Chapter 8

Law, computing and redistricting in the 1960s

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CHAPTER SUMMARY

Computers have been used to draw maps for decades. This chapter takes a look at how computing and redistricting intersected in the 1960s, along with the critical role "one person, one vote" played in opening the door for them.

1 AGAINST COMPUTERS

THE CASE AGAINST ONE PERSON, ONE VOTE

In 1963, political scientist Alfred de Grazia published *Apportionment and Representative Government*, a polemical attack on what he called the "equal-populations doctrine" [9]. An expert in the history and theory of political representation, de Grazia was a professor of government and social theory at New York University and a founder of *The American Behavioral Scientist*.[1] Over his career, de Grazia wrote monographs on numerous topics such as the American government, the welfare system, and international politics, but he found the problem of representation uniquely pressing: "no political problem is more fascinating than that of arranging the representation of the many local and general interests that compose modern society, and none is more frustrating to the scientist and the man of good will" [8].

[1] The journal was founded in 1957 under the title *PROD: Political Research: Organization and Design* and was renamed in 1961.

If de Grazia found the apportionment problem to be frustrating at the best of times, in 1962, when the Supreme Court ruled in *Baker v. Carr* that malapportionment cases are justiciable, de Grazia was livid. The case originated when citizens sued the state of Tennessee, claiming that the state legislatures violated their Fourteenth Amendment guarantee of equal protection under the law by refraining from apportioning the state's General Assembly since 1901. The Court's ruling—that the appellants had standing and that their claim could be heard in the District Court—overturned the Court's earlier position that districting and apportionment were legislative rather than judicial matters.[2] De Grazia believed that the new decision set a dangerous precedent, and he directed his critique at legal and political scholars, believing that they were skewing the conversation by presenting a consensus when none existed.[3]

It is important to note that in *Baker v. Carr*, the Supreme Court did not specify a standard by which lower courts could determine the validity of a given apportionment scheme. Only in 1964 (*Reynolds v. Sims*), after legal challenges to legislative malapportionment mounted in the states, did the Court rule that districts must be comprised of roughly equal population. Even though de Grazia published his work before the Court clearly articulated the now famous "One Person, One Vote" doctrine, he focused much of his critique on that ideal.[4] In the nine months following the Supreme Court ruling in *Baker v. Carr*, litigation on apportionment occurred in twenty-one states, and in almost all of these cases the lower courts based their decision on the equal population principle.

De Grazia argued that if the goal of apportionment and districting was to ensure better representation, then protecting community and interest groups must be more important than numerical equality. Geography, local, ethnic, and religious interests had all been taken into account in forming constituencies in the past—properly, in his view.[5] And while the courts never explicitly suggested that these other factors were less crucial for effective representation, de Grazia worried that an emphasis on equal population would give rise to a "number obsession," which not only would lead to degraded representation but would also give rise to "a mechanical view of man and human relations" [9]. The ideal of equal population, he believed, risked treating citizens as nothing more than numbers that can be interchanged for one another.

[2] *Colegrove v. Green*, 328 U.S. 549 (1946)

[3] "With few exceptions, the legal briefs and numerous research reports that I have since read have been deplorably shallow and unobjective. Our national history has been rummaged largely with an eye toward illustrating the feelings for numerical equality to be found among the people. But the case on apportionment is far from closed. What stands now cannot be permitted to represent all that political science has to say about apportionment and representative government" [9].

[4] In fact, the principle was initially called "One Man, One Vote," but the language has since evolved.

[5] For instance, a system of randomized district assignments could achieve numerical equality, but each district's residents would have nothing in common besides the very fact of belonging to the same district.

