number of seats should be fixed at 435. Doing so implied that apportionment turned into a zero-sum game. If one state gained a seat, it necessarily meant that another one lost a seat. Agreeing on an algorithm for distributing the House seats among the states became pressing in a whole new way.

[17] Historian Charles Eagles examined the apportionment battle in the 1920s in order to discover to what degree the urban-rural divide serves as a historical explanation. Eagles notes the technical debate but for the most part treats it as separate from the political struggle. Eagles, *Democracy Delayed*. More recently, Dan Bouk has written about the fight over method, situating it squarely within the political fight. Bouk, "The Harvard Mimeograph," Census Stories, USA, September 1, 2020, https://censusstories.us/2020/09/01/harvard-mimeograph.html.

[18] For example, Burton E. Sweet, a Republican who represented Iowa's 3rd congressional district, insisted that the 1920 census was "not fair." "Many of the great plants engaged in war activities," he argued, "still retained men who had left the farms in the great Mississippi Valley to assist the Government in the carrying on of the war." *Apportionment of Representatives: Hearings Before a Subcommittee of the United States House Committee on the Census*, 67th Cong., 1st sess. 41 (1921).

[19] Representative William Vaile of Colorado argued that founders did not foresee the "danger" and "evil" that arose out of the concentration of great numbers of undocumented immigrants. If they had known, "it is probable that they would have based representation on number of citizens." 61 Cong. Rec. H6339 (daily ed. October 14, 1921) (statement of Rep. Vaile).

[20] "The real anarchist in the United States, the real leaders of lawlessness, are the Members of this House of Representatives who refuse obedience to the Constitution which they have sworn to obey." Representative George H. Tinkham (MA), in 61 Cong. Rec. H6312 (daily ed. October 14, 1921).

[21] This was without doubt the crux of the debate. In many ways, the fight over method was used as a pretext by those who wanted to increase the size of the House and were worried that they were losing the debate. Those seeking to restrict the size of the House pointed to lack of space, the diminishing standing of House members, and the worry that more and more work would be done through committees. Representative Theodore E. Burton from Ohio even warned that the "House will be a genuine mob." *Apportionment of Representatives: Hearings Before a Subcommittee*, 21. Dan Bouk has recently reached a similar conclusion: Dan Bouk, *House Arrest: How an Automated Algorithm Constrained Congress for a Century* (New York: Data & Society, 2021), https://datasociety.net/wp-content/uploads/2021/04/House-Arrest-Dan-Bouk.pdf.

Huntington made the case clear in October 1921. "I beg to call attention to the fact that several States are in danger of being deprived of their proper representation through the application of an inaccurate method of computing the apportionment," he wrote in the *New York Times*.[22] Huntington warned that if his method were not adopted, New York, North Carolina, and Virginia would each have one representative more than they were entitled to and Rhode Island, New Mexico, and Vermont would each lose a representative.

More than just warning the public that Congress might adopt the "wrong" apportionment method, Huntington also tried to define the terms of the debate. Whether the size of the House were to increase, he maintained, was a political question. However, once the number of Representatives has been agreed upon, the apportionment "is clearly a problem of *mathematical fairness*, to be decided by Congress on the basis of purely scientific facts."[23] Huntington sought to create a clear distinction between the political and the mathematical problem of apportionment, and held onto this steadfast conviction for the next two decades. But how can one abstract the mathematical from the political?

A TALE OF TWO ALGORITHMS

Huntington was a contributor to the mathematical subfield known as postulational analysis.[24] This subfield, which emerged at the turn of the century, is indicative of the professionalization of an American mathematical community.[25] Postulational analysis developed out of David Hilbert's 1889 *The Foundations of Geometry*.[26] Hilbert used postulational analysis as a philosophical tool to secure the logical foundation of geometry, but in the hands of young American mathematicians postulational analysis became a research subject in its own right, and Huntington was one of its most prolific writers. What postulational analysts set out to do was to find the smallest set of postulates from which a given mathematical subject matter can be deduced and to prove that the postulates were complete and not self-contradictory.[27] Huntington, for example, published papers offering a postulational system for positive rational numbers, abelian groups, real algebra, and many more.[28]

[22] Edward V. Huntington, "House Reapportionment: Mathematics and Politics in Fixing the Number of Seats," *New York Times*, October 18, 1921, 13.

[23] Huntington, "House Reapportionment," 13.

[24] Michael Scanlan, "Who Were the American Postulate Theorists?," *Journal of Symbolic Logic* 56, no. 3 (1991): 981–1002.

