Optimality of Social Choice Systems: Complexity, Wisdom, and Wellbeing Centrality

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Abstract

Since circa 1900, civilization has experienced radical changes including changes in the size and distribution of populations, the power of technologies, the magnitude of energy and materials use, and the depth of scientific knowledge. With these have come increasingly complex challenges and elevated risks, and thus a heightened need for wise decision making. Accordingly, the need has grown for efficient and functional decision-making systems, also called *social choice systems*. I use these terms to refer to economic, governance, and legal systems. The seeming inability of societies, both individually and collectively, to effectively mitigate excessive climate change, poverty, income inequality, pollution, habitat loss, and other major problems suggests that underlying social choice systems are sub-optimal relative to need. I raise two overarching questions: (1) What characteristics would more optimal social choice systems exhibit? (2) How could research and development of more optimal systems best proceed?

The answers I explore in this paper are based on the premise that the relative optimality of a social choice system is a measure of its relative capacity to help communities solve problems and organize activities such that collective wellbeing is elevated. The characteristics of complex adaptive systems, successful problem-solving systems found in nature, are explored in order to suggest useful design motifs and monitoring indicators. I emphasize the need for research and development of new social choice system designs, and argue that field testing of these can best occur at the local (e.g., community, city, or county) level. Efforts in this direction by the science and technology sectors and academic community are still nascent. The work described here suggests a new multidisciplinary program that I term *wellbeing centrality*: the design, testing, promotion, and operation of social choice systems that place wellbeing measurement, evaluation, forecasting, and deliberation at the center of decision-making activities.

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1 Introduction

Societies worldwide face difficult challenges, some entrenched and intractable and others just emerging. The long list includes accelerating climate change, habitat and biodiversity loss, pollution, water shortages, forced migrations, unemployment, financial instabilities, soil erosion and desertification, infrastructure decay, social unrest, political polarization and extremism, violent extremism, and income inequality. It also includes the production and use of weapons of mass destruction, epidemic rates of preventable diseases, and the potential misuse of synthetic biology. New challenges are emerging from seemingly beneficial technologies. Robotics, for example, is expected to increase productivity over the next few decades. But it could also induce mass unemployment—up to 50% of US jobs could be at risk [1]. Further, professionals fear an arms race in the production and use of autonomous killer-robots [2]. Individually and in concert, these challenges threaten the stability of nations, if not the continued existence of *homo sapiens* and numerous other species.

If societies and civilization are threatened, it is sensible to search for underlying causes of the diverse set of problems. One possibility is that human nature is fatally flawed. Perhaps societal problems stem from excessive selfishness or other innate maladaptive characteristics of individuals. Fatal flaws in human nature are not supported by recent research in fields such as game theory, evolutionary biology, psychology, and behavioral economics. Indeed, just the opposite appears true. Regardless of culture or national origin, humans tend to value fairness and prefer cooperation, if these are not thwarted or distorted by external factors [3, 4].

A more likely explanation is that the decision-making systems in use—defined here as the formal and semiformal systems by which societies self-regulate their behavior—are outdated or otherwise inadequate to meet modern challenges. I use the terms *decision-making system* and *social choice system* interchangeably to refer to three broad types of systems: economic/financial/monetary, governance/political, and legal/justice. For brevity, hereafter the terms *economic system* and *governance system* are used to refer to the first two in the list. Although this paper focuses on economic and governance systems, similar considerations apply to legal/justice systems.

Note that social choice systems can include as components one or more preference aggregation methods, which are the the topic of *social choice theory* [5]. A social choice *system* consists of policies, rules, laws, social norms, education programs, information flows, preference aggregation methods, and/or other components that describe a collective decision-making process, as well as *how* all the components combine into a functional whole, including any emergent properties (see Section 5 for the meaning of emergence).

That societies use governance systems to make collective decisions and implement actions is well understood. Less understood is that societies use economic systems to do the same. Societies use economic systems, for example, to help decide what products to produce, how the profits and outputs of production will be distributed, what human and natural resources will be used, how workers will spend their time and attention, what wastes will be produced, how wastes will be disposed of, and who holds decision-making power. Indeed, economic decisions can sometimes have greater impacts on a society and/or the environment than those made through governance systems.

This is not to imply that decision-making power within current economic systems is distributed evenly. Due to severe income and wealth inequalities, among other factors, elite investors and property owners, large corporations, and similar groups hold the overwhelming advantage. Nor is it to imply that individuals and organizations necessarily think of and use their economic systems as a means of making collective decisions. Perhaps more commonly, individuals think of an economic system as the master of their actions, not the other way around.

The possibility that current social choice systems are inadequate to meet challenges raises a fundamental question that has so far been infrequently asked in academia and other sectors of society: *What characteristics would more optimal social choice systems exhibit?* To answer this question, a definition of relative optimality must be advanced, and this, in turn, requires that the purpose (user requirements) of a social choice system be identified. As analogy, the purpose of a new jet airplane might be to safely carry a specified number of passengers over a specified distance in any weather conditions that might be reasonably expected. The relative optimality of competing airplane designs can be assessed by determining how capable each is of achieving this purpose.

This paper examines optimality of social choice systems through the lens of *complex adaptive systems*, as are discussed in biology, physics, and other fields. Because numerous concepts from complex systems are introduced, and uncommon connections are drawn between them and social choice systems, it might be helpful to start with a synopsis of primary arguments. The main ideas are:

1. Societies face *super wicked* problems that, especially in combination, hold the potential for catastrophe (a definition for this class is provided in Section 2).

2. The public's demand for innovation of social choice systems, at the design level, will likely increase sharply in years to come. There is need and opportunity for the science and technology sectors and the academic community to play a pivotal role in system development and testing.

3. The *relative optimality* of a social choice system is a measure of its relative capacity to help communities solve problems and organize activities such that collective wellbeing is elevated. Collective wellbeing is broadly defined to include social and environmental flourishing, both local and global. Problem solving is the proximal aspect of relative optimality, and elevated wellbeing is the distal aspect, or result, of successful problem solving.

