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AI governance through fractal scaling: integrating universal human rights with emergent self-governance for democratized technosocial systems

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Abstract
One of the challenges facing AI governance is the need for multiple scales. Universal human rights require a global scale. If someone asks AI if education is harmful to women, the answer should be "no" regardless of their location. But economic democratization requires local control: if AI's power over an economy is dictated by corporate giants or authoritarian states, it may degrade democracy's social and environmental foundations. AI democratization, in other words, needs to operate across multiple scales. Nature allows the multiscale flourishing of biological systems through fractal distributions. In this paper, we show that key elements of the fractal scaling found in nature can be applied to the AI democratization process. We begin by looking at fractal trees in nature and applying similar analytics to tree representations of online conversations. We first examine this application in the context of OpenAI's "Democratic Inputs" projects for globally acceptable policies. We then look at the advantages of independent AI ownership at local micro-levels, reporting on initial outcomes for experiments with AI and related technologies in community-based systems. Finally, we offer a synthesis of the two, micro and macro, in a multifractal model. Just as nature allows multifractal systems to maximize biodiverse flourishing, we propose a combination of community-owned AI at the micro-level, and globally democratized AI policies at the macro-level, for a more egalitarian and sustainable future.

Keywords fractal · democratic · egalitarian · self-organization · OpenAI

1 Introduction

One of the challenges confronting AI governance is the need for a balance between universal human rights and localized democratic empowerment. Asking AI if vaccinations are harmful to children, or if voting rights should be restricted by race, should lead to negative answers no matter where you are. Universal human rights include, as Latour (2004) put it, both matters of fact and matters of concern. On the other hand, frameworks such as "strong democracy" (Barber 1984), "deep democracy" (Kadivar et al. 2020), and "participatory democracy" (Bua and Bussu 2021) have emphasized the need for bottom-up self-governance. They show that top-down bureaucratic entrenchment, and managerial

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privatization in industries like finances, health, housing, mining and so on have accelerated wealth inequality, racial stratification and environmental damage. In such cases, a society can have "democracy" in terms of voting, and yet suffer such vast inequality in power and lifeways that the nation has non-democratic social characteristics. Since AI may be a powerful force in determining the allocation of jobs, markets, resources, social networks and other aspects of life, establishing more diverse, localized control over the ownership of these technologies should be part of democratizing efforts as well. But how do we bring together these potentially opposed aspects of democratization—universal ethics vs local control—for AI?

Ideally, we would like forms of democratization that can be consistently applied at every scale, and lead to the flourishing of egalitarian, liberatory forms of living. Nature has many examples in which a bottom-up process is applied across multiple scales: it does so through fractal distributions, and they result in the flourishing of biological diversity. In this paper, we show that key elements of the fractal scaling found in nature can be applied to the AI democratization process and that this may contribute to its goal of flourishing, egalitarian social diversity.

Fractals are defined by recursive scaling, and they are associated with healthy biological states, whether cells, organisms or whole ecosystems. Trees, for example, can be modeled as fractals that are recursively composed of branches of branches, from trunk to limbs to end twigs. Trees invest enormous resources, over long time periods, building up the stability of the trunk. The limbs are slightly more subject to change, smaller branches still more, and the hundreds of end-twigs can snap off in a storm or regrow in the spring with little cause for concern. One reason why fractals are so ubiquitous in biology is that by making the largest scale features the slowest to change, and the smallest scale the quick responders, nature finds the optimal compromise between stability and adaptability.

US law, similarly, has its "trunk", the longest and strongest investment, in the US Constitution. State laws, like branches, are subject to more frequent changes, and scaling continues out to the twigs of localized neighborhood ordinances that could easily change overnight. One reason for this relation between scaling and resistance to change is that the legal decisions that operate at the largest scale have a kind of social inertia, requiring more extensive deliberation, just as a tree trunk will only bend after many years of adaptive growth. For example, when the Supreme Court overturned Roe v Wade in 2022, many legal critics noted that this is breaking *stare decisis*, the common-law practice binding judges to prior court decisions. To summarize the comparison: just as the stability of tree structures change with scale, the stability of legal structures change with scale.

One disadvantage of fractal systems is that an error at the largest scale will be slow to correct: US slavery was not abolished until 1865. But AI governance can also learn from the scaling patterns for error correction. For example, when things are going right, laws usually propagate from the universal scale down to the local: I can only enact a local law if it does not conflict with the state, whose laws cannot conflict with the constitution. But in cases like slavery, the error correction tends toward "back propagation" in the other direction: the acts of local abolitionists[1] led to regional changes, state laws, and eventually (after a civil war) constitutional amendments 13, 14, and 15. "The moral arc is long but it bends towards justice". The same is true for biological fractals: if enough leaves end up in the shade, eventually the whole tree will bend towards the light.[2]

We started with this verbal description of the analogy between tree scaling patterns in biology, and law scaling patterns in democracy, simply to introduce the concept. In Sect. 2 we will extend that using quantitative metrics. We show how the fractal dimension can be calculated for models of biological trees, using only the scaling factor (how fast each limb shrinks per iteration) and branching factor (how many branches gained per iteration). We note that nature's branching structures—not just vegetation, but also lungs, veins, neurons and others–have correlations between health and deviation from the fractal dimension norm for that structure. Low fractal dimensions (sparse branching) indicate unhealthy states such as poor nutrients. High fractal dimensions (chaotic branching) indicate unhealthy states such as cancerous growth.

In Sect. 3, we show how to apply this to conversation trees, the common threads of discourse in online media. Sparse conversations are too dull, and chaotic too controversial: the same fractal dimension measures are thus an indicator of the healthy, robust conversations at the core of concepts of deliberative democracy. Using a survey of OpenAI's "Democratizing Inputs" research projects in 2023, we examine the role of tree-like conversations in these deliberations. These projects also reported that the most robust outcomes required a balance between controversy and convergence. Thus we have our first example indicating that fractal dimension metrics may be helpful in guiding such efforts for democratizing AI policies. However, this example is limited to the search for governance at the global scale.