[25] Karen Hunger Parshall and David E. Rowe, *The Emergence of the American Mathematical Research Community, 1876–1900: J. J. Sylvester, Felix Klein, and E. H. Moore* (Providence, RI: American Mathematical Society, 1997).

[26] David Hilbert, *The Foundations of Geometry*, trans. E. J. Townsend, 2nd ed. (Chicago: Open Court, 1910).

[27] On the adaptation of Hilbert's method, see Leo Corry, "Axiomatics between Hilbert and the New Math: Diverging Views on Mathematical Research and Their Consequences on Education," *International Journal for the History of Mathematics Education* 2, no. 2 (2007): 21–37; Alma Steingart, *Axiomatics: Mathematical Thought and High Modernism* (Chicago: Univ. of Chicago Press, 2023).

[28] A representative sample includes Edward V. Huntington, "Complete Sets of Postulates for the Theories of Positive Integral and Positive Rational Numbers," *Transactions of the American Mathematical Society* 3, no. 2 (1902): 280–84; Huntington, "Sets of Independent Postulates for the Algebra of Logic," *Transactions of the American Mathematical Society* 5, no. 3 (1904): 288–309; Huntington, "A Set of Postulates for Abstract Geometry, Expressed in Terms of the Simple Relation of Inclusion," *Mathematische Annalen* 73, no. 4 (1913): 522–59; Huntington, "A Set of Independent Postulates for Cyclic Order," *Proceedings of the National Academy of Sciences* 2, no. 11 (1916): 630.

It is thus not surprising that in the first paper Huntington published on apportionment, he anchored the problem in postulational grounds.[29] His first postulate stated that since perfect apportionment is impossible, the next best thing we can ask for is that the ratio between the size of a district in one state and another should be as close to one as possible. With that principle in mind, Huntington's second principle was that a good apportionment would be one in which these ratios are optimized. The ultimate apportionment would be one such that any transfer of seat from one state to another would result in an increase of that ratio, not a decrease. The next step for Huntington was to prove which apportionment method, or algorithm, would satisfy both postulates.

Two points are worth noting. First, Huntington's first postulate amounts in effect to an abstract mathematical definition of fairness. If a state representative from Massachusetts and a state representative from Texas each represented 240,000 individuals, then the ratio between the two numbers would be one. In reality, such perfect equality is impossible to achieve, but the closer the ratio is to one, the better. Second, by adopting a postulational approach, Huntington shifted the emphasis from the procedure, or algorithm itself, to principles. Huntington proved that his two postulates can only be satisfied by a particular algorithm. However, in presenting his method he emphasized not the step-by-step procedure by which statisticians in the Census Bureau would compute apportionment numbers but the principles behind it. As I will show, in arguments before Congress, the latter point would be especially problematic because to the untrained eye it was not obvious how the principle led to the algorithm.

Willcox, Huntington's main opponent, had a different understanding of how the constitutional provision should be interpreted. At first, Willcox insisted that instead of using *relative* difference, *absolute* difference should be used. The difference between the number of residents that a state representative from Massachusetts and a state representative from Texas each represented should be as close to zero as possible. The difference in how to measure the nearness of two numbers might seem a small detail, but the decision resulted in two differing algorithms. Still, there was another way to account for the difference between how each method measured fairness. One could measure the number of residents per representative by dividing a state's total population by the number of its representatives. Or one could measure each resident's "share" of the representative, by dividing the number of representatives a state is entitled to by its total population, the idea being that if a representative had 200,000 residents in his district, each resident shared 0.0005 percent of him (1/200,000). The difference amounted to what is the numerator and what is the denominator, and all and all there were four ways to measure these ratios.[30] Whereas Huntington's equal proportions treated all different measurements similarly, Willcox's method defined fairness as one's share in a representative.[31]

The difference between the two methods was articulated clearly in a 1921 report by a joint committee of the American Statistical Association and the American Economic Association.[32] The report was commissioned by the Senate Committee on the Census

[29] Edward V. Huntington, "The Mathematical Theory of the Apportionment of Representatives," *Proceedings of the National Academy of Sciences* 7, no. 4 (1921): 123–27.

[30] See Edward V. Huntington, "A New Method of Apportionment of Representatives," *Quarterly Publications of the American Statistical Association* 17, no. 135 (1921): 860.

[31] The difference between their views is made clear in their competing testimonies before the Committee on the Census (see below), as well as their back-and-forth in *Science* (see note 3 above).