4. To better understand the design requirements for successful problem-solving systems, it helps to look at examples in nature. Many types of natural systems, called *complex adaptive systems*, function as problem-solving systems.

5. Complex adaptive systems exhibit certain hallmarks, including a (dynamic, multidimensional) balance between stability and agility. For example, successful systems might balance a search for solutions in familiar versus unfamiliar territory.

6. Systems increase their complexity in order to mitigate (casually, *solve*) otherwise intractable problems. Generally speaking, a complex adaptive system characterized by a certain level of complexity can only solve problems that are more simple than a certain level of difficulty. To solve more difficult problems, a system must become more complex.

7. Much of human experience falls under the problem-solving umbrella. A high capacity for problem solving is closely related to wisdom. As bequeathed by evolution, joy is a natural result of expressing (personal and collective) wisdom, and frustration a natural result of failing to do so.

8. The super wicked problems that societies face are more difficult than current social choice systems can solve. In order to solve them, the complexity of social choice systems must increase. New designs that exhibit increased complexity and problem-solving capacity might hardly resemble existing systems.

9. The relative optimality of existing and experimental social choice systems can be assessed, in part, through computer simulations and data collection and analysis. Assessment will require that data be collected on indicators that are not now common in UN, public health, and government surveys. These include, for example, indicators related to wisdom, creativity, benevolence, frustration, joy, problem-solving, and system complexity.

10. Field trials of new social choice system designs can best occur at the local (e.g., community, city, or county) level. This approach can allow testing by relatively small groups, at relatively low cost and risk, in co-existence with existing systems, and without new legislative action. Due to public demand, systems that demonstrate clear benefits in local trials could spread virally to other local areas.

In a type of jagged spiral evolution, social choice systems have been transformed many times over in human history. Feudalism gave way to mercantilism, for example, which gave way to colonial imperialism, which gave way to modern socialism and capitalism. Slavery gave way to modern capitalism. Monarchies gave way to democracies. Capitalism grew more dominant than communism. In all these cases, the complexity of social choice systems increased, and thus the new systems were able to solve a richer class of problems than the ones they replaced. But by no means should we expect that social choice systems could stop evolving, as this would invite failure.

Failure, unfortunately, might be closer today than many imagine. Pamlin and Armstrong highlight the need for a coordinated approach to assess current and emerging global risks [6]:

> *The idea that we face a number of global risks threatening the very basis of our civilization at the beginning of the 21st century is well accepted in the scientific community, and is studied at a number of leading universities. But there is still no coordinated approach to address this group of risks and turn them into opportunities.*

Nor is there yet a coordinated approach to address the relative optimality of existing versus conceivable social choice systems, the former of which are implicated in the risks that Pamlin and Armstrong [6] identify, and the latter of which could be designed to demonstrably elevate collective wellbeing.

This approach implies a new multidisciplinary program I refer to as *wellbeing centrality*. In network science, *centrality* is a measure used to identify the most important nodes within a graph. The term *wellbeing centrality* alludes to the focal role that wellbeing would play in more optimal social choice systems. In short, wellbeing centrality spans the design, testing, promotion, and operation of social choice systems that place wellbeing measurement, evaluation, forecasting, and deliberation at the center of decision-making activities.

As noted in item #10 in the preceding list, the prudent approach to developing and field testing new systems is to do so at the local (e.g., community, city, county) level. Despite frequent use of the words *society* and *civilization* in this paper, I do not intend that a new system design would be tested in one or a few local areas and then, if beneficial, be abruptly adopted by a nation. Rather, I view local testing and implementation as a viable path for more or less continuous change. If a few systems show benefit in a few local areas, the best of these systems might spread quickly, even virally, to other local areas. As they do, bugs would be worked out, features added, and adjustments found to improve and increase problem-solving capacity. Eventually, the presence of a very large number of successful local implementations would begin to influence national governments in beneficial ways.

This path of change is likely to be fastest and safest. If funding can be secured and clear benefits demonstrated in field trials, within just a generation or two a substantial portion of the global public could be participating in local systems that are markedly better at solving problems and elevating wellbeing than are current ones. Moreover, these systems could be networked and cooperating in trade, in the benchmarking of results, in assisting the startup of new systems, and in other matters. Once a critical mass is reached, additional spread should be rapid.

A prototype wellbeing-centrality design for a local economic system is described in *Economic Direct Democracy* [7]. That system, the Local Economic Direct Democracy (LEDDA) framework, is in early-stage development. Section 9.2 of this paper discusses its properties and summarizes simulation results [8]. An interactive model of currency flows in an idealized system is available on the Internet [9].

2 Societies and civilization at risk

Many of the problems that societies face can be categorized as *wicked*, meaning in part that they are ongoing (not solvable once and for all time); they lack a definitive formulation; no ultimate test exists for success; solutions are not absolutely right, wrong, or optimal, but only relatively so; and there is an unlimited or undefinable set of potential solutions [10]. In effect, wicked implies intractable and difficult. Levin et al. [11] extend the concept to *super wicked,* potentially catastrophic problems, where, in addition, time is running out, there is no central authority, those seeking to solve the problem are also causing it, and current policies irrationally discount the future. The problems of most interest in this paper are super wicked.

The potential of super wicked problems to cause catastrophe is made explicit by Pamlin and Armstrong in a list of 12 current or emerging *existential* threats to civilization [6]. As they emphasize, it is difficult to accurately quantify the probability of a catastrophic impact (or impacts) on civilization. Data are lacking, uncertainties are high, and conventional risk approaches are ill-suited to the problem. Nevertheless, to initiate conversation, they have published probability estimates for reaching or exceeding ten different infinite-threshold events within the next 100 years, eight of which are human-caused or human-mediated.[1] Pamlin and Armstrong define the term *infinite threshold* to mean a threshold where "social and ecological systems become so unstable that an infinite impact could ensue." For convenience, I refer to such an occurrence as an *event*.