FROM PARITY TO PARODY

To illustrate the absurdity of the principle in his opinion, de Grazia concluded his introductory chapter with a section entitled “Drawing of State Apportionment Boundaries by Computer,” in which he offered an algorithm to accomplish just that. The “instructions to machine” included steps such as assigning a set of numbers to all the people in a given district and transferring one individual at a time from one district to an adjunct one until all possible permutations were exhausted and millions of maps were produced. The algorithm was a theoretical one. His goal was not to implement it but to document the futility of such an endeavor: “which of these millions should be chosen?” By adding voters’ affiliations, the algorithm could be further adjusted to either favor one party or even “group people around existing communities,” but it would not solve the question, which map to choose? De Grazia was not inherently opposed to the use of computers. There could be a time in the future when computers would be able to be used for determining constituencies, but de Grazia insisted that this possibility was still in the future. “Until a machine can do human work,” he concluded:

> “It is best to limit its use strictly and so also limit the use of machine-like theories that try to organize society. American society is not a collection of faceless particles. It is composed of highly diverse and yet interconnected sets of people. A political theory suggesting that people are interchangeable like nuts and bolts is likely to be both fallacious and detrimental to the personal happiness of the citizenry.”

Using computers in the work of redistricting exposed the absurdity of the principle of equal population. It also threatened to promote the “number obsession” into an organizational democratic principle.

In the years following the publication of his book, de Grazia’s parody became a reality, as computers paved the way to strict numerical equality. But the impact was perhaps even more extensive than de Grazia first anticipated. Malapportionment cases arrived in the courts because the votes of rural citizens had more weight than those of urban dwellers. It is this problem that the principle of equality addressed. Yet as strict equality started to overshadow other factors such as counties and communities of interest, it also became a shield protecting legislators from potential challenges. As the history of racial and partisan redistricting in the second half of the century demonstrates, with time equality became a proxy for equity.

2 THE APPORTIONMENT REVOLUTION MEETS THE COMPUTER REVOLUTION

Throughout the 1960s, political scientists and allies began turning to computers to aid them in redistricting. In response to *Baker v. Carr* and the consequent court decision in *Reynolds v. Sims*, computer redistricting moved from a theoretical musing to an active research agenda, bringing in people from industry and the academy to enter what Justice Frankfurter had famously termed the “political thicket."

The principle of One Person, One Vote opened up apportionment to computational remedies. Before *Baker v. Carr*, many states had districts of widely differing sizes. For example, when Tennessee's apportionment plan came before the Supreme Court, Moore County (population 2,340) and Rutherford County (population 25,316) each sent two representatives to the Tennessee General Assembly. This was a way for lawmakers to maintain power for rural areas despite growing urbanization. Computational methods for ensuring mathematical equality would have not been appealing in such cases because the balance being struck was not between any two abstracted citizens, but between the interests of an urban and a rural citizenry. For that matter, there might not even be an opening for a calculative approach because states like Tennessee had simply not districted in decades. In other states, factors such as existing coherent geographical units (counties, cities, etc.) and historical antecedent (such as incumbency) guided most apportionment efforts, with little to no regard for numerical equality. Computers only became useful to the problem because both a legal demand and a numerical standard had been established. Furthermore, computers not only became tools for implementing One Person, One Vote—their use even helped to establish a definition of what One Person, One Vote might mean. During the 1960s, courts and legislatures around the country were still unclear about the scope and strictness of the equal population principle.[6] Without any formal criteria by which to address this ambiguity, computers artificially foreclosed the problem. As political scientists, computer scientists, and state legislators began advocating the use of computers in redistricting, a computable definition of perfect equality as a rough proxy for political equity cemented the principle of One Person, One Vote as the governing criterion for apportionment and redistricting.[7]

The "apportionment revolution," as the mushrooming of legal challenges to districting plans around the country were referred to in the 1960s, began just as computers were becoming more ubiquitous in academic and industrial research. In the 1950s, the market for digital computers was still limited. By the 1960s, as computers became smaller, cheaper, and easier to operate, a growing number of Americans had the opportunity to interact with the new technology and imagine new uses for it. As historian of computing Paul E. Ceruzzi puts it, in the 1960s "the computer was reinvented yet again."[8] The transformation in the computing hardware industry was matched by growth of a new software industry [4]. New companies offering programming services for interested parties were growing at a fast rate, and some of these new startups became involved in computerized districting efforts.[9] The

[6]Public Law 94-171 was passed in 1975 calling for the Census Bureau to create official population tables for redistricting. See Chapter 13.

[7]Today, the terms apportionment and redistricting mainly designate two distinct activities. Now, *apportionment* names the process by which the number of seats in a governing body is designated for a particular territory, while *redistricting* is the division of the geography of the state into this number of districts. However, in the 1960s the two were often thought of together—because allowable deviation was a major live question—and were not as clearly separated as they are today. As a vestige of the earlier way of using the terms, population imbalance in districts is still called *malapportionment*.