[32] C. W. Doten et al., "Report upon the Apportionment of Representatives," *Quarterly Publications of the American Statistical Association* 17, no. 136 (1921): 1004–13.

in February 1921, just before Congress adjourned with no apportionment bill in sight. Having studied both methods, the committee recommended Huntington's equal proportions. However, the committee went to great lengths to explain their choice as not one between right and wrong but rather of logical superiority. Both methods were correct and logically sound. But the committee believed that Huntington's use of relative rather than absolute difference and his indifference to the form in which the ratios were expressed were marks of its technical superiority. The committee was also careful to emphasize that they did not necessarily believe that "purely technical criteria" were the only ones that mattered. Willcox's method, they wrote, adhered more closely to precedent. This was a matter for Congress to decide. Indeed, five years later, when both Willcox and Huntington found themselves testifying in front of Congress, the question of whether criteria other than technical ones should be taken into consideration would become central.

Congressional debates over apportionment resumed again in 1927. E. Hart Fenn (R-CT), who chaired the House of Representatives' Committee on the Census, put before the committee a new apportionment bill. The bill had at least three distinguishing features. First, Fenn wanted to include an automatic safeguard in the bill. In case Congress was unable to pass an apportionment bill after the census, the responsibility would fall to the secretary of commerce. The bill was also written with an eye not toward the 1920 census but in anticipation of the 1930 census. Finally, it opened for discussion the question statisticians had been debating for a while: namely, which apportionment method Congress should adopt. When the director of the census, William M. Steuart, appeared before the committee, he commented that it was the latter question "that is the most important feature of this law."[33] Steuart then delegated the task of explaining the issue to the members of the committee to his assistant director, Joseph Hill.

In Hill's testimony, it soon became clear that another definition of fairness was of concern to the congressman, one motivated not by abstract methodology but rather by pragmatic concerns. "Why do you say equal population? Is it not true that there is a variance?" asked Representative Clarence J. McLeod (R-MI). McLeod was concerned that New York would lose a representative, despite its obvious growing population, if equal proportions were used. John E. Rankin (D-MS) had similar reservations. Why should New Mexico, with a population smaller than half a million, receive two representatives? "It looks to me," he added, "as if it was giving an undue advantage to the smaller States at the expense of the larger."[34] Nine days later, on January 28, the issue came up again when Willcox testified before the committee. After a long conversation about the difference in measurement between his, Huntington's, and older methods used in apportionment, Willcox added, "Perhaps from my point of view an even stronger argument in favor of the method of major fractions is that it seems to me to hold the balance between the large and the small states."[35]

Two things become clear. First, once you move from the basic mathematical symbolism of fractions and percentages to the social reality they supposedly stand for, how you "read" the data makes a big difference as far as politics is concerned. Second, as the debate heated up, the meaning of fairness shifted. While the two were connected, arguing

[33] *Apportionment of Representatives in Congress Amongst the Several States: Hearings on H.R. 13471, Before the United States House Committee on the Census*, 69th Cong., 2nd sess. 13 (1927).
[34] *Hearings on H.R. 13471*, 44.
[35] *Hearings on H.R. 13471*, 78.

about whether absolute or relative difference offers a more accurate measurement is different from debating whether each method favored large or small states. Of course, which method was more biased toward large or small states was itself a matter of contention. Economist Allyn A. Young, of Harvard University, who testified in front of the committee on behalf of equal proportions, reached a conclusion opposite Willcox's. Using economic theory as an analogy, Young argued before the committee, "Obviously, the correct thing to do is to use the method which has a bias neither in favor of the larger States nor the smaller States, but a method which gives results intermediate between the results given by the two biased methods. The method of equal proportions is such an intermediate method."[36] The way Young described the question was somewhat misleading. Since perfect apportionment is impossible, each method will necessarily exhibit some bias. The only way to compare them is in relation to one another. From that perspective, it was agreed by all that in comparison, equal proportions favors the smaller states while major fractions was preferable for the larger ones.

After numerous testimonials, reports, and letters, Speaker of the House Nicholas Longworth resolved to have the National Academy of Sciences (NAS) appoint a special committee to study the question and report back to Congress. When the report was issued in February 1929, Huntington was elated. The committee unanimously supported the method of equal proportions.[37] "All controversy concerning the mathematical aspects of the problem of reapportionment in Congress should be regarded as closed by the recent authoritative report of the NAS," Huntington declared in *Science*.[38] In justifying its decision, the committee explained that it had selected the method of equal proportions "because it occupies mathematically a neutral position with respect to emphasis on larger and smaller states."[39] The language here is telling. By that point in the debate, it was understood that there were exactly five apportionment methods. Thus, the NAS committee members ranked the methods' biases in relation to one another, and within this ranking the method of equal proportions lay in the middle. Two of the known methods were more favorable to large states, and two were more favorable to smaller states.