Pamlin and Armstrong's probability estimates are, rightfully, accompanied with strong caveats. Taking estimates at face value, however, and assuming independence and non-exclusivity, the probability of experiencing one or more of the eight human-caused or mediated events within 100 years is about 22%.[2] To put this value in perspective, it is almost identical to the US lifetime probability of dying from cancer and about 25 times higher than the probability of dying in a motor vehicle accident [12, 13].

Strong caveats apply to the probability of combined events as well. Nevertheless, my simple analysis makes the point that an uncomfortably high probability exists that civilization will face one or more infinite threshold events within several generations. In fact, if business as usual continues, the probabilities of some events are almost certainly higher than Pamlin and Armstrong estimate. Considering climate change alone, the probability of an event within 100 years could climb to more than 50% without mitigation efforts.[3] Focusing on environmental problems, Ceballos et al. [15] report that the sixth great mass extinction event may have already begun.

[1] The eight threats arise from climate change, nuclear war, global pandemic, ecological catastrophe, synthetic biology, nanotechnology, misuse of artificial intelligence (and robotics), and unknown causes.

[2] Pamlin and Armstrong estimate the probability for a climate change event as 5% within 200 years. For convenience, a value of 2.5% within 100 years is used here. The probability of an artificial intelligence event is given as 0–10% within 100 years. For convenience, a value of 5% is used here.

[3] Global temperature is expected to exceed a 4-degree Celsius rise over background by 2100 under a no-mitigation scenario [14]. The 95% confidence interval for RCP8.5, a high-end business-as-usual scenario, is about a 3.0- to 5.5-degree Celsius rise over baseline. The IPCC Fifth Assessment Synthesis Report rates the chance of exceeding 4 degrees for this scenario as more likely than unlikely. Here, I use 4 degrees as the threshold for a climate change event.

Based on a 2015 survey, the Western public appears to be keenly aware of the dangers. A majority (54%) of adults in the United States, Canada, Australia, and the United Kingdom rate the probability of an end to their normal way of life within the next 100 years as 50% or greater [16]. Almost a quarter (24%) rate the probability of human extinction as 50% or greater. The responses are somewhat uniform across countries, age groups, gender, and education levels.

3 A pivotal role for the academic community

The science and technology sectors and the academic community (hereafter referred to as the academic community, for brevity) have played important roles thus far in identifying and analyzing major social and environmental problems and in assessing proposed solutions. But social choice systems themselves are integral to the unfolding of events, to the study of problems, and to implementation of actions. Thus, the academic community also has a responsibility to study the relative optimality of existing and conceivable social choice systems.

Some academics have advocated for this type of program [17, 18, 7, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30]. Nevertheless, the academic effort remains nascent. At the present moment, lack of funding is perhaps the largest hindrance. Numerous authors, religious leaders, and civil society organizations, often in partnership with academia, have also advocated for deep structural change [31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42].

It is reasonable to expect that public pressure for design-level innovation of social choice systems will grow rapidly, likely in concert with pressure for operations-level policy and regulatory changes. In addition to the direct pain and fear caused by failure to mitigate super wicked problems, I highlight three drivers for design-level innovation.

First, recent advances in computer science, medicine, evolutionary biology, psychology, cognitive science, physics, sociology, ecology, and other scientific fields have ushered in a paradigm shift in the way that humans understand themselves and the natural world. Now more than ever, science is able to address the question *What do humans need to thrive?* No parent, for example, would wish mere survival for her child. No person would wish mere survival for anyone when thriving is a possibility. As the public increasingly understands the requirements for thriving, societies will be increasingly compelled to alter the designs of social choice systems to achieve those requirements.

Second, the rapid expansion of scientific knowledge and technology over the past century provides not only a narrative in support of radical innovation—and thus system innovation as well—but also the tools to develop, test, and compare alternative designs. Social choice systems are technologies, in the broadest sense, and the public now expects that technologies will rapidly improve. As this paper will explore, the possibility that small groups can locally test designs at relatively low cost and risk, in co-existence with existing systems and without new legislative action only adds to the inevitability of design-level innovation. Economically depressed or challenged communities may be among the first to seek out partnerships through which to test new social choice system designs.

Third, these same scientific advancements have given societies vast information—big data—that help us discover the extent to which problems exist and how to monitor progress. Knowledge of climate change, for example, is largely due to a sophisticated global data collection and analysis program. Without it, we would have only scattered anecdotal evidence of peculiar weather patterns.

As the public's demand for design-level innovation grows, the academic community will have greater opportunity to play a pivotal role in development and testing. If it fails to accept the challenge, others may step into the leadership vacuum and pursue less safe or less effective routes of change and experimentation. Indeed, history suggests that public frustration and anger are easily directed once these emotions reach critical thresholds. If social choice systems are to undergo major changes, then societies should hope for those changes to be informed and guided by the latest advances and most profound discoveries in medicine, psychology, public health, sociology, and biological and environmental sciences.

The remainder of the paper address two questions. First, what does *optimality* mean in relation to social choice systems? I use concepts from complex adaptive systems to help provide some answers. Second, how can research and development of more optimal designs best proceed?

4 What does *optimality* mean?

With the 2030 Agenda for Sustainable Development and its attendant Sustainable Development Goals (SDGs), the United Nations has helped focus the world's attention on not only the fight against extreme poverty and other hardships, but also the challenges of ensuring more equitable development and environmental sustainability for all humanity [43, 44]. The proposed SDG data collection and analysis effort is massive. One hundred indicators have been suggested, spanning 17 identified goals. All member nations have agreed to participate.

These efforts are in keeping with a general trend in public health [45, 46] to focus attention on collective wellbeing. One can think of collective wellbeing as the degree of collective thriving or flourishing, or the state of the common good. A high degree of wellbeing implies vibrancy, resilience, sustainability, diversity, creativity, and health. As used here, wellbeing encompasses such topics as public health, education, justice, security, economic stability, quality of life, biological diversity, and ecological health and sustainability.