[1] For example, in 1851 the Boston Vigilance Committee (BVC) freed Shadrach Minkins, jailed under the fugitive slave act. President Fillmore demanded prosecution of the BVC members, and sent secretary of state Webster as prosecutor. The BVC was exonerated by a Boston jury, humiliating Webster in his home state and destroying his hope of winning southern votes for the presidency.

[2] Loehle, C. (1986). Phototropism of whole trees: effects of habitat and growth form. *American Midland Naturalist*, 190-196.

In Sect. 4, we examine empirical evidence that fractal distributions can guide democratization at multiple scales, not just the global. Because the micro-level structure may have a different fractal dimension than the macro-level (tree vs forest), we refer to these as multifractals. We examine this multifractal model in four other cases of bottom-up consensus: Wikipedia, open source software, Indigenous social organization, and the self-organization of animal flocking.

Section 5 brings this broader vision for multiscale governance back to AI. Local control over citizens' own communities, jobs and environments are increasingly overwhelmed by either the economic domination of corporations or political domination by authoritarian states. Even if AI operates by universally agreed principles, the centralization of its economic power could undermine the social, cultural and environmental fabric necessary for democratic life. We report on two experiments our research group has conducted in the ways that AI might empower community-based economies, and reduce the kinds of economic inequality, racialized stratification and other sociotechnical interactions that can undermine the democratic character of social systems.

We conclude with a synthetic vision for how the democratization of AI can proceed in a bottom-up, emergent fashion, ensuring that there is democratization at every scale, from the localization of community-based economies to the democratization of larger scale processes, culminating in the global scale in which universal human rights are honored and implemented in AI outputs through democratic consensus. By offering democratization in a fractal perspective—the kinds of bottom-up, emergent processes that create fractal structures in nature—we can design more egalitarian, inclusive and stable structures for merging the technical power of AI[3] with the social principles of democratic societies.

2 Quantitative metrics for fractal scaling

In this section, we will review some quantitative relationships that can characterize fractal scaling. We have already noted the useful comparison between stability changing with scale in the case of law, and stability changing with scale in the case of tree biomass. We can extend that comparison with the concept of fractal dimension. For example, if we compare seedlings from the same plant in good versus poor growing conditions, we tend to see sparse or stunted branching in poor growth conditions, which lowers their fractal dimension.[4] The same occurs for improperly nourished democratic processes.

A simple branching fractal, such as a tree, will depend on two characteristics. The branching factor determines how many new limbs emerge in each iteration. Figure 1 below shows a branching factor of two. The other characteristic is the scaling factor, which determines how quickly the limb size shrinks in each iteration. Those two factors combine to scale the biomass at each iteration. Most tree species, when healthy, have about half their biomass (volume) in the trunk.[5] The next iteration, the volume sum of the first heavy limbs, takes up a smaller percentage, and the same for each successive iteration. In Fig. 1, for example, the scaling factor for the length of each branch is 60%. If the trunk is length 1, the next two limbs are length 0.60. Since the length scales by 0.60, the volume of biomass scales by the cube of that factor (0.22). If we think of the trunk as one unit of volume, the first two limbs sum to 0.44 trunks. The end twigs, even though there are 32 of them, only sum to a small total volume (0.0165 trunks).

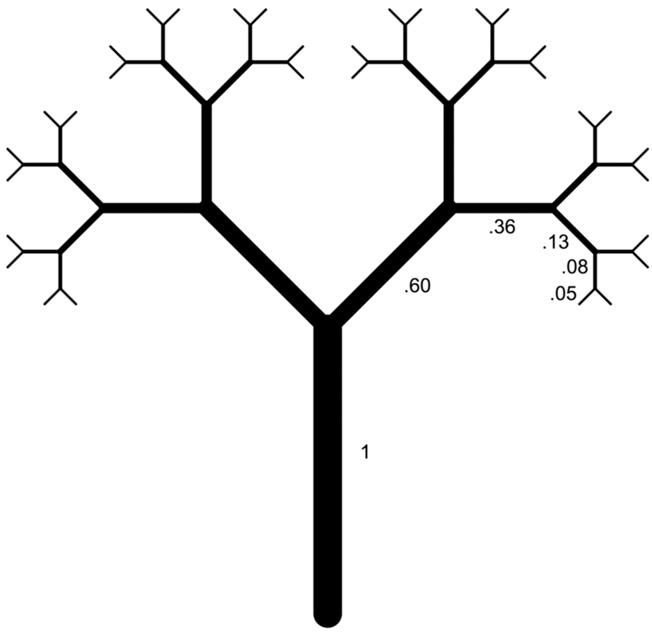
We can use this to derive a single number, the scaling exponent of the power law, that characterizes how quickly the tree biomass scales down at each iteration level. As noted above, that depends on the scaling factor (here it is 0.60), and the branching factor (here it is two). If we also wanted to include the angle of the branches—how "spread out" in space the structure is—we would need a more comprehensive metric, the fractal dimension determined by a method such as box counting. But that is only appropriate for structures that have complete self-similarity. For example, a Koch curve is self-similar at all locations of the curve; so are (within limits) many coastlines. But the trunk of the tree is an ordinary Euclidean cylinder: the tree structure is only completely self-similar at the boundary of the growing edge at the top. For that reason, it is often preferable to either use the scaling exponent itself or estimate fractal dimension from it.

A generalized way to calculate the scaling exponent, as well as extend it to estimates of the fractal dimension, is using a log–log plot of power vs frequency. In signal processing, this is referred to as a spectral density function. An advantage of measuring fractal dimension this way is the analogy to social laws we reviewed above. A periodic signal like a sine wave has all the power at one wavelength (dictatorship). A random process like white noise has the same power at every wavelength (anarchy). But fractal

[3] Since similar power law scaling can also improve AI at the technical level, such as training complexity (Meir et al. 2020) and other metrics (Kaplan et al. 2020), there are possibilities for intellectual co-development with frameworks for emergent democratization in AI's socio-economic dimensions.