This is not to say that equal proportions did not exhibit any bias, as this was by definition impossible. Rather, within the theoretical framework Huntington erected, it was the most neutral method. It is also interesting that none of the five possible methods besides major fractions and equal proportions was ever really under consideration. The other three methods were deemed inadequate for different reasons. Yet when it came time to define this pragmatic idea of fairness, they were used in order to construct a ranking. If these three additional methods were not considered by the committee, then there really was no way to debate which one was more biased. From an abstract perspective equal proportions could be said to lie in the middle between the various methods in balancing the smaller and larger states; however, from a pragmatic standpoint, this statement did not make any sense. The problem of how to interpret the two methods did not end there.

[36] *Hearings on H.R. 13471*, 100.

[37] The report is printed in the congressional records: "Report to the President of the National Academy of Sciences," in 70 Cong. Rec. S4966–67 (daily ed. March 2, 1929).

[38] Huntington, "Report of the National Academy of Sciences on Reapportionment," 471–73.

[39] Interestingly, the committee began by noting that since the problem of apportionment is one of applied mathematics, its solution "must be chosen for other than mathematical reasons among those which are mathematically possible." However, having listed the five possible solutions, the committee concluded that "on mathematical grounds, the method of equal proportions was the method preferred." "Report to the President of the National Academy of Sciences," S4967.

FROM METHOD TO PRINCIPLES

Huntington's postulational analysis enabled him to analyze the apportionment problem from the broadest perspective. However, in doing so, he fully broke with tradition. Since the problem was first acknowledged, it was understood in terms of a simple question—what should be done with the remainders? The problem arises from trying to compute an apportionment and confronting the inevitable fact that no state can send a fraction of a representative to Congress. By reframing the problem in terms of two governing postulates, Huntington discarded the question of what to do with remainders, making it practically moot. It is here that Huntington's otherwise straightforward method collided head-on with political reasoning.

Huntington did, of course, devise an algorithm, but it did not resemble in the slightest any procedure that had been used before. To compute the apportionment according to Huntington's method one had to:

1. Assign one representative to each state as guaranteed in the Constitution.
2. Divide the population of each state successively by $\sqrt{1 \times 2}$, $\sqrt{2 \times 3}$, $\sqrt{3 \times 4}$, etc.
3. Arrange the quotients computed in step 2 according to their size with the largest on top to arrive at a priority list.
4. Divide the additional seats among the states according to the priority list.

As is evident, unless you read through Huntington's 1921 paper it was in no way clear why the two postulates he began with give rise to the above algorithm. Where did these numbers come from? And why?

During a January 1927 hearing, the conflict came to a head. When Hill testified before the committee, he carefully explained the rationale for the method; he walked through examples, showing how one would measure the disparity between any two states and why he and others believed that this measurement of fairness was the one Congress should adopt. As soon as he had ended, Meyer Jacobstein (D-NY) responded: "Will you not take up a little time . . . to give us a clear description of what your equal proportions method is?" Hill tried to deflect.[40] "The process by which you apply that method is not the important thing; it is a question of what principle of measurement you shall accept. If you accept this as being the right way of measuring differences, the mathematicians can apply that principle."[41] Jacobstein, however, was not persuaded and refused to drop the issue. A few minutes later he continued, "As I said, here we are, sitting on a committee, and some Member of the House may say to us, 'I understand that the committee has agreed on equal proportions. What is it?' Is it a magic thing that we have to accept from the Bureau of the Census because it is too 'high-brow' for us to understand?"[42]

Other members expressed similar concerns. Ralph Lozier (D-MO) interjected, "In other words, suppose that you were the chairman of this committee and the committee had adopted the formula of equal proportions, and you were on the floor of the House explaining to the membership that formula, what would you say? How would you describe it? And what argument would you advance for its acceptance?"[43] Hill tried to repeat his explanation. You can nearly hear his frustration in the transcripts of the hearings. The best way to explain the method, he insisted, was *precisely* the way he himself

[40] *Hearings on H.R. 13471*, 23.
[41] *Hearings on H.R. 13471*, 23.
[42] *Hearings on H.R. 13471*, 23.
[43] *Hearings on H.R. 13471*, 23.

had just done minutes before by outlining the underlying principle and affirming that as long as one accepts the premise, then there is only one apportionment scheme that will satisfy these criteria. The content of the algorithm, he repeated, was irrelevant: "We can trust the mathematicians to apply that principle correctly, and that it is not necessary that we should be able to understand the mathematical process or formula by which it is applied."[44] Despite his best attempts, members of the committee did not drop the issue. Hill tried to push back, insisting that all they had to agree upon was the correct measure of fairness—whether absolute or relative difference was superior—but all the congressmen wanted was a formula or a "30-word definition" of each method. Hill did not explain the source of his hesitancy. The computational method was, after all, submitted to the record. The reason must have been that it was in no way obvious to the untrained eye why the principle led to this specific method. This was the heart of Huntington's analysis and required more knowledge than arithmetic. Moreover, unlike past apportionment the algorithm was not intuitive. It was not as easy to account for why each step was taken (which was the case with past apportionment methods).