[8]At first, digital computers were understood to be giant calculators. It was only in the 1950s that the computer's potential for data processing and scientific machines was established [5].

[9]Both Computer Applications Inc. and the Council for Economic and Industrial Research (C-E-I-R)

1960s also witnessed a growing interest by political scientists in digital computers as a new research tool for mathematical modeling, simulation, and large-scale survey analysis.[10] It is across this background that some political scientists turned to computers to study apportionment and redistricting. Finally, early efforts at computerized redistricting were spearheaded by postwar engineers, scientists, and mathematicians trained in operations research, systems theory, dynamic processing, and game theory. Often working in industry, these researchers had access to computing equipment and were eager to put into practical use their academic training. For them redistricting was just another problem that proved to be amenable to their new theoretical tools.

In what follows I survey three of the earliest efforts to tackle the problem of apportionment and districting in light of *Baker v. Carr* using digital computers. As will become clear, the individuals who turned to computer districting in the 1960s employed a wide range of methods and sought to forge differing political alliances. Yet, they were united by the belief that computers were apt for the task—not for their ability to crunch the numbers much faster than any human could, but for potentially offering an *objective* solution to a deeply political problem.[11] This is not to say that these historical figures were naïve or believed that computerized redistricting would bring an end to gerrymandering. On the contrary, they were acutely aware that their products would be used in a highly partisan environment. Their efforts, as such, can be seen as attempts to isolate a technical aspect of redistricting that is independent of its political implementation. The belief that this is possible persists in many venues today.

IN SEARCH OF A MECHANICAL FORMULA

One of the earliest papers offering a computer solution to apportionment was published by James B. Weaver and Sidney W. Hess in 1963 [17]. Weaver was a member of The Committee of 39, a civic group in Delaware that gathered historical data and information to inform the redistricting battles in the state. Weaver recalled that in 1963 the urban district he lived in had thirty-five times as many people as the smallest farming district in the state. "It hit me like the electric lights over people's heads on the comic pages," Weaver recalled years later, "that the computer could create districts which were blind to politics. Not only do they process numbers better than humans, they can't introduce politics if no party affiliation is in their memories" [16].

Weaver enlisted Hess, who was his younger colleague in Atlas Chemical Industries and a recent PhD in operations research from Case Western University, and the two began testing potential programs. What Hess and Weaver proposed as an objective function was a new measurement for compactness that took into account not only the shape of a district but also the population density in given areas. The goal of the computer program was to draw maps that optimize this measurement of

got involved in computerized districting in the 1960s.

[10] In his book, de Grazia points to some of the earliest work on computer simulation of voting behavior when discussing computers.

[11] For analyses from 2005 and 2010 of the various computing approaches to redistricting, see Altman et al. [2, 1]. A current overview is found in this volume, in Chapter 16.

compactness overall. The main breakthrough for Hess came when he realized that this optimization problem was structurally similar to a well-known class of problems in operations research, known as warehouse allocation or optimal transport: How should you direct customers' orders to specific warehouses so as to optimize freight costs? Hess was thus able to apply existing ideas and algorithms to offer new methods for redistricting.

In the introduction to their paper, Weaver and Hess explain that the goal of such computerized redistricting was not to replace legislative efforts, but rather to intervene in cases in which the legislator failed to provide a map. In the wake of *Baker v. Carr*, the authors explained, courts may strike down representation schemes as unconstitutional, but there was no clear guidance as to how "to administer relief" [17]. More often than not, the courts would choose to give the legislature another opportunity to draw a districting map, but in cases when this additional attempt failed, the court might have to offer a direct solution. It is at this remedial stage that the court might wish to appeal to computers to produce a map: "since redistricting usually affects the political balance of a legislature, a court undertaking affirmative apportionment and districting is likely to become the subject of highly partisan appeal and criticism... To avoid this 'political thicket,' a court may desire to limit its own discretion in creating a new legislative district."