In line with these trends, and according to the reasonable assumption that typical individuals in all cultures wish for their world to thrive, I base this paper on the premise that relative optimality of a social choice system is a measure of its relative capacity to help communities solve problems and organize activities such that collective wellbeing is elevated. Note that this definition of optimality consists of two parts: capacity to (identify and) solve problems, the primal part, and capacity to elevate wellbeing, the distal part, or the result of good problem solving.[4]

As for the distal part, approaches to measure and assess wellbeing levels have received considerable attention in recent years. As mentioned, the UN has identified 100 indicators. We can add to this many thousands of economic, social, public health, and environmental indicators that are regularly collected by various agencies of some governments. It is reasonable to assume that as a group, these indicators reflect, in some fashion, societal levels of wellbeing.

Quite likely, some modeling would be useful to tease out and make comprehensible the meaning contained within a large group of indicators. Simple techniques like dimension reduction exist for this, but more sophisticated modeling approaches could likely tease out even more information and be more useful.

The situation for the primal part, problem solving, is quite different because it has received relatively little attention. Consider, for example, that economic systems are not often viewed as problem-solving systems subject to innovation at the design level. More often, a researcher will take the design of an economic system as a given; the research topic might be one of policy, for example, or maximization of utility given design and policy. Thus, the questions of which indicators are appropriate for assessing design, and what design motifs are most useful, remain open. I focus the paper on these topics.

Fortunately, nature provides a wealth of examples of successful problem-solving systems, and these can be examined to better understand common characteristics. Once identified, these characteristics can be used to suggest appropriate indicators and design motifs for human social choice systems. To this end, in the next two sections I examine how problem-solving systems might be conceptualized. The focus is on abstraction, on the big, holistic picture. Future work can begin to apply big-picture insights to concrete tasks.

The first step in this abstraction is to view the natural world as comprised of complex adaptive systems that, one could say, do problem solving as a vocation.

5 Complex systems

Complex systems were not on the radar 50 years ago, but today we see them everywhere. The Internet, markets, social networks, cells, ecologies, climate, the brain, immune systems, and other aspects of nature, biology, and society are now all studied as complex systems. Many of the scientists who laid the foundations are alive and active today. Brian Castellani provides a helpful infographic that traces the field's development, sub-disciplines, and influences [47].

[4] I use the word *solve* in a casual sense. By definition, super wicked problems don't have absolute solutions. The quality of a given solution is measured by the degree to which it elevates wellbeing relative to other solutions.

Introductory texts provide background on complex systems [48, 49] and I highlight only a handful of features here that are particularly important for the paper's arguments. Think of a complex system as a large group of components, sometimes called *agents*, that interact in such a way as to produce complicated behavior. Agents might be people, animals, or businesses, for example. Non-biological examples also exist.

By definition, any two agents not connected directly are connected indirectly through a chain of intermediate agents. Thus, we can envision agents as nodes in a fully connected graph, where the edges between them represent influences. Through some path of edges, the conditions and/or behavior of an agent can affect any other one, to a strong or vanishingly weak degree. The Earth itself behaves as a complex system. Our planet houses a massive number of agents, some biological, some inert, and its agents interact in myriad ways.

We are particularly interested in a special class of systems called *complex adaptive systems* that can alter their behavior or structure in response to conditions. By casual definition, successful systems are those that demonstrate more or less beneficial responses. In general, responses can be beneficial or detrimental, and the outcomes of action difficult to predict. Typically, the agents of complex adaptive systems organize into communities, clusters, or nested hierarchies. Human organs are an example of such communities, as are corporations and the US Congress.

Complex adaptive systems commonly display emergent properties. Emergence is the process by which a whole becomes greater than the sum of its parts. More specifically, the new whole becomes irreducible to its parts. Emergence produces new *patterns* [50] that are categorically different from their components. The term *patterns* is used here to include almost any identifiable phenomena, including physical forms, ideas, emotions, behaviors, organisms, traits, and social structures.[5] An example of emergence is the rise of consciousness within mammalian brains; the whole brain exhibits properties that individual cells do not. Note that emergence and biological evolution (the passing down of traits, emergent otherwise, to new generations), are not necessarily smooth. They can be punctuated in time, for example, and can be set back by extinctions. Further, they are driven, in part, by apparent randomness [51].[6]

The meaning, or perhaps meanings, of *complexity* require explanation. The field of complexity science is new, as mentioned, and is still very much in a turbulent-growth phase. Numerous definitions of complexity have been put forward, but as yet a consensus regarding a single universal definition does not exist. I therefore sidestep a discussion of complexity measures and simply say that complexity, for our purposes, increases with the number of agents, the degree of their interactions, and the balance between their coherence (cooperation) and their flexibility (spontaneity).

I focus on what complex adaptive systems do. From an information theory perspective, they compute. Said another way, they try to solve problems.

[5] Another term for patterns is *information*, as in information theory.

[6] Deterministic systems driven by chaos can appear to exhibit signs of randomness. I do not address the issue of whether the universe is random or deterministic.

5.1 Problem solving

Terrestrial systems and subsystems try to solve an uncountable number of problems daily. How far should a particular bird fly to gather a meal? It is safe to say that the vast majority of such problems share the same two characteristics: some solutions are better than others, and finding the best or at least an adequate solution (satisficing) often requires a trade-off between attention to what is familiar—perhaps the bird should look in his neighborhood, where food was found before—and exploration of the unknown—perhaps even better or more food can be found in an unfamiliar area, far away. In mathematics, the first is called exploitation (of gathered information) and the second is called exploration. Thus, a good problem solver balances exploitation-exploration. Exploration, in particular, can exhibit qualities of randomness, as in wild guesses at a good solution.

An illustration might be helpful. Imagine standing on top of a small hill surrounded by tall mountains. Your task is to reach the point of highest elevation. While you can see peaks in the distance, a step in any direction would first reduce your height. To mimic the more common and difficult setting, now imagine that you are blind and do not know the direction where higher ground can be found, or if it exists at all. You only know the record of past elevations and can measure your current one upon taking a new step.

Call the operation of measuring elevation and of giving preferential value to high locations the *objective function*. Call the (potentially rugged) terrain the *fitness landscape*—higher elevations are more fit as per the objective function. Then the small hill is a local fitness maximum. It is better than any other nearby location. The tall peaks in the distance are potentially, but not necessarily, global maximums. It could be that upon reaching those peaks, even higher ones lie beyond.