The tension did not arise solely from a mathematical misunderstanding. The congressmen in attendance were used to thinking about the apportionment problem in one way, and they were now suddenly asked to forgo everything they knew and just trust the mathematicians. The issue was compounded by the fact that Willcox's competing method was premised on a more intuitive understanding of the problem. Since it turned out to be impractical to use the exact divisor (total population divided by number of seats), Willcox had the idea to use an approximate divisor, such that when used, the quotients for all states would add up perfectly to the desired number by either rounding up or down. The name of the method, major fractions, captures this intuitive understanding. When major fractions was used, Congress would receive a table indicating the quotient for each state, and if they checked it, they would be able to verify easily that only if a state's quotient was greater than half would its allocation be rounded up. The crux of the matter was to find that approximate divisor that produced the desired table, but once it was accomplished the process accorded with precedent.

Huntington demonstrated that Willcox's major fractions method could be described by a similar algorithm with the first step being the same, and the multiplication numbers in the second step changed to 1.5, 2.5, 3.5, etc. A priority list was then produced, and from it one could devise the desired divisor. In other words, the method could be described by a similar algorithm, but it had the additional and crucial feature that, when it was used, Congress would be handed a table as it had been on every prior occasion. Willcox was clearly aware of the superiority of his method over Huntington's in that regard. Closing his testimony before the committee in January 1928, he added that major fractions is superior to equal proportions exactly because it "provides a series of divisors with quotients showing that for every major fraction you get an extra Representative and for every minor fraction you do not get an extra Representative, which corresponds to the uniform conviction of Congress."[45] That was not all. If the committee chose to adopt equal proportions, it would be questioned by congressmen, who would "at once be asking you where is the divisor that yields these quotients."[46] It did not matter that

[44] *Hearings on H.R. 13471*, 52.
[45] *Hearings on H.R. 13471*, 88.
[46] *Hearings on H.R. 13471*, 88.

the divisor computed by major fractions was an artificial one. The important thing was that it offered oversight and adhered to Congress's expectations.

Willcox's strategy illustrates that the same algorithm can be described in different ways and that these levels of description are not easily interchangeable. Moreover, how they are deployed depends on the audience. For the statisticians in the Census Bureau, Willcox described the method by which the artificial divisor was achieved, known as a sliding rule. To members of the Committee on the Census he explained the principle behind the method (namely, finding the desired divisor); to Congress writ large he simply presented a table. All three were dependent on one another, but in the fight over fair representation, each held a different meaning. Dan Bouk has shown that by 1928 the statisticians in the Census Bureau recognized that each of the methods could be computed in two different ways (or according to two different algorithms). Moreover, they were able to show that Huntington's equal proportions could also be computed by a divisor method. However, when asked to confirm the fact, Huntington, according to Bouk, vehemently resisted and insisted that only his original algorithm should be used in the apportionment computation.[47] In other words, both Willcox and Huntington realized that how an algorithm is described is just as important as the principle it seeks to uphold.

Willcox also sought to describe Huntington's method in a disadvantageous light. In comparing the two methods before the committee, he noted of Huntington's method, "Under the method of equal proportions, as soon as the fraction rises above 1.41 that State is entitled to a second Member, whereas under the method of major fractions, the State is not entitled to another Member until quotient rises above 1.50."[48] The account must have resonated with members of the committee, for when Huntington next took to the floor the question came up again.

Huntington, like Hill, began his testimony by explaining the overall principle behind his method. Almost as soon as he completed his prepared remarks, he was asked by Jacobstein about Willcox's remarks that a state with a fraction of 1.41 would be immediately entitled to an additional representative. Huntington tried to dismiss the question as meaningless, but Jacobstein did not relent: "Do you admit the allegations?" he asked. Huntington was no longer able to remain silent: "No, I have nothing to do with those figures. All I can look at when you propose a transfer of representative from one State to another, all I can inquire about is this: Is the inequality between those States reduced or increased by the transfer? . . . All the other questions of a ratio chosen or assumed or computed, all that question of States acquiring a claim to a new representative when a certain arbitrary fraction passes a certain point, all belongs to the time before the deluge."[49] His response was met with laughter but it in no way put an end to the conversations. Jacobstein, now visibly upset, added, "I do not know enough about the mathematical theory, but what about the facts?"[50]