In other words, the appeal of computer programming was that it removed human discretion from the mapping process. "One means of accomplishing this end," Weaver and Hess wrote, "could be to adopt a mechanical formula which makes the actual drafting of district lines non-discretionary once general principles of representation have been determined." To accomplish this goal, Weaver and Hess came up with a new definition of compactness, which took into account both geography and population. Intuitively, their goal was to keep centers of population intact. They therefore instructed their program to generate a series of maps through an iterative process and kept only those maps whose "compactness score" was highest and whose population deviation among the different districts was smallest. Whereas the former measure was unique to their program, the latter would become a standard for computerized districting efforts. In other words, Weaver and Hess subscribed to a mode of mechanical objectivity that reduced the nuanced notion of democratic "fairness" to a computational problem that could be studied and (like freight costs) optimized.[12,13]

In his concurring opinion in *Baker v. Carr*, Justice Tom C. Clark described the Tennessee apportionment plan as "a crazy quilt without rational basis."[14] No consistent scheme or standard, he explained, could account for the representational disparity among the various Tennessee counties. "Certainly there must be some

[12] "Mechanical objectivity" is a epistemic style articulated by Lorraine J. Daston and Peter Galison, who place its emergence in the mid-nineteenth century: "to be objective is to aspire to knowledge that bears no trace of the knower—knowledge unmarked by prejudice or skill, fantasy of judgment, wishing or striving" [7].

[13] The first call for automated redistricting came from economist William Vickrey in 1961. Vickrey did not call upon the computer directly, but instead described a theoretical algorithm for achieving automatic districting. The "elimination of gerrymandering would seem to require the establishment of an automatic and impersonal procedure for carrying out a redistricting" [15].

[14] *Baker v. Carr*, 369 U.S. 186, 254 (1962) (Clark concurring opinion)

rational design to a state's districting," Justice Clark added.[15] Early attempts to use digital computers to draw congressional and state legislative districts could be viewed as a response to Justice Clark's criticism. Numerous computer programs could be written and each one could produce thousands of maps, but an interested observer could always discern an operating rationale behind each map, one which had to be literally written into computer code.[16]

Weaver and Hess were able to put their program to use because the Committee of 39 had already gathered much of the necessary data. Still, when it came to running the algorithm on a computer, they quickly realized that the one purchased by Atlas Chemical Industries did not have the necessary computational power. They described the problem to operations researchers at DuPont, who got interested in it and offered the two access to the company's computer. In the following years, Weaver, Hess, and their DuPont colleagues founded Computer Research on Nonpartisan Redistricting, or CROND, Inc. For a while they continued to use DuPont's computer, but as their research expanded, they received a major ($96,000) grant from the Ford Foundation through the National Municipal League. As they improved their method and computational capacity, the group also began contracting directly with legislatures. They first drew districting maps for the Delaware state legislature and in the following years consulted with other states, including Pennsylvania, New York, and Nevada.

"THE ART OF DECISION MAKING"

Another early approach came from Chandler Harrison Stevens, who was supported through CROND's grant. Stevens earned a Ph.D. in economics from MIT in 1967 and served in the Massachusetts House of Representatives from 1965–1968.[17] He was impressed by Weaver and Hess's computational approach, but he did not believe that the process should be fully automated. In 1966, while working at MIT's Center for International Studies, Stevens developed a new computer districting application, building upon Weaver and Hess's algorithm, but he added a graphic component. The addition of a graphic display was conceived by Stevens as a way of construing computer districting as not fully automated, but instead a hybrid "man-machine" endeavor. A cathode-ray tube (TV screen) could be connected to the computer, enabling the user to see in real time how the new districts mapped onto the geography of the state. A user could visually inspect a districting map the program produced and then instruct the computer to move a given town from one district to an adjunct one. The program would then automatically evaluate the new

[15] Justice Clark did not require numerical equality nor did he believe that mathematical exactness is required to produce a "rational" plan. *Baker v. Carr*, 369 U.S. 186, 258 (1962) (Clark concurring opinion)

[16] Historians of science have argued that a novel brand of rationality, one they termed "Cold War Rationality," dominated much academic and policy thinking at the time. Algorithmic and rule-bound, this way of thinking stood in opposition to judgment and experience. Cold War Rationality was a child of the atomic age, a world in which computerized algorithms might be a safeguard against the human fallibility that could lead to total destruction [10].