If the rule for taking steps is *greedy*—return from any new step that is lower in elevation than the present one—you will remain stuck on the small hill forever. To reach the distant peaks you must either jump to a higher elevation or be willing to reduce your fitness as you take steps in search of higher ground. In general, the more complicated the fitness landscape, the more difficult it is to find a global solution (and the more likely it is to get stuck in a local fitness maximum).

The best approach is to balance exploitation-exploration in some fashion. For example, perhaps a small bit of exploration and a larger amount of exploitation might be appropriate in a certain circumstance. In another, the reverse might be true.

The term exploitation has negative connotations in some settings (not so in the mathematical use of the word). Another pair of terms less charged, and more suited for discussion of complex systems, might be stability-agility. If a complex adaptive system is too stable, it might be too rigid and thus not creative enough to solve new and bigger challenges. If a system is too agile, it might waste too much time looking in uncharted territories for answers and not have enough structure to sustain itself.

Robustness and resilience can be viewed from the stability-agility perspective. Robustness is the capacity of a system to continue functioning in the presence of stress without fundamental changes to its structure or dynamics (the familiar is preserved). Resilience, in contrast, is the capacity of a system to adapt to stress by changing its fundamental structure or dynamics, without loss of function.

5.2 Self-organized criticality

For many diverse complex adaptive systems, it appears that the right stability-agility balance for problem solving occurs when the system is operating near critical thresholds. Coined by Bak et al. in 1987 [52], *self-organized criticality* describes the phenomenon of a system self-organizing in such a way that it maintains operation near a phase change threshold (a critical state, in physics). A system exhibiting criticality is on the verge of transition from one state to the next; thus its future trajectory is particularly sensitive to small perturbations, or bumps.

The existence of critical states in physical systems is not controversial. The idea that natural systems can self-regulate structure and/or dynamics to maintain operations near critical states is more so. Many questions remain open, but in the roughly 30 years since Bak's proposal, a large volume of work has been published suggesting that some systems, including the human brain, display self-organized criticality or something very close to it [53, 54, 55].

Somewhat poetically, systems at criticality are said to operate "on the edge of chaos" where a balance is achieved between system stability, the continuance of existing patterns, and agility in exploring and adopting new, potentially beneficial patterns [56].[7] Viewed another way, a critical state occurs when the use of stored information is balanced with the use of new information arriving from agents. At one extreme, no new information is used and the system is rigid. At the other extreme, the flow of new information is an incoherent flood that swamps the dynamics of the system.

Because agents can produce both useful information and noise, operating near a critical state injects a sort of randomness, or unpredictability, into a system. Small bumps can lead to unpredictable cascading events that sometimes, if rarely, impact large parts of a system or even the system as a whole.[8] More than this, or perhaps because of it, information processing appears to be maximized when a system is near a critical state. In some experimental networks, for example, information storage and transfer are maximal near criticality. So too is the capacity for any single agent to impact the system [57].

The three take-home points are: (1) systems near criticality display some randomness; (2) small bumps can set off (scale-free) cascades of events; and (3) information processing is at a maximum. For all these reasons, complex systems appear to function

[7] Highly complex systems display a multitude of aspects, scales, and dynamics, with numerous tunable features. Rather than a balance point or line, a dynamic, multidimensional, multi-scale space or region might exist where balance is relatively optimal.

[8] The distribution of event cascades follows a certain pattern. For an idealized complex adaptive system operating near criticality, plotting the size of impact versus frequency of occurrence produces is a straight line on a log-log plot. This particular straight line is suggestive of *scale-free*, *power-law*, and/or *fractal* behavior. Small impacts occur frequently, large ones occur infrequently, and the pattern is the same or similar no matter what level of resolution is considered.

optimally when they operate near critical regions, and operation near such regions appears to be favored [58, 59]. Think of a system at criticality as one that is stable yet alert and flexible. Old patterns tend to continue, yet the system is poised for unexpected next moves. Said another way, criticality enhances a system's capacity to solve problems.

5.3 Manifest complexity

The main problem that complex adaptive systems try to solve is predicting future states—the outcomes of their actions and inactions relative to environmental challenges and conditions. Of course, predictive models (or anticipation apparatus) for some systems are very simple. A bacteria might need only move toward food and away from danger, for example. In highly complex organisms like humans, complex internal models are necessary to match complex needs and the challenges presented by complex environments.

Ashby's law of requisite variety holds that a positive correlation exists between the complexity level a system and the maximal complexity level of the challenges that it can successfully address [60, 61]. As challenges become more complex, systems tend to adapt by becoming more complex themselves. Several recent lab experiments demonstrate this phenomena [62, 63]. For example, if animats—simple adaptive sensing robots—are exposed to increasing environmental complexity, they evolve to increase their internal complexity [64]. As one might imagine, relatively more complex systems face more complex challenges and become more complex more quickly.

The virtuous cycle of challenge leading to greater complexity explains much of cosmic and terrestrial evolution. A remarkable thread in emergence and evolution is that form and behavior started simple, and, over time, in aggregate (or in maximal), became more complex. Atoms organized into molecules, for example, molecules into cells, and cells into animals and plants. Some have called this bumpy trajectory *manifest complexity* [65], others call it the *arrow of complexity* [66].

The arrow of complexity can be seen in human history. Early modern humans were small in number and had few tools to aid communication or to alter the environment. In short, they were not very complex. In the intervening 200,000 years, complexity and the difficulty of challenges increased in tandem. Human population, technology, use of energy, flow of information, and sophistication of social organization have all grown exponentially fast [67, 68, 69, 70, 71, 72, 73, 74, 75].