[4] This also holds for root branching below ground (e.g. Eghball et al 1993).

[5] For example, Xue et al. (2016) found that the trunk accounted for 47.6% of the biomass in young trees and 62.9% in mature trees in their samples of a tropical forest. Age matters because many species shed lower branches as they grow, which affects this ratio (Mäkelä and Valentine 2006).



Branch iteration	Number of branches	Biomass volume of one branch	Sum of the volumes at this iteration
Trunk	1	1.0000	1.0000
2	2	0.2200	0.4400
3	4	0.0484	0.1936
4	8	0.0106	0.0852
5	16	0.0023	0.0375
6	32	0.0005	0.0165

Fig. 1 A tree that scales the length of branches by a factor of 0.60, giving a volume scaling of 0.22. The table shows how the biomass (volume) is distributed at each level of branching

distributions have the most power in the longest wavelength, (like the constitution), and the rest is distributed in diminishing proportions (less power at state laws, less than that in sub-state regions, down to the smallest in local city ordinances). The same is true for the biomass distributions of our tree.

This spectral density approach is used for determining fractal dimension in many natural and social phenomena: music for example has a fractal structure measured in this way (Voss and Clarke 1978). Because they typically plot power vs frequency (the reciprocal of wavelength), these distributions are generally referred to as "1/F noise" (see Gardner 1978 for a wonderfully intuitive introduction to this topic).

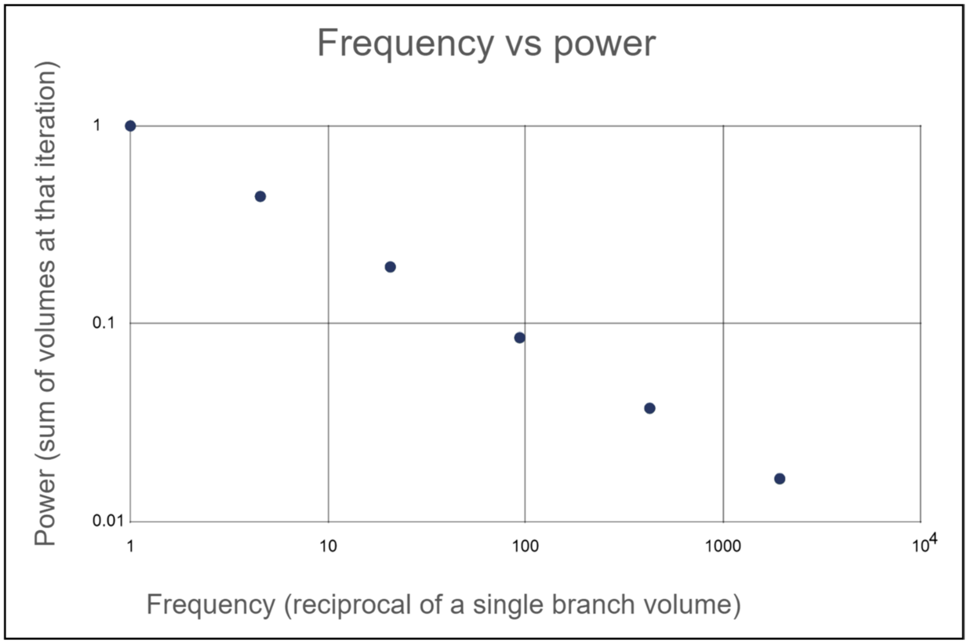
Spectral density analysis can be applied to patterns in time, patterns in space, and parametric domains such as our tree's pattern of volume change (Fig. 2). The wavelength of the "signal".

(X axis) is the volume of a single branch at a given iteration level. The power of this signal (Y axis) is the total amount of biomass at a given iteration level (sum of those branches' volumes). The trunk has the most biomass and the longest wavelength. The next iteration level, the first two limbs, will sum up to less biomass, and they have a shorter wavelength. Since frequency is the reciprocal of wavelength, we can plot the reciprocal of the branch volume on the x-axis, creating the conventional 1/F plot. That allows us to use the slope to obtain the scaling exponent beta, from $y = x^{-\beta}$ (in this case $y = x^{-0.54}$). We can then use the scaling exponent to estimate the fractal dimension D_f as it would be applied to any signal's spectral density, which is $D_f = (2-\beta)/2$ (in this case $D_f = 0.73$).[6]

The importance of a scaling metric can be understood by looking at the relationship between tree health and fractal dimension. On the one hand, poor growing conditions can lead to a scrawny, poorly branched tree: its lower fractal dimension is reflecting this poor health (Arseniou and MacFarlane 2021; Murray et al. 2018; Sinclair et al. 2015). On the other hand, certain diseases such as cancer or viruses can cause "witches' broom disease" (Christita et al. 2023), in which there is excessive branching, and thus pathologically high fractal dimension. Figure 3 models how these health-associated changes in branching will change the

[6] See Voss (1986) for a technical description of this relationship. A whole number can be added to represent the model's embedding dimension. But in the abstracted parametric space of biomass, 0.74 defines its scaling properties.

Fig. 2 The log–log plot of the reciprocal of single branch volume, versus the sum of branch volumes, at each level of branching for the tree in Fig. 1



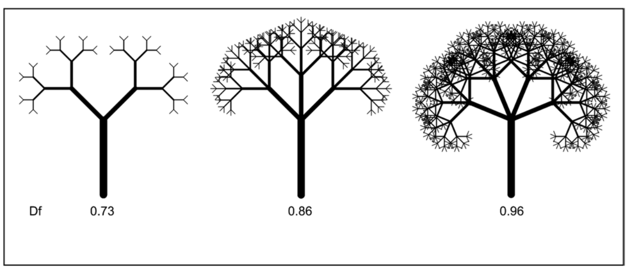


Fig. 3 increased fractal dimension with increased branching factors

fractal dimension.[7] Note that the number of iterative levels (6) and the scaling factor (0.60) is the same for all three, only the branching factor (2, 3, and 4 respectively) has changed. We can think of the left image as under-branched, the right image as over-branched, and the center as the "just right" healthy condition. Of course, real trees are not as consistent—a branching factor might vary randomly between 2 and 4 branches per level, for example—but one can create a statistical version using the same metrics.