What to make of this interaction? In rephrasing the problem of apportionment according to his mathematical principles, Huntington had in effect erased all previous work on the problem dating back to the 1790s. Computing divisors and quotas was deemed meaningless. The two approaches were simply incommensurable. Yet unless the congressmen in his audience were willing to accept postulational analysis, there was no way

[47] Bouk, "Harvard Mimeograph."
[48] *Hearings on H.R. 13471*, 86.
[49] *Hearings on H.R. 13471*, 94.
[50] *Hearings on H.R. 13471*, 94.

they would be willing to forget what had been, for more than a century, the basis for apportionment bills. When Huntington began his testimony, he praised Congress for the "ingenuity and patience" in handling the question, only to assure the members of the committee that they could stop their worrying: "You do not need any more patience, you do not need any more ingenuity."[51] In the same way that he had asserted that the mathematical and political aspects of the problem could be divorced, he now tried circumscribing the work of the congressmen and separating it from the work of the mathematicians. For those in attendance, it was not clear why they should forsake their oversight.

Two years after this testimony and after the NAS weighed in in his favor, Huntington once again addressed the difference between his and Willcox's approaches: "It has been contended that when it comes to actual vote in Congress, the method of major fractions has a 'marked advantage' . . . not because it gives a fairer or more equitable apportionment—which it does not—but because Congress likes to have before it, as 'on every previous occasion,' a 'table,' containing a 'constant divisor' and a 'series of quotients' in which 'each fraction larger than one half' given an additional member." He then asked, "Why should Congress be so attached to a table of this particular sort?"[52] Huntington could not understand why a representative would choose to have a table knowing that the divisor that appeared in it was "artificial," and insisted that Willcox's method was neither fairer nor more simple. "*All these useless complications about 'divisors' and 'quotients' and 'fractions' are completely done away with in the modern theory*," he added.[53] For Huntington simplicity was a mathematical quality defined by the governing principles of his method, and by the abstract theory he developed. However, nothing about the "modern theory" was simple for members of Congress. On the contrary, one could argue that Huntington took a relatively simple problem and couched it in such complicated mathematics as to make it anything but simple. This at least is what Willcox tried to argue when he insisted that mathematicians' account of fairness was the only one to consider.

WHOSE EXPERTISE?

From the moment he entered the debate Huntington insisted that it was possible to separate the mathematical nature of the problem from its political interpretation and that hence mathematical certitude should serve as the ultimate guide in deciding on an apportionment method. However, Willcox was not willing to concede the point. When he appeared before the Committee on the Census in 1927, he opened his testimony on this point: "It seems to me the question before the committee might be put in either one of two ways: Either it might be put: What method of apportionment is theoretically best? Or, it might be put: What method will best satisfy, first, the committee, and second, the Congress, and ultimately the public opinion of the country?"[54] The question of which method was theoretically best was beside the point: now the definition of fairness should also include some measure of comprehensibility. This, then, is the third definition of fairness that came into play—one that is neither abstract nor pragmatic but procedural.

[51] *Hearings on H.R. 13471*, 94.
[52] Huntington, "Report of the National Academy of Sciences on Reapportionment," 472.
[53] Huntington, 472, emphasis in original.
[54] *Hearings on H.R. 13471*, 61.

When he returned to testify before the committee in 1928 Willcox was ready to argue the point and brought additional evidence with him. While the mathematicians might seem to be in agreement, he noted, their voice was not the only one that should be heard:

> There is, however, another group of scholars who, it seems to me, are entitled to express opinions in this matter, and who were not at all represented at this time, and that is the group of students of constitutional law and constitutional history and political science in the United States. I say that because it seems to me that the question of the method of apportionment turns very largely on the question of what is the main purpose to be subserved by apportionment, and that question, I take it, can be discussed with expert knowledge by the political scientists and constitutional lawyers rather than by the statisticians and mathematicians.[55]

Willcox contacted political scientists and constitutional law scholars to canvass their opinion. He reported that twelve out of the thirteen scholars who replied to his letter expressed preference for the method of major fractions.

At least in part the reason these scholars gave for endorsing major fractions was *intelligibility*. Willcox reported that even W. S. Rossiter, a member of the census advisory committee who in 1921 recommended the adoption of equal proportions, had written to him recently to say that he preferred the major fractions method because he did not believe that "the average legislator or citizen would understand the method of equal proportions if explained 24 hours continuously."[56] Other scholars similarly did not critique the method of equal proportions on its mathematical grounds but on the likelihood that it could be comprehended by nonmathematicians. Charles E. Hill, from George Washington University, wrote: "While the method of equal proportions would carry out the intent of the framers of the Constitution with greater exactness, that solution is, in my opinion; less easily comprehended. I should therefore advocate the method of major fractions as the guide to be laid down by [C]ongress. The most untutored mind can understand this method."[57] Professor Thomas Reed, of the University of Michigan, concurred, saying, "It is very much more necessary that the system used be understood by the public at large and regarded by them as fair and reasonable than that it should attain a theoretical perfection."[58] At stake for Willcox and others was not simply a question of how a given set of numbers is correctly analyzed or even what the methods of doing so were. Rather, they asked: who gets to define what fairness is?