6 The human experience of problem solving

In human systems, problem solving via stability-agility dynamics can be experienced in rich, complicated, sometimes deeply meaningful ways. Depending on the situation, a wide range of nouns and verbs might be associated with the stability aspect, including affection, fondness, love, protection, nurture, support, preserve, refine, sustain, conserve, rear, study, tweak, improve, grow, and examine. Similarly, a wide range of nouns and verbs might be associated with the agility aspect, including imagination, innovation, invention, transformation, new, replace, create, expand, and explore. To capture some of these flavors, hereafter I also call the stability-agility (exploitation-exploration) space the benevolence-creativity space.

As just one example of how benevolence can play out in human experience, most mothers feel deep love for their children and are willing to protect them even at risk of their own lives. Biochemically, these behaviors are mediated in part by hormones in the mother's brain. For example, women who have low levels of oxytocin tend to have more trouble bonding with their children [76]. But the profound meaning of a mother's experience is lost by a purely biochemical explanation. While hormones might be a proximal mediator, the distal cause of the hormones is evolution (and emergence). The beautiful and extremely important experience of the mother is a form of intelligence, or memory, passed down through countless lives in countless species over billions of years. To act against it is to act against nature.

6.1 Internal models

The example of the mother suggests that biochemistry and structure, passed down through evolution, play a role in human problem solving. Of course, so do cognitive processes, which themselves can be affected by biochemistry. The mother thinks about how to best protect her child, for example, even if the drive to protect is mediated in part by hormones.

Cognitive processes are inexorably linked to learning, and learning can be thought of as testing and re-testing mental models of the world against experience, and refining, transforming, or discarding them as appropriate. Given Ashby's law, it is not surprising that a model is usually only useful if it is complex enough to capture essential elements of the situation at hand.[9] Good models are able to reconcile or predict, with some success, what did happen, what is happening, and what will happen next.

Of course, the human experience of learning is not usually phrased in terms of model making or model complexity. Nor is accurate prediction typically the conscious goal [78]. The human mind appears to do far more than solve problems, but model making is at the core. As Phillips et al. describe it:

> *Humans induce complex multi-layered world models to enhance adaptive success, but as a spin-off, we became able to build complex social and physical environments. When marinated in the unique statistical baths of such designer worlds, minds like ours spawn new local goals and projects. We build worlds that enable us to piggy-back the satisfaction of our basic needs upon the exploration of complex rewarding spaces—the spaces of*

[9] According to the good regulator theorem of Conant and Ashby, "every good regulator of a system must be a [good] model of that system" [77].

> *art, science, and culture. By designing, re-designing, and re-re-designing our own environments we continually move the goalposts for our own prediction-based learning. Our evolving cultural practices thus generate minds that go where no human minds have gone before.*[79]

Learning and problem solving, seen from this light, encompasses the full range of human experience [80]. Thus, the better a person or society is at problem solving, the more likely that person or society is to thrive, in the broad sense.

6.2 Wisdom

We say that an individual is *wise* if he is a good problem solver. More specifically, a wise person is good at solving diverse, difficult problems, especially those that involve the wellbeing of others. Wisdom is somewhat different from intelligence, which refers more to the capacity to learn about and solve specific problems. Intelligence lies more on the creative side, whereas wisdom is more balanced between benevolence and creativity. In recent years, a substantial volume of research has been published on the topic of wisdom, especially in the field of positive psychology. The general consensus is that wisdom is multifaceted, with most definitions involving the following components [81]:

1. Social decision making and pragmatic knowledge of life
2. Pro-social attitudes and behaviors, which include empathy, compassion, warmth, altruism, and a sense of fairness
3. Reflection and self-understanding, which relate to introspection, insight, intuition, and self-knowledge and awareness
4. Acknowledgment of and coping effectively with uncertainty
5. Emotional homeostasis, which relates to affect regulation and self-control.

Wisdom is perhaps one of the most complex of all human traits. It is a small step, then, to view wisdom as an outcome of operating in a beneficial region of the benevolence-creativity space, which is related to being sufficiently complex, which is related to making sufficiently complex internal models of the world.

From descriptions of the benevolence-creativity space, and consistent with the five listed components of wisdom, we can imagine that a wise person treats others with love, affection, and respect. She is creative, curious, and inquisitive, listens carefully to a problem, is self-honest, and reflects on her own rich experience. In this way, over time, she learns—constructs accurate internal models of the world—and so is able to offer appropriate advice. She is steady yet flexible. Receptive yet active. Consistent yet unpredictable. Moreover, her affection is not limited to family, community, or the human species, but is extensive.

It is reasonable to believe that what is true for the individual with regard to wisdom is also true for the society, which is a collection of individuals. The relative optimality of a social choice system has already been defined as a measure of its relative capacity to help communities solve problems and elevate collective wellbeing. Thus, we can add to this that relative optimality is also a measure of how well a system helps a community to develop and express wisdom. The develop aspect is not out of place. Social choice systems contain components, such as social norms, education, and flows of information, that are flexible and that can be tailored toward the task of developing wisdom.

To reiterate, the reason that societies might wish to develop and express wisdom through their social choice systems is that doing so would help them to solve challenging problems and thus improve wellbeing. This implies not only tangible benefits, such as better education, higher employment, a cleaner environment, and improved public health, but also intangible benefits, such as greater happiness and lower frustration.

It is probably no coincidence that it feels good to develop and express wisdom, and feels bad when prevented from doing so. According to Grinde [82], "Feelings are a feature introduced by evolution for the purpose of evaluating behavioral options. They tend to be either positive or negative due to their role in directing behavior either toward opportunities or away from danger." The experience of joy felt on discovery (curiosity and learning are components of wisdom) might have a genetic basis, for example [83]. Park et al. [84] speculate that character strengths such as wisdom are "grounded in biology through an evolutionary process that selected for these predispositions toward moral excellence as means of solving the important tasks necessary for survival of the species."

Thus, the joy and meaning that humans and societies derive from expressing wisdom, indeed, from growing in complexity, and the frustration they feel when these are thwarted, might reflect, like the mother's experience, intelligence passed down through countless species over eons of history.