Woody trees are only one example. Scaling exponents can similarly characterize the healthy states of fractal structures created by many living[8] growth processes. Here too, some disease states show a low fractal dimension. For example, lung X-rays show a decrease in fractal dimension for a wide number of pulmonary diseases, including COVID-19 and pneumonia (Namazi and Kulish 2020). That is because the fine structure of the fractal degrades, closing off the smallest end terminals of the air passages. The same occurs for blood vessels: for example, retinal blood networks have lower fractal dimensions when patients are diabetic (Yu and Lakshminarayanan 2021). And lower fractal dimensions of brain structures are associated with disease in several neurological domains, from dendritic networks to cortical folding (Ziukelis et al. 2022).

Just as in the case of botanical tree branching, a pathological *increase* in fractal dimension can also indicate a disease state. This is often the case of cancerous growth. For example, brain tumors tend to create an increase in fractal dimension, because they create rougher, tangled, disordered tissues (Hoyos and Martín-Landrove 2012). In their study of blood vessel branching, Ternifi et al. (2021) report that fractal dimension increase can quantify the degree to which "newly grown microvessels in malignant tumors are randomly and heterogeneously shaped" (p. 3891).

The above examples describe health as *a balancing point between low and high fractal dimension*, sometimes referred to in complex systems theory as a "critical point" or "self-organized criticality" (Bak 1996). Human-nature interactions also follow this principle. For example, spatial patterns such as regular stripes are "periodic noise", with a spectral density clustered around one dominant frequency, and hence a low fractal dimension (Abboushi et al. 2019). Large-scale industrial farming, with its endless rows of monocropping, is thus a spatial pattern with low fractal dimension: too much order leads to an unhealthy state (e.g. low biodiversity).

[7] We can also change the fractal dimension by changing the scaling ratio, which can also mimic effects such as stunted growth or pathological over-growth.

[8] They can also apply to non-living systems like river deltas, but we are focusing here on concepts of health that can lead to confusion outside of biology.

But highly fragmented spatial patterns are closer to "white noise", and thus a high fractal dimension. Dispersed, concentrated grazing operations result in an unhealthy, high fractal dimension, fragmenting the ecosystem (Alados et al. 2005). The "1/F noise" of natural ecosystems is neither too ordered nor too disordered. Regenerative farming, agroecology, and Indigenous traditions all utilize this balance between ordering processes and "wilding" processes to promote both biodiversity and production (Altieri 2004).

This phenomenon of biological health positioned at a balancing point between low and high fractal dimension has clear parallels to fractal scaling in democratic knowledge domains. A society that is too ordered—suffocating from bureaucratic over-regulation—will have a low fractal dimension. But if organizing structures are completely lacking, the fragmented system will suffer from the unresolved conflicts of high fractal dimension. It is no wonder that our main political struggles are split between advocates for more top-down structuring, and advocates for more bottom-up free agency: adaptive monitoring of that balance is how nature also maintains its healthy states.

3 Fractal structure as a guide for democratizing AI: the role of online conversations

If the most powerful AI becomes centralized, and designed for the self-serving interests of a few large corporations or autocratic nations, we are endangered by its lack of democratically determined alignments (Ovadya 2023). In 2023, OpenAI's research grant program for "Democratic Inputs to AI" sponsored 10 projects (including our own) for experimenting with online deliberation as a means of determining the ethical principles for generative AI's responses to public information requests.[9] Three examples appear below:

1. Konya et al. (2023) modeled their approach on peace negotiations, and thus focused on controversial questions, such as "how should AI handle requests for vaccine information when there is wide-spread debate?" Using the platform Remesh, they balanced opportunities for open-ended conversations, with a feedback mechanism such that respondents could see which were the most commonly-held views. AI-generated "bridging statements" then allow the creation of policy development.
2. Chen and Zhang (2023) modeled their approach on case law. They used the subreddit r/legaladvice to source their controversies. They too sought cases that are "close to a decision boundary (e.g., at least somewhat controversial)". An LLM is used to identify the dimensions of each case and to then generate further cases along those dimensions. Finally, a process is used to seek consensus, assigning the AI responses to a set of templates.
3. Shaotran et al. (2023) modeled their approach on the US Constitutional Convention of 1787 but envisioned this as ongoing rather than one-time. Their lab developed a taxonomy of topics, selected for sufficient controversy, and allowed users to submit and vote on AI guidelines (e.g. "responses on election misinformation should name the source of claims when they are made by groups with political or financial interests").

Despite the wide variations of approach, all 10 groups relied on a balance between two processes: one in which deliberations expanded the diversity of thought, and another in which democratic decisions guided convergence to policy. This maps well to our prior discussion of fractal metrics showing healthy states as a similar balance between high and low dimensions. Investigating those attributes through the lens of fractal analysis can offer some useful insights and potential metrics. We will begin with the expansive process of fruitful deliberation.