[17] In fact, he was the first Independent elected to the Massachusetts state legislature. Stevens was at various points a programmer at the Pentagon, a science advisor to the governor of Puerto Rico, and a retirement-aged Peace Corps volunteer in Ukraine. In his obituary, his family describes him as a futurist committed to social justice (https://perma.cc/46G3-6HVR).

map according to a series of criteria such as population deviation, compactness, and contiguity.

When he presented his program at the 73rd National Conference on Government as part of a CROND-organized session, Stevens explained that the motivation for the work came from desire to couple "human judgment with the computer, which I felt the districting problem required" [13]. Stevens was quick to acknowledge that the insistence on human judgment might seem antithetical to those who researched computerized districting, but he insisted that the approach is both more practical and sounder. Certain districting criteria, Stevens explained, simply cannot be quantified or computerized and thus require human intervention. Moreover, "human judgment such as contained in the subjective weights applied to conflicting criteria can never be completely eliminated."

Drawing on his experience as an elected official, Stevens maintained that additional criteria besides population equality, compactness, and contiguity should enter into the decision process of the legislature. "I personally feel that we need much better correspondence between election districts and other districts used for regional planning, mass transportation, mental health, pollution control, welfare and employment services and a myriad of other programs." Using the visual display, Stevens envisions a system in which the user could project on top of a given map slides of additional information such as "newspaper reading patterns" or "commuting patterns." It was man–machine interaction that Stevens believed showed promise, not full automation. Unlike Hess and Weaver, Stevens believed that not only was there room for subjective judgment, but that it was in fact necessary.[18] He advanced this view when he declared that "there is an *art* as well as a *science* to drawing election districts." Stevens did not mean "art" in a derogatory sense to refer to gerrymandering. Rather, what he had in mind was "the art of decision-making, for the qualitative as opposed to the quantitative" [14].

Still, Stevens recognized that it was now possible to minimize population deviation using computers, a point he made sure to impress upon his colleagues in the legislature. When he appeared before the districting committee with some preliminary results, he emphasized two points above all. First was that it was possible to achieve districting plans approaching population equality, with as little as 1% deviation. Second was that, even within such limits, great variation in the plans themselves was possible. Foreshadowing what would become a pattern in decades to come, Stevens reported that the committee "seemed to understand the first point, for every districting plan which they subsequently considered had population deviation of 1% or less. But they ignored the second point." The districting maps the committee ended up considering were the least compact. Even within the court-imposed criterion of population equality, he concluded, "traditional Gerrymandering had plenty of room in which to operate."

This realization made Stevens decide to expand the potential utility of his program. As Stevens was developing his program, the United States District Court for the

[18] Thus, Stevens did not subscribe to the same "mechanical objectivity" that Hess and Weaver did, but to what Daston and Galison have named "trained judgment." This regime of objectivity, which emerged in the twentieth century, did not seek to completely erase the subjective. Rather, practitioners believed that intuition, gained through experience, plays a critical role in the production of true knowledge.

District of Massachusetts ruled that the state's current Congressional plan was unconstitutional and instructed the legislature to produce a new map. Stevens had a chance to put his program to the test sooner than he had planned. The sole Independent lawmaker in the Assembly, Stevens tried to convince his colleagues in the Joint Legislative Committee, which was tasked with producing a new plan to use his computer program. His goal, fundamentally, was not to suggest a new plan, but rather to use the computer as a tool with which to evaluate the existing proposals. Stevens renamed Weaver and Hess's measurement of compactness the "Gerry Index," and in a public demonstration at MIT, Stevens sought to expose the Joint Legislative Committee's plan as the least compact. "This type of public exposure," he wrote later, "should help hasten the day when state constitutions will be revised and/or courts will be armed to force fairer districting" [14]. Rather than simply serving as an aid to mathematical or calculative equality, Stevens also put computing to work as a tool to oversee, evaluate, and even expose unfair apportionment and districting.