7 Design motifs for optimized systems

Recall that our purpose for exploring natural complex adaptive systems is to identify common characteristics of successful problem-solving systems. The hope is that these characteristics might suggest: (1) appropriate indicators for monitoring social choice system optimality; and (2) design motifs (distinctive features or dominant ideas) that could increase problem-solving capacity. I address design motifs first. In particular, I try to contrast motifs found in existing social choice systems with those that might be found in future, more optimal ones.

What follows is meant to be suggestive, not prescriptive. Viable, not utopian.[10] But viable is not the same thing as commonplace. Indeed, some viable, potentially beneficial

[10]The design motifs discussed here are painted only in broad strokes. Extensive refinement and testing, including extensive testing via computer simulations, would be necessary before any system advances to field trials.

things do not yet exist. The heart of innovation is to discover them.

For example, income equality is mentioned as a beneficial design motif. But over the past half century, incomes in the United States and other developed nations have grown more unequal, not less. [85, 86]. Yet a reasonable person can conceive of economic system designs that achieve income equality. It is one of the elements of the prototype local economic system discussed in Section 9.2.

More generally, if stark differences seem to exist between current designs of social choice systems and designs that could markedly increase problem-solving capacity, that starkness might be an indication of how poorly current designs reflect actual human nature and needs. System designs are deemed relatively optimal to the degree that they reflect who we actually are. There is no need for us humans to be other than what we are, but there is need, even a yearning, to be what we actually are more fully. Frustration, joy, anxiety, and contentment are among the gauges by which we can measure success.

7.1 Eight initial motifs

Relative to those we know today, future social choice systems better at solving problems might:

1. Decentralize decision-making power
2. Expand engagement
3. Nurture critical thinking
4. Reward cooperation
5. Increase transparency and the flow of information
6. Employ broad motivations
7. Value self-honesty
8. Operate near criticality.

The first item, decentralizing decision-making power, increases the complexity of a social choice system, and thus its problem-solving capacity, by increasing the number of active agents and/or their influence. For example, a decentralized governance system might shift some or most of the power to draft regulations, laws, and policy to the public. There would be many ways to achieve this, including the use of direct collaborative democracy [7], as well as sortition, the election of officials by random selection from a pool of candidates. The proliferation of online tools for deliberative/collaborative democracy is a promising step in this direction [87, 88]. So too are efforts at participatory budgeting [89].

A decentralized economic system might view money as a bona fide voting tool. Here the decentralization of decision-making power implies achieving equality of income and wealth, or at least achieving distributions that are closer to uniform. The counterpart to one person, one vote in a system of political democracy would be one person, $50,000 votes (or whatever the target income is) in a system of economic democracy.

The second item, expanding engagement, increases complexity by increasing the number and intensity of interactions. Direct collaborative democracy again serves as an example. Of course, participants must feel that engagement is meaningful (which also implies it is efficient and effective) or else the full benefits would not be obtained. People must also have sufficient free time to think about solutions and to engage fully.

The example of direct collaborative democracy is not to imply that flat decision-making systems are more desirable than those that employ hierarchies and/or other forms of structure. Historically, increased social complexity has been accompanied, perhaps even made possible by, increased structure [73]. Structure in the form of networked communities is a hallmark of complex adaptive systems, one can assume, because it increases their capacity for problem solving. Obviously, the existence of hierarchies for hierarchies' sake in human social choice systems would not be useful. Nor would top-down hierarchical structures be optimal, as their complexity is limited [60].

As another example of engagement, a future economic system might produce meaningful jobs, such that workers are engaged on multiple levels. Today, polls suggest that only about 13% of employees worldwide are engaged in their work [90]. Meaningful jobs are discussed again under item No. 6, the broadening of motivations.

The third item, nurturing critical thinking, increases complexity and thus problem-solving capacity by increasing the independence of agents. If two or more agents act almost identically, the effect on system complexity is as if there were only one; complexity is not increased by adding duplicate or near-duplicate agents. Similarly, complexity would be hampered by social conformity that leads to premature consensus (groupthink). Critical thinking is necessary to critique and improve internal models of the world (Section 6.1). Indeed, the scientific method boils down to making earnest efforts to prove existing models false. Critical thinking is a skill that can be developed through education, encouraged by social norms, and nurtured in other ways.

The fourth item, rewarding cooperation, reflects the coherence aspect of complexity. Cooperation is a key tool in the problem-solving arsenal of nature. Evidence for cooperation can be found in just about any species examined, including those of bacteria, mold, birds, insects, and mammals [91, 92, 3, 93]. Increased cooperation within a large group implies increased sophistication and interdependence of relationships, an embrace of diversity, and increased flow of information, all signs of increased complexity.[11] Future economic systems might be based squarely on cooperative, rather than competitive relationships, and thus signs of cooperation could appear in many guises. Examples could include cooperative finance and the joint management of real property through commons mechanisms [94].

[11] Cooperative groups must confront the free-rider problem, where most individuals cooperate but a few choose to enjoy the benefits without cooperating themselves [3]. Nature has found several ways that this problem can be successfully addressed.

In contrast, capitalism can be viewed as a system that favors competition over cooperation [95]. Competition, especially when it is vicious, can promote self-centered behavior and bring out the worst (anti-social) behavior in people and companies [96].

The fifth item, increasing transparency and flow of information, provides fuel for creativity and allows internal models of the world to be tested. It also highlights problems that would otherwise go unnoticed. Future economic systems might rely more heavily on shared intellectual property via open source, creative commons, or related licenses. There is evidence that the current system of intellectual property protection reduces overall creativity [97, 98, 99].

Another aspect of information flow is the indicator set by which a system self-regulates its behavior. Capitalism, as practiced, employs a rather limited indicator set that leans heavily on gross domestic product (GDP), a measure of economic throughput. But GDP is a poor measure of collective wellbeing [19, 100]. Indeed, it can go up with pollution, income inequality, and other things that harm wellbeing. All else being equal, an economic system that self-regulates using a wider set of indicators (that contain more information) would be more complex than one that uses a simpler set.