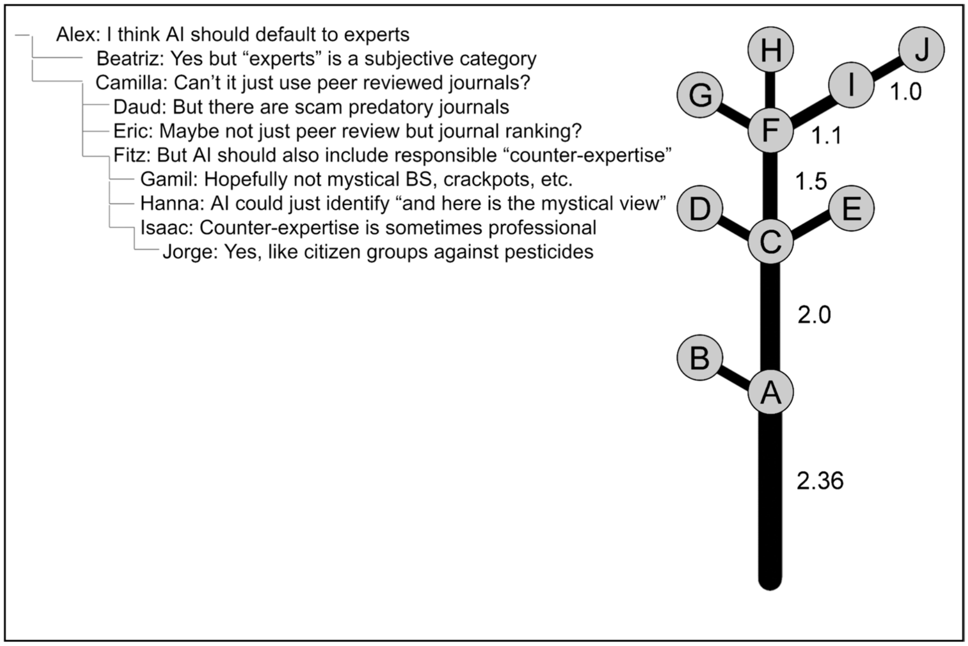
Vigorous conversations in the public sphere have long been a bedrock principle of democracy. They are enshrined in the constitutional guarantee for freedom of the press; theorized in frameworks such as Habermas' "public sphere", romanticized in our love of the coffee house, and digitized in contemporary citizen's assemblies (Habermas 2020; Itten and Mouter 2022). But during the research groups' weekly meetings hosted by OpenAI in the fall of 2023, many reported on the challenges of defining the right ingredients for fruitful discourse. Too much agreement and conversations die out. But endless debates and polarization can be unhelpful as well. Fractal metrics offer some insight into how that concept of "fruitful deliberation" might be reconceived and even measured.

Figure 4 shows a hypothetical online conversation, and its tree graph representation. Each node in the tree corresponds to the name of the respondent. The number of replies to a comment provide its branching factor. This is not as consistent as our simulations in the prior illustrations, but as we noted above, real botanical trees are not as consistent either. In both cases, statistical versions can use the same metrics (Pluciński et al. 2008).

Recall that the fractal dimension depends on both the branching factor and the scaling factor. To derive a scaling factor, we used a variant of the Google PageRank

[9] https://openai.com/blog/democratic-inputs-to-ai-grant-program-update

Fig. 4 Tree representation of online conversation, with scaling proportionate to the number of outgoing links



algorithm.[10] In the original PageRank, it recursively assigns weight based on incoming links to a node. My website's importance is calculated by not just how many sites point to it, but how important they are, and so on fanning out recursively. In the case of conversations, we want to track *outgoing* links: how well a comment "sparked conversation". So the weight is not just the number of replies to a comment, but also how well their branches sparked subsequent conversation, again fanning out recursively. We set the link to a terminal node as size one, and we selected a scaling factor of 1.1. For example, Isaac's link size is scaled up to 1.1^1, since he has one reply. Since Fitz has four subsequent replies, his link size is increased to 1.5 (rounding 1.1^4). Since the result is a tree with fractal scaling, the slope of the spectral density function can be used to calculate the fractal dimension in the same way it was introduced in Fig. 2 above. Graphing the volume of each branch size versus the sum of the volumes for that size on a log–log plot yields a slope of −0.78 or a fractal dimension of $D_f = (2–0.78)/2 = 0.61$, even more sparse than the 0.73 value we had for "sparse" branching in the botanical tree example. As noted above, the number is only meaningful relative to an empirically derived value, but once that is obtained for statistically significant samples, it may be a useful metric.

The concept of social properties that are statistically correlated with "sparking a conversation", and the way that determines conversation tree structures, are well studied in the literature (Bollenbacher et al 2021). Here we simply extend that to thinking about link weights as scaling, and the combination of branching and scaling as fractal dimension. Conversation trees, like biological trees, can have occurrences where branching is lush, and conversations are fruitful, but they can err on either side of poor branching or cancerous branching. By measuring the fractal dimension on conversation trees during AI deliberations, we may be able to provide an aid to measure and guide the flow of conversations.

The scaling factor of 1.1 was selected simply to optimize visibility, but as long as one is consistently using the same scaling factor, the fractal dimension of all trees can be compared relative to each other, and thus provide a metric for conversation assessment as discussions proceed. For example, as long as the scaling factor is consistent, they could be used for comparisons between different platforms or contexts: what were the fractal dimension changes that lead to the best outcomes? With sufficient empirical data, it may be useful as an aid to real-time decision-making about when conversations need to be brought to a conclusion for summary, or extended because they are still in a fruitful branching mode, or need intervention due to over or under-branching.

The conversation tree fractals map well to the fractal structures we examined in biology, such as the correlation between health parameters and the "critical point" balance for a structure's fractal dimension. We can deepen this connection by understanding the balancing point not as a final static number, but as constant shifting through "entropic modulation", as framed in Eglash et al. (2023). Here they describe how biology uses cycles of high and low entropy

[10] The use of recursively weighted links has been independently invented many times, from Landau's analysis of chess in 1895, to Markov, Perrin, and others. See Franceschet (2011) for an historical review.

for hill-climbing on fitness landscapes. Species evolution cycles between low entropy genotype (where DNA's orderly structure communicates) to high entropy phenotype (where fitness is tested). In the immune system, antibodies maintain lower diversity (entropy) in health and shift to higher entropy when searching for the best response to a new infection (Wang et al. 2017). Eglash et al. then extend this framework to similar entropic cycles in human-nature coupling. For example, many Indigenous groups used controlled burns to modulate between the high entropy growth phase and low entropy nutrient returns during burning.