POLITICAL REALISM

A third early paper calling for the use of computers in redistricting came from political scientist Stuart S. Nagel. Nagel received his Ph.D. from Northwestern in 1961 and directly joined the faculty of the University of Illinois Urbana-Champaign. Over the years Nagel published on numerous topics, authoring dozens of articles and books, with a long-term focus on technological applications in public policy. As one Illinois colleague put it: "like early Progressives, Nagel faithfully believed that the application of scientific rigor to public tribulations would virtually guarantee human progress" [18].

In 1964–1965, Nagel was a fellow at Stanford's Center for Advanced Study in the Behavioral Sciences, where he tackled the districting problem using the university's IBM 7090 computer. In 1965, he published his results, "Simplified Bipartisan Computer Redistricting" in the Stanford Law Review [12]. Unlike Weaver and Hess, Nagel promoted the use of computers in districting as a bipartisan rather than nonpartisan tool. Nagel believed computers could help solve legislative deadlocks. Instead of helping the court, Nagel wanted to help elected officials.

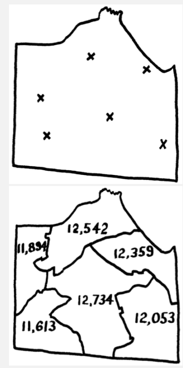
In Illinois, the inability of Republicans and Democrats to agree on new districts resulted in an at-large election; at the same time, the parties were coming to similar dead ends around the country. Nagel's Stanford Law Review piece envisioned a computer program that would save time and money by letting politicians examine a set of possible maps and arrive at a compromise. He explained that his program was "designed with realistic politics in mind." It therefore included past voting records for each district and could in principle produce a plan favoring one party over another, or remain neutral. "Such a parameter," Nagel explained, "might be needed to convert a compromise between the political parties into a redistricting pattern." Democrats and Republicans, Nagel reasoned, would need to be able to predict how each party will fair in future elections before they would be willing to sign onto a new districting map.

In emphasizing the importance of political information for the districting map, Nagel called into question early efforts to present computer redistricting as objective and an antidote to gerrymandering. There was nothing inherent in the computational approach to redistricting that prevented politicians from seeking to maximize their position. In particular, Nagel was pushing back against a 1964 paper by Edward Forrest describing a computer program for districting as not only generally useful for avoiding legislative deadlock but even capable of producing "truly neutral and unbiased" maps. "Since the computer doesn't know how to gerrymander—because two plus two always equals four—the electronically generated map can't be anything but unbiased" [11]. An academic, Nagel provided his program for free to anyone who was interested and he was eager for others to use it. In contrast, because Forrest was working for Computer Applications, Inc., one of the earliest software service companies, the details of his program remained classified.

Nagel's belief that the computerized districting should be used by politicians shaped the algorithmic approach he proposed. Unlike Hess and Weaver, the program was aimed at improving upon existing districts rather than overhauling the entire districting plan. Instead of starting from scratch, in each step the program created new maps by trading a geographical unit from one district for another and then checking if equality and compactness were improved. Nagel decided to adhere as closely as possible to a state's existing map because it aligned with his "realistic" approach. "It is naïve to think that incumbent politicians are likely to want to upset the status quo any more than the minimum extent required by the state constitution and courts or by the federal constitution and courts" [12]. Nagel never forgot that it was politicians who approved new districting plans, even if a computer drew the lines. Fairness, for him, was a pragmatic rather than a theoretical concept, a compromise aided by computers.

Nagel first put his program to the test in Illinois, but he was unable to impact the deliberation of the state legislature. Then, in 1965, an analyst named William Below adapted the program in order to help the California Assembly to produce a new districting plan. Below was on staff for the Assembly Committee on elections and reapportionment. During a November committee meeting, Below explained to committee members that the program he worked on "does not try to go to any unique plan for redistricting but one which is rational and which conforms to population and political registration. This is a fairly accurate method of maintaining the political status quo in California legislative district" [6]. When asked about the criteria used in the program, he dodged the question, asserting that the "mathematical plan is the best plan... it is the plan that fits best." As Below's remarks make clear, he believed that Nagel's program carved out a technical aspect of the problem that could be solved independent of the political context of its applicability. As long as a set of some criteria that were legal (population equality, contiguity) or political (maintaining the status quo) could be agreed upon and programmed into a computer, the creation of the maps themselves was better left to a computer than to humans.