On April 18, 1929, the Senate Committee on Commerce met to discuss the latest apportionment bill before Congress. Reflecting on the Senate's failure to pass the last apportionment bill, Senator Arthur Vandenberg (R-MI) suggested that the debate over method had been exaggerated. He noted that the two methods resulted in almost completely identical apportionments (they differed on only one seat out of 435). However, when the question of method was discussed on the floor of the House, it "was magnified . . . to a fatal degree." The debates in the Senate, he explained, "reflected a difference in the country at large among the scientific experts, the great mathematicians

[55] *Apportionment of Representatives: Hearings on H.R. 130, Before the United States House Committee on the Census*, 70th Cong., 1st sess. 49 (1928) (statement of Walter F. Willcox).
[56] *Hearings on H.R. 130*, 49.
[57] *Hearings on H.R. 130*, 70.
[58] *Hearings on H.R. 130*, 70.

of the country, as to what is the proper method of actually making an actual apportionment."[59] To avoid a similar fate, Vandenberg suggested that instead of directly specifying the method, the bill would instruct that in case Congress failed to pass a bill within a given timeframe, an apportionment would automatically be computed based on the methods used in the last apportionment bill. To support this change, Vandenberg canvassed experts around the country, all of whom, he was happy to report, supported the language in the new bill.[60] "You say all these statisticians agree?" asked Senator Hiram W. Johnson (R-CA). When Vandenberg responded in the positive, Johnson added, "Mirabile dictu!"[61] Amazing indeed.

CONCLUSION

The most important aspect of the final bill, which both the House and Senate eventually agreed upon, was that it included an automatic provision. As Vandenberg explained, "We have taken all the identification of controversial detail out of the bill . . . so that all that is left is a general enabling act which takes nothing from Congress except its right of anti-Constitution inertia. That is all it takes from it."[62] Congress, in other words, had the power to choose a new method and decrease or increase the size of the House, but it no longer had the right to fail to act and fulfill its constitutional mandate. The 1929 apportionment bill simply instructed the president to send to Congress the apportionment number according to the method of major fractions, the method of equal proportions, and the last method used. It was up to Congress to choose which one, or simply not to choose.

This could have been the end of the fight between Huntington and Willcox, but of course it was not.[63] As the 1940 census was approaching, the disagreement over method ignited again. Whereas both apportionment methods yielded the same apportionment numbers after the 1930 census, this was not the case after the 1940 census. The NAS was asked to appoint another committee to study the question and this time it included some of the most celebrated mathematicians of the country, such as John von Neumann, Marston Morse, and Luther P. Eisenhart. Huntington and Willcox, for their part, renewed their public spat.[64] It was in light of this renewed interest that Huntington in 1940 begged his colleague George Birkhoff to stay out of the conversation. He was unsuccessful.

Just a month after he received Huntington's letter, Birkhoff delivered a series of lectures at the Rice Institute in Houston, Texas. His first was titled "A Mathematical Approach

[59] *Fifteenth Decennial Census—Apportionments of Representatives in Congress: Hearings on S. 2 and S. 3, Before the United States Senate Committee on Commerce* 71st Cong., 1st sess. 50–51 (1929).

[60] Vandenberg did not claim that these statisticians endorsed the method of major fractions, but rather the "phraseology that is in this bill." *Hearings on S. 2 and S. 3*, 50–51. According to Dan Bouk, Vandenberg did try to convince Huntington to support the new bill but was unsuccessful. Bouk, "Harvard Mimeograph."

[61] *Hearings on S. 2 and S. 3*, 50–51.

[62] *Hearings on S. 2 and S. 3*, 50.

[63] See, for example, Edward V. Huntington, "The Role of Mathematics in Congressional Apportionment," *Sociometry* 4, no. 3 (1941): 278–82; Walter F. Willcox, "A Role of Mathematics in Congressional Apportionment: A Reply," *Sociometry* 4, no. 3 (1941): 283–98. The two men also continued to pressure Congress.