In similar ways, the 10 OpenAI research groups all utilized some mechanism to modulate between the high entropy of "sparked" conversations, and the low entropy needed to create consensus-backed, actionable policies or statements. The differences in mechanism are at the heart of their approach. Some used AI to directly transition from the high entropy of open conversations to the low entropy of "common ground" or "bridging" statements (Theuns 2023; Konya et al. 2023; Fish et al. 2023; Mendoza 2023). Devine et al. (2023) created recursive layers of open conversations alternating with layers of LLM-derived summaries. Shaotran et al. (2023) used an algorithm similar to that of X Community Notes to ensure a combination of diversity and common agreement. Sharma et al. (2023) used Decentralized Autonomous Organizations (DAOs) to examine which modulation strategies performed best in the context of diversity and inclusion.

From the above survey, we can see that all of the projects for democratizing AI required finding the balance point between the expansiveness of open deliberations, and the reduction to bridging statements or policy. We hope that future versions of such projects will be able to use the fractal dimension of conversation trees as a metric for guiding that balance. As noted above, knowing at what point an open conversation should be summarized by AI, versus when it should be extended (or other interventions made) because it has yet to reach its critical point, could be monitored by the fractal dimension of the conversation trees. Determining what number of participants best facilitates the conversations and other seemingly subjective properties might be measured as well. If there is an optimum for fractal dimension in specific contexts or purposes, that can serve as guidance in future cases.

4 Multifractals: differentiating local and global collaboration processes

So far we have discussed how fractal dimension might guide the design of collaborative processes at the global level. If we want a single set of AI policies that people from many different nations can agree with, the fractal framework and metrics can help model and perhaps guide the branching conversation structures and processes that lead to bridging statements, compromise and common ground. But that is AI policy at a single temporal and spatial regime, the global. What kinds of decision-making processes might be used at smaller scales? How can we know which issues belong in which spatial and temporal regime?

It is common sense to note that policies with the strongest correspondence to enduring universal human rights (e.g. as measured in Konya et al. 2023) should be those requiring the largest spatial reach, and their temporal range should require the most extensive deliberations before changing. Those at the other end of the scale—most specific to a particular context, with less impact on fundamental rights—could be the most amenable to change, and most variable by location.

Konya et al. used the UN's 1948 Universal Declaration of Human Rights as one standard to measure against. Goodale (2006) notes that a year prior to the 1948 statement, the UN requested a report from the American Association of Anthropology (AAA), thinking it would provide support. However, the AAA's 1947 report did the opposite, stating that "anthropologists had amply documented a richness of diversity in moral systems and that the cross-cultural data did not support the assertion of a universal set of substantive rights" (Goodale p. 486). They did so because they feared that Western nations would impose their own biased morality: criminalizing homosexuality, restricting reproductive rights, and requiring capitalist economic policies under the guise of "individual rights". Goodale notes that although the two reports are opposed—1947 on normative diversity, and 1948 on normative universality—they are both crucial aspects of contemporary advocacy for Indigenous rights, worker rights, sex/gender rights and others. Can a fractal analysis help to bring together these seemingly opposite aspects of human rights, the local and the global?

Imagine a pristine national park of 2000 square miles: it has a fractal dimension for "patchiness" of forested vs grassy areas (Andronache et al. 2019). An individual tree also has a fractal dimension, but it is different from that of the park's. You cannot simply "scale up" the tree's structure to get that of the forest, even though their dimensional values are codependent (Liu et al. 2022). Disease at the level of individual trees will lower their fractal dimension, and that is reflected in the increased patchiness determining the forests' dimension: codependency despite different dimension numbers. The term "multifractal" was introduced for similar reasons: many systems have different scaling exponents associated with different spatio-temporal regimes.[11]

[11] Halley et al. (2004) suggests that the scaling exponent should change smoothly to qualify as multifractals, and "abrupt" changes at a scale boundary are more properly termed "mixed fractals". But that phrase is sometimes used to describe examples with no codependen-

The codependency—the ways in which the structure of individual trees "bubble up", so to speak, to create the forest's frothy fractal—is a good model for thinking about the relationship between different levels of AI governance.

Wikipedia offers a good example of how democratized systems can take this multi-level approach. It has had extraordinary success in using a bottom-up consensus process to converge on accurate and rigorously documented knowledge representations. This success is in part because they allow locally specific topics their own self-governance (e.g. Wiki "talk" pages). From that, the organizational roles that would normally be assigned top-down in industry or government are emergent (Arazy et al. 2017), creating a macro-level for global policy. As Mehler et al. (2018) put it, "the duality of macro- and microscopic diversification is mirrored by processes of social differentiation regarding the roles and statuses of Wikipedians". Both macro and micro-levels have their own fractal characteristics, evident in the "tree-like structures of talk pages" (Mehler et al., 2018). Zlatić et al. (2006) measured the scaling exponents of both temporal and structural features in Wikipedia and found that they differed at micro and macro scales. While universal at the macroscale, there were variations for the localized Wikipedias established by some languages (for example Polish and Italian Wikipedias have lower fractal dimensions at the micro-level because they emphasized standardizing templates). This is exactly the kind of multifractal freedom we need for AI: convergence for universal rights at the macro-level, independent self-governance (communities own their own AI) at the micro.

Such multifractal governance, allowing for more independent self-organization at the micro-level, and convergence on shared principles at the macro,[12] can also be found in open-source software communities (Hindle et al. 2011). Turnu et al. (2013) show the "witches broom" or cancerous growth effect for open source: excessively high fractal dimension correlates with the number of software bugs and other defects. Traditional Indigenous societies are also well-known for their democratic and egalitarian character. They too show a tendency for greater independence at the micro-level, and convergence on shared large-scale structure through ritual and ceremony (Johnson 1982), resulting in organizational structures that work best when adhering to a fractal dimension norm (Hamilton et al. 2007). Even non-human organisms can show self-organized swarms (flock, herd, etc.) analogous to the human consensus process at the local level (Couzin et al. 2011), as well as a macro-level coordination of "inter-swarm" interactions (Tarling et al. 2009; Kajtoch et al. 2017).