8.1 WHAT'S ACTUALLY IN THESE ALGORITHMS?



Weaver and Hess (1963) introduced a district compactness metric closely related to the moment of inertia of a physical object (sum the squared distances from the units to district centers). To create compact districting plans, they used what is now called a *naive k-means* approach—the term was not coined until a few years later, but they recognized this as an already fairly standard technique. Starting with an initial guess of good locations for population centers of k districts, they assigned units to districts to minimize the moment of inertia. When a plan was complete, they recalculated the population centers of the just-created districts, which would likely differ from their initial guesses. Using these new centers as their next guess, they then iterated until the procedure stabilized.

The most obvious problem is that this optimizes for compactness alone, and might sacrifice population balance or even contiguity, let alone the more human criteria. Another problem is that there's no practical way to be sure that you iterate toward a global optimum. In the meantime, they imagined that the program could be used to produce a small number of acceptable plans, leaving a situation where "some discretion may be necessary to choose."

Stevens' `Geodata` was not really an algorithm at all, but what today we would call a GUI, or graphical user interface. Researchers used punch cards to feed data into an IBM 360 computer, which could then display a map of the districting plan on a TV screen. Users could type in instructions—e.g., "MOVE LEXINGTON FROM DISTRICT 5 TO DISTRICT 3"—and see the map change accordingly. The evaluation of plans by a pre-programmed score could be done quickly, and Stevens revived the moment of inertia score, now branded the Gerry Index. He mused about compactness with respect to travel time or social difference, but that was a more sophisticated version planned for the future. As a good reminder of the state of the hardware in 1965, Stevens used plastic overlays on the screen for fixed boundaries so that the "computer-controlled beam of light" could be saved for dynamic information. He also lamented that "we do not have a means as yet for making permanent the maps which show on our TV screen" and suggested using a camera to take a picture of the screen.

Nagel (1965) proposed a program that modified a given districting plan into something "better," working in a language called ALGOL (and he actually mocked Weaver and Hess for working in hard-to-understand FORTRAN!). To define what would be better, Nagel built a compound score by essentially multiplying a population deviation penalty by a compactness (normalized moment of inertia) penalty. The program looped over the units (say, the counties) in a state and proposed to "Move" a unit from one district to another or to "Trade" two units from adjacent districts. Proposals had to pass validity checks and had to improve the score to be adopted. Because this was essentially just hill-climbing with respect to a score, he could build in a partisan objective as part of the score function—this could be a deviation from proportionality penalty if you want to seek partisan balance or a partisan-favoring score if you seek a gerrymander! To gerrymander for a party, he proposed using the average margin of victory in a winning district. Making this lower would translate to more wins by efficient margins.

3 THE WIDENING GAP BETWEEN EQUALITY AND FAIRNESS

The computational approach pursued in each of the cases outlined above was highly determined by the authors' understanding of the nature of the problem. Weaver and Hess, operating outside the political process, believed that districting can (and should) be reduced to a purely technical optimization problem. As a state elected official, Stevens held that human judgment had a place in the districting process and hence emphasized the human–machine interaction. Finally, Nagel, as a behavioralist political scientist, chose pragmatism over optimization. Computers were a tool for negotiation, *not* full automation. Despite their differences, all of these early researchers wished to eliminate direct human intervention from some part of the districting process. Computers, they believed, were apt for the job because they fundamentally subsumed human intentionality to programmed randomness.

As these three examples make clear, *Baker v. Carr* had served as the impetus for a swell of early research studying computerized redistricting. As legal cases mounted around the country, the idea that newly available digital computers might offer a tool to counter the practice of gross malapportionment grew in popularity.

On the whole, their attempts to promote algorithmic plan generation were unsuccessful. As the Advisory Council on Reapportionment to the Legislature of the State of New York learned in 1965, existing computational approaches were still far from being practically useful. Having contracted Forrest to help the planning process, the Council concluded that "it ultimately became apparent that, in the present state of computer technology, there are some problems that can be handled more effectively by human judgment than by machines."[19] The impact of early attempts at computerized districting has nonetheless been profound. As several commentators noted, by the end of the 1960s, far from removing human intentionality from the process, computers only made the problem more acute by allowing increased and unnecessary emphasis on the principle of One Person, One Vote. With the help of computers, the legal requirement got subsumed by its mathematical proxy.