[64] Huntington, "Role of Mathematics in Congressional Apportionment"; Willcox, "Role of Mathematics in Congressional Apportionment," 283–98.

to Ethics."[65] Birkhoff came to believe that mathematics was applicable to almost any domain of knowledge. Mathematics was powerful not because it helped measure and compute but because of its ability to formulate problems and bring clarity where complexity reigned. Birkhoff thus started with a simple proposition according to which the "ethically-minded person endeavors always" to maximize the total good achieved. He chose to illustrate his new ethical theory with the problem of apportionment.

Like Huntington, Birkhoff started with two postulates, only his were different. His first postulate stated that if state A has a population greater than state B, then it should have at least as many representatives. His second postulate stated that every state should "receive at least the integral part of the exact (fractional) number which it is ideally entitled to." Regardless of what algorithm you use, if you compute each state's quota by the exact divisor (as was customary in the past) then no state should receive fewer representatives than the whole number that appeared before its fraction. Having stated his two postulates, Birkhoff noted that neither of the methods considered at the moment fulfilled his second postulate. "*It seems to be abundantly borne out*," he concluded, "*that apparently justifiable postulates are often mutually contradictory, so that a choice has to be made between them*."[66] Unlike members of Congress or legal scholars, Birkhoff could not be faulted for not understanding Huntington's mathematical analysis. For Birkhoff, the mathematics involved was elementary. His objection as such was much more stinging. Birkhoff suggested that perhaps what an apportionment should try to minimize was "the largest injustice of underrepresentation for any state, then the next largest injustice for some other underrepresented state."[67] It is not clear what Birkhoff necessarily had in mind, nor what an apportionment method that fulfilled this new criterion would look like. However, his musings are instructive. They serve as a reminder that there are many ways to codify fairness, which after all is anything but a mathematical formula.

The fight over method in the 1920s makes two things clear. First, the debate over algorithmic fairness cannot solely be explained by simply pointing to the complexity of contemporary algorithms. Second, and more fundamentally, translating between ethical principles and mathematical formalisms is never straightforward. Even if we as a society were to agree upon which ethical guidelines should govern the use of algorithms in different domains from medicine to finance and education (and that is a big *if*), implementing those standards in computer code is not a simple act of translation. Everyone involved in the debate in the 1920s agreed that apportionment should result in as equal representation as possible among the states, but how to measure such equality was open to interpretation. Even a seemingly small detail, such as whether to count members per representative or a state's inhabitant's share of a representative, made a world of difference. In the case above, these details were aired in public; they were argued over in scientific publications, magazines, and in front of Congress. In today's algorithmic society, however, these decisions are often made in private. There are many ways to measure inequality, but who gets to decide which method is the "correct" one?

In pointing out that even under relatively ideal conditions in which the various stakeholders can agree on what an algorithmic system should accomplish, the step from

[65] George David Birkhoff, "A Mathematical Approach to Ethics," in *Three Public Lectures on Scientific Subjects, Delivered at the Rice Institute, March 6, 7, and 8, 1940*, Rice Institute Pamphlet 28, no. 1 (1941): 1–23.

[66] Birkhoff, "Mathematical Approach to Ethics," 18, emphasis in original.

[67] Birkhoff, 18.

principle to mathematical formula is complex, I do not mean to suggest that efforts to counter algorithmic bias are futile. On the contrary, I think that they are that much more important. My goal is different. I think that what all sides need to acknowledge is that an ideal system *never* exists. We should start from the assumption that all algorithmic systems are biased in some way and will always be so. The question then becomes: what sort of biases are we as a society willing to live with and, more importantly, what sort of mechanisms can we put in place to counter the impact of these algorithmic systems? Willcox was correct when he insisted that the statisticians were not the only ones who deserved a seat at the table. Mathematical precision is important, but it is only one of several ways algorithms should be judged. One lesson that this history offers is that we should require that the algorithmic systems around us be described in multiple registers and acknowledge that none de facto takes precedence over the other. We can ask about the computational principles behind different methods, their pragmatic implications, and their intelligibility. Acknowledging each one of these registers to be as important as the others might not solve the problem of incomprehensibility, but it would enable more honest conversation. What we need is a richer language, one that does not try to reduce the complexity of contemporary algorithmic systems but rather aims, to borrow a phrase from Donna Haraway, to "stay with the trouble."[68] If Adrian Johns and James Evans are correct that "algorithms have *already* taken over," then this might be our least worst option.[69]

[68] Donna Haraway, *Staying with the Trouble: Making Kin in the Chthulucene* (Durham, NC: Duke Univ. Press, 2016).

[69] James Evans and Adrian Johns, "The New Rules of Knowledge: An Introduction," *Critical Inquiry* 46, no. 4 (2020): 806–12.