Is it really necessary to have a micro-level of independent, worker-owned organizations? Or could a corporate giant achieve similar results, simply by allowing more worker self-management? Techniques such as "flat" management or "holacracy" have attempted exactly that. But they are often linked to an ideology of anti-unionism and increased precarity (McCann et al. 2021). Empirically some show decreasing diversity, and reports of "Lord of the Flies" dominance patterns (Macgregor 2023). In contrast, worker-owned platform cooperatives have shown less extractive work practices, new opportunities for vulnerable gig workers, and innovations in business collaborations such as data sharing (Zhu and Marjanovic 2024).

This contrast also helps alert us to the "magic fix" delusion that "if we just make it fractal, we get more democracy". An authoritarian hierarchy can be self-similar but it is imposed from the top down. The direction of causal flow is the crucial distinction. Fractals in nature are the outcome of a bottom-up process: emergent growth over time is the reason it is linked to health. Thus we need to carefully define the micro/macro distinction in cases like Wikipedia, where developers first impose a fractal scaffolding, to nurture a bottom-up, emergent process. A useful analogy can be found in the design of environmental restoration structures, such as artificial reefs, where the fractal dimension of the scaffolding can be used in optimization for emergent processes for ecological flourishing (Riera et al. 2023).

In summary: self-organization in Wikipedia, Open Source, Indigenous social structures, and animal swarms indicate that a multifractal model offers substantial advantages.[13] By allowing independent self-governance at the micro-level, emergent processes can facilitate the development of global characteristics at the macro-level. If multifractal structure also applies to AI governance, then we need to go beyond the models for macro-level consensus in the last section. We need micro-level independent self-governance as well. In the next section, we examine experiments in community-based and worker-owned AI.

Footnote 11 (Continued)

cies, so it too is somewhat unsatisfactory.

[12] Of course this need not be a scale binary (micro/macro); it can be gradients or multiple levels.

[13] Future research might examine other commonalities across these domains. For example, all four have instances in which group size at one scale is modulated in adaptive response to conditions at another scale; a point emphasized in Johnson's (1982) concept of "scalar stress".

5 A fractal lens helps us see the forest for the trees: democratizing the AI sociotechnical ecosystem

In healthy biological ecosystems, flows of value—nutrients and other attributes that make growth possible—eventually cycle back to their generative source. These emergent, adaptive cycles maximize biodiversity. In the case of Indigenous societies, this circulation of unalienated value constitutes the "generative justice" that characterizes egalitarian structures and commons-based agroecology. But in modern human technosocial systems, value is often extracted and siloed ("alienated") as wealth accumulation for a small elite. Extraction creates wealth inequality correlated with deprivations in health, environment, education and other foundations of the generative capacity of communities, including that of democracy itself (Jetten et al. 2021). Attempting to correct that by imposing redistribution from the top down, after extraction, is often unhelpful: USSR, Cuba, China, and other communist states have had poverty, pollution and civil rights destruction at least as bad as high-inequality capitalism (Eberstadt 2017). The solution we propose is to avoid extraction altogether, and develop advanced technologies, including AI, that enable contemporary versions of generative justice (Eglash 2016; Eglash et al 2024).

If AI's economic power is centralized in the hands of large corporations or authoritarian states, its control over markets, jobs, land use, and other dimensions of social existence could make macro-level policies irrelevant. The prior section described how fractal analysis need not be restricted to the macro-level. It can also help frame the design of multi-scale systems, in which there is emergent diversification at the micro-level, with democratized AI ownership, governed by local communities and ordinary workers.

Our research group is examining two approaches to this question. At the geographically local, physical scale, our NSF grant has examined the role that AI might play in developing a community-based economy in Detroit (Eglash et al. 2024). At a larger, virtual community scale, our OpenAI grant has allowed us to examine how AI's data accumulation and model training might be democratized for the creative economy in Africa (Nayebare et al. 2023).

Our NSF-funded study, "Race, Gender and Class Equity in the Future of Work: Automation for the Artisanal Economy" is developing a platform (https://www.artisanalfutures.org/) by which low-income communities in Detroit can develop their own community-based economy. We begin with small-scale, worker-owned enterprises (the majority are Black-owned, about 50% female) in which there is "artisanal labor": people doing what they love, in their own creative styles and pace. These included clothing makers, hair salons, urban farms, furniture, jewelry, youth education, and a wide variety of other products and services. We investigated the role of AI at 3 levels. At the micro-level, how can digital technologies (3D printing, laser cutting, soil sensors, etc.) work with AI to enhance labor practices, such that work retains its beloved artisanal character, but improves its repertoire of products, rates of production, sustainability, profitability, or other dimensions of concern to the workers? At the community's meso level, how can AI establish or enhance local business-to-business linkages, such as urban farms growing biomaterials for fashion items? At the community's macro-level, how can AI agents guide consumers to more localized, sustainable and deliberative forms of consumption, such as buying groups and feedback to local suppliers? For a preliminary report on the results see Eglash et al. 2024.

The second approach (Nayebare et al. 2023), funded by OpenAI, developed a platform in which African creatives can receive payment for the use of their work by AI (https://ubuntu-ai.net). Here the scale extends far beyond any geographic community and thus tackles a different set of democratic challenges. While financial compensation to contributors for their data, often referred to as a "data dividend", is increasingly popular, evidence increasingly shows that the compensation is meager and fraught with manipulation risks (Bakir et al. 2023; Moerel and Lyon 2020). More importantly, art and designs are not merely "data", they are expressions of human agency and creativity. The role of AI should be to empower those capabilities, offering tools for support and financial sustainability. Image licensing is one way to accomplish this.