Even though *Reynolds* had set population balance as the ideal in 1964, it was still not clear what deviation from perfect equality the court would tolerate. In the wake of One Person, One Vote, legislatures understood that they should strive to produce districts of equal population, but no one, not even the justices, believed that perfect equality could be demanded. As Chief Justice Earl Warren wrote for the majority, "we realize that it is a practical impossibility to arrange legislative districts so that each one has an identical number of residents, or citizens, or voters. Mathematical exactness or precision is hardly a workable constitutional requirement."[20]

In the following years, numerous cases arrived in state and federal courts testing the limits of, and the justifications for, permissible population deviation. It is in

[19] "Report of the Advisory Council on Reapportionment to the Legislature of the State of New York," December 23, 1965, 14.

[20] *Reynolds v. Sims* 377 U.S. 577

the gray zone between "mathematical exactness" and practical considerations that researchers had first hailed computers as a possible solution. Legislatures found computers attractive exactly because they could quickly compare how different districting plans deviated from total equality.[21] The preservation of counties' historical and natural boundaries gave way to statistical equality.[22]

By the end of the decade, the Supreme Court began to tighten the expectations when it struck down a Missouri congressional districting plan (*Kirkpatrick v. Preisler*, 1969) and a New York congressional districting plan (*Wells v. Rockefeller*, 1969) for excessive population deviation. Following these court decisions, though they did not establish precise numerical bounds, top-to-bottom deviation of congressional districts is typically no more than 1% of ideal district size, and state legislative districts deviate no more than 10%. Taken together, the two decisions were seen to elevate numerical equality to a guiding principle. Population equality became an end in itself rather than an indicator of fairness.

In his dissenting opinion in *Wells v. Rockefeller*, Justice Harlan wrote that "the Court's exclusive concentration upon arithmetic blinds it to the realities of the political process, as the Rockefeller case makes so clear. The fact of the matter is that the rule of absolute equality is perfectly compatible with 'gerrymandering' of the worst sort."[23] He then noted that a "computer may grind out district lines which can totally frustrate the popular will on an overwhelming number of critical issues. The legislature must do more than satisfy one man, one vote." Justice Harlan recognized that mathematical exactness was a byproduct of computerization and he foresaw a future where "a computer can produce countless plans for absolute population equality, one differing very little from another, but each having its own very different political ramifications." If the dominant criterion for districting was population equality, then computers, so the logic went, could easily (and more efficiently than before) produce numerous configurations that would satisfy the legal requirement while allowing for political manipulations of any kind.[24]

By the early 1970s, Justice Harlan's critique was taken by some political scientists as fully just. Gordon E. Baker, who had been directly attacked by de Grazia in 1963 for promoting numerical equality, later wrote that "the singleminded quest for mathematical equality of districts at the expense of some adherence to local governmental subunits carries with it the potential for extensive gerrymandering" [3]. Baker celebrated the Supreme Court's decision allowing a less strict numerical standard for state-level as opposed to congressional districting. "This development could help minimize some of the computerized equal-population gerrymandering that ignored local governmental subunits as well as communities of interest." The

[21] As Gordon E. Baker reflected, in the years following *Baker v. Carr*, "lawmakers increasingly sought to make redistricting statutes invulnerable to legal challenge by aiming for statistical precision at the expense of geographic boundary constraints."

[22] In their early paper, Weaver and Hess argue that state geographical units such as counties must be broken down to prioritize a map that was both compact and adhered to population equality.

[23] *Wells v. Rockefeller*, 394 U.S. 542, 551 (1969) (Justice Harlan dissenting)

[24] In 1983, Weaver was quick to distinguish his and his colleagues' early efforts from those that came later. CROND, Inc. spent the grant money by first holding a seminar in Washington for interested national lawmakers, and then focusing on research for publication. "Then the political parties took over—both have now developed ways to gerrymander districts to their heart's content, using the computer" [16].

computer, seen at first as a solution for gerrymandering, had within ten years come to seem like a source. If numerical equality was intended as a constraint on lawmakers' ability to construct district maps to favor their own interests, in the end the implementation of population equality through computer technology increased their power to do so—and all within the bounds of the law.

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