Open source platforms such as Wikipedia and Creative Commons were carefully designed in consultation with legal experts to ensure designations with specific licensing. In some cases, the media are designated as free for commercial use.[14] Many of the media are explicitly licensed for non-commercial use only. In contrast, platforms such as Wikiart (unrelated to Wikipedia), have great ambiguity regarding copyright.[15] Thus corporations developing for-profit, proprietary AI by training on all of Wikipedia, including images for non-commercial use, or all of Wikiart, which often fails to specify the distinction, may be in violation of copyright law according to some legal scholars (Opderbeck 2024).

The legal argument in Opderbeck hinges primarily on the ways in which most court cases supporting the rights to "non-expressive use"—which would include images for AI training—described the issue. They assume that instances

[14] For example Creative Commons' CC0, BY and BY-SA licenses, as well as BSD, LGPL, and GPL licenses.

[15] All images on WikiArt have a "fair use" icon, and that simply links to a page explaining that image copyright typically expires after 70 years. They generally lack the date or other relevant information about the photo itself, so it is not possible to ascertain if it is copyright protected or not.

in which one is merely absorbing data for other purposes, rather than replicating any particular image for sale, would not impact the artist's own sales. But in the context of AI, that is no longer true. Thus we are now deceptively focused on the replication question, whereas the original court decision was actually asking about the potential financial harms. Those clearly do exist, given AI's ability to encroach upon market niches occupied by the particular artists whose works it trained on. However, even Opderbeck's objections may be mute points. AI corporations are now so well funded that they can simply buy massive image archives. OpenAI recently created image licensing agreements with Shutterstock and the Associated Press. Restrictive AI laws may merely serve to prevent small companies from competing with corporate giants, furthering their siloed extractions.

Thus our own research in Nayebare et al. (2023) examines another strategy altogether, using a case study on African artists, crafters and designers. The ubuntu-AI platform, like the artisanal futures project in Detroit, is based on generative justice (Eglash 2016). It examines how to use AI to both prevent value extraction and expand unalienated value circulation, such that emergent diversification is enhanced. For example, shipping from Africa to the US would create an enormous carbon footprint, essentially extracting ecological value from the global commons (the carbon sinks of forests and seas) and privatizing it. For that reason, we focused on charging fees to license images from individual artists. We have also focused on AI algorithms such as Neural Style Transfer that can specify the particular work of art used as input, and even facilitate deliberations between consumers and artists, returning to the tradition of a "relational economy" in the spirit of ubuntu (Mhlambi 2020). The system also gathers mass data for use in LLM-style processes, but that too requires licensing, with all net profit being returned to the artists. As the platform slowly grows, and we learn more about the outcomes, we are engaging the artists in conversations about how they would like to see AI utilized, and the use of distance technologies to circulate both knowledge and financial exchanges in a decolonized economy.

Both the Artisanal Futures project in Detroit, and the Ubuntu-AI project in Africa, have been developed through "participatory synergy" (Eglash et al. 2024) in which the design begins as temporary scaffolding, and gradually incorporates the ideas and experiential feedback of users into its structural changes, as we discussed in the previous section. As pointed out by Richie (2023), such "emergent strategies" cannot succeed alone, they require institutional support, civic alignments, legal frameworks, and other co-innovations. If one is to grow a "trunk" for democratic stability, it must be facilitated by roots across the entire technosocial landscape, including government. One example might be the Los Angeles County regulations giving worker-owned enterprise bid incentives on public procurement contracts. Another might be the 2019 California laws allowing city and county governments to establish their own "public banks", boosting lending for affordable housing and solar energy, and cycling banking profits back to the communities that created them (Chi and Sevier 2023). One can imagine the equivalent regulations supporting worker-owned AI or community-owned "public AI". Integrating machine learning into the infrastructure of economies for generative justice, including legal and governmental support, is a crucial next step.

Fractal branching structures in nature are often described as the result of evolutionary pressures for efficient flow or material cost/benefit (Tekin et al 2016). They occur at every level of the ecosystem, from microbes to continental river basins. Frontier (1987, p. 335) provides a systemic perspective on this: "the surface area of the contact zones between interacting parts of an ecosystem is considerably increased if it has a fractal geometry, resulting in enhanced fluxes of energy, matter, and information". From a computational perspective, it is because there is fractal nesting of recursion, the multifractal loops of self-generation and self-organization at every scale. The same applies to a multifractal perspective on social systems. Shallow democracy is limited to voting, while "deep democracy" (Kadivar et al. 2020) can only be achieved if there is bottom-up emergence at every scale.

Where, in this multifractal model, are the global ethical principles and policies that OpenAI's "democratic inputs" projects explored? If they are restricted to those kinds of abstracted forums, it is hard to see how they can have an impact on more fundamental aspects at the base of the socioeconomic ecosystem. Instead, we propose that they should arise from emergent economic foundations: AI empowering community-based economies, and AI trained by contributor-owned data platforms. The development of specific tools for allowing higher-level consensus to "bubble up" from micro-level organizations, such as the "recursive summarization" framework proposed by Zhang et al. (2017), might be a positive step in that direction.

6 Conclusion

The new technical innovations of AI need to be coupled in co-evolution with new social innovations required for achieving deeper forms of democratic commitment. A society that allows AI ownership to expand unilateral control over the extraction of value from ecosystems, labor systems, and social systems, need not bother with deliberations over AI communication policies: its democratic mission has already failed. But top-down imposition of value control, as seen in most communist state histories, does little to address the underlying problem. Deeper forms of democratic lifeways require generative justice, in which unalienated value circulates back to those human and non-human agents that created it, from the bottom up. The question then becomes: what kinds of structures can these emergent processes develop, such that similar commitments to democratic, egalitarian, and diverse self-governance are at work across every scale, from the workplace, to local, state, nation, and international governance? Nature seems to be hinting at fractal scaling as a means by which such emergent diversification can flourish, and we would be wise to listen.

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