The sixth item, employing broad motivations, captures the notion that humans are naturally motivated by a diverse set of needs. Manfred Max-Neef contends that human needs are, and always have been, few, interrelated, and co-existing. He identifies nine categories: subsistence, protection, affection, understanding, participation, leisure, creation, identity, and freedom [20].[12] Future economic systems might gain complexity by engaging these needs more directly, rather than through simpler surrogates. One result would be more meaningful jobs. Perhaps they would be more focused on helping others or the environment, allow for more leisure time, be more creative, provide greater self-autonomy, or better enhance skill development.

Capitalism, in particular, uses the surrogate of private wealth instead of direct fulfillment of real needs. If it can be secured, wealth might be used, for example, to obtain subsistence and protection, which are real needs. But by using wealth as a surrogate, capitalism motivates activity through strict self-interest; it is a system based on income inequality in which selfish decisions are rewarded, sometimes lavishly. Because selfish decisions are typically less wise than those made for the good of all concerned, capitalism can harm people and the environment, and thus be antagonistic to meeting real needs.[13]

Evidence that capitalism can cause harm is plentiful. As one example, a report by the Union of Concerned Scientists suggests that over past decades multiple energy companies have conducted disinformation programs to confuse the public about climate change [102, 2]. These efforts are reminiscent of the tobacco industry's fierce

[12]The nine categories of needs that Max-Neef identifies can be viewed as falling somewhere in the benevolence-creativity space. At an abstract level, subsistence, protection, leisure, affection, and identity can be viewed as types of benevolence, including self-love and love for others. Understanding, creation, freedom, and participation can be viewed as types of creativity, including creativity in movement and thought.

[13]There is no reason to suspect that, in general, complex systems perform best when each agent acts in its own strict self-interest. For example, travel time on a highway system can actually be increased when each driver attempts to move at as high a speed as possible [101].

campaign to confuse the public about smoking-cancer links [103, 104]. One can also question the antisocial practices of the banking, pharmaceutical, agriculture, and sugar industries [105, 106, 107, 108, 109, 110]. The point is not that a few executives or a few companies or industries are bad actors—it is that capitalism rewards selfishness. As such, it is ultimately self-destructive. To put this into perspective, no responsible mother would encourage her children to be selfish because doing so would lead to dysfunction, if not calamity.

The seventh item, valuing self-honesty, speaks to the acceptance of information. Complexity is not increased very much if information is available but disregarded. Self-honesty in the face of information spurs an individual to refine, transform, or discard internal models of the world as necessary. Self-honesty often occurs in tandem with honesty toward others, a type of information flow. When that flow is substantial, we call it transparency. Similar to critical thinking, self-honesty and honesty toward others are skills that can be nurtured through education, social norms, and in other ways.

The last item, operating near criticality, captures several ideas. The structures of future social choice systems could be designed to foster critical dynamics. And aspects of benevolence-creativity could be encouraged as needed, through education, increased leisure time, reduced competition, greater funding for arts and sciences, and in other ways. Recall that in experimental networks the potential for any single agent to impact a system is maximized when that system is operating near criticality [57]. Thus criticality is also related to the decentralization of power.

Other design motifs that might increase problem-solving capacity can be identified by considering humans in the macrocosm, done next.

7.2 Self-identification

Human self-identity is flexible [111]. A person might identify as a member of a family, community, social group, religion, or nation, for example. Of interest is the extent to which a person's core sense of self extends either beyond his or her physical body or to shared concepts. For convenience, this is referred to as *expanded self-identity*. Some people might identify very deeply with a religion, for example, as if they are a part of it and it of them.

While some flavors of expanded self-identity are surely unhealthy to an individual, others may be beneficial. In particular, it could be beneficial for an individual to honestly explore her sense of self and make adjustments according to understandings obtained. The process suggested is the same as building quality internal models of the world (Section 6.1), but here the focus is on self-identity.

Modern science has a lot to say about what humans are. In particular, fields related to complex systems science, evolutionary biology, ecology, medicine, physics, and cosmology have a lot to say. The picture offered is that while "human" is a useful concept that allows us to examine ourselves as if we were distinct from other species and things, in a real sense we are not distinct, especially if natural history is taken into account. Given that Earth (and beyond) functions as a complex system, that humans are a part of it, and that all parts are interwoven, it is reasonable to consider the view that humans are not on the Earth (or in the universe) so much as an expression of it, like waves are an expression of water.

To begin, the physical distinction between "human" and "other" lacks absolute boundaries. There are about as many bacterial cells in what we commonly think of as a human body as there are human cells, for example [112]. Their health and types and distributions greatly impact mental and physical health, appearance, disease resistance, and longevity [113, 114]. Some authors have labeled humans as super-organisms for this and related reasons [115].

Further, humans are embedded in relationships that in some sense define us. We would die without oxygenated air to breathe, which itself is generated largely from phytoplankton in the oceans [116]. Phytoplankton, in turn, depend on energy from the sun, as well as on stable carbon cycles in the atmosphere. Further, humans are the way we are in part because viruses have provided genetic material during the long course of evolution [117, 118]. The list of co-dependencies is long, laterally in space and backward in time.

The idea that humans are of the whole is not new, but the perspective is still uncommon in modern cultures. Its potential to inform problem solving, and the behavior and reorganization of society, can be easily overlooked. In short form, the logic is that humans are inseparable from the whole and have reason to identify with it. People naturally experience self-love. Thus, people naturally experience love for the whole. Indeed, there is much poetry, from ancient times onward, suggesting as much. At least some of the modern environmental movement, and of indigenous cultures, is probably motivated by such an expanded self-identity.

To the degree that individuals identify with the whole they naturally wish to care for and protect its many parts. This includes other humans, of course, as well as non-human species, ecosystems, and environments. By identifying with the whole, and by understanding the arrow of complexity, humans have the opportunity to assist, rather than impede, the natural trajectory of life on the planet. An example would be repairing damaged ecosystems to increase biodiversity (and thus complexity). A similar example would be switching agricultural acreage from monoculture to polyculture or even to permaculture, which has potential to be more diverse and thus more complex [119, 120].

One might expect that identifying with the whole would have survival value. The further we expand our self-identity, the more information we engage, the more sophisticated our relationships become, and the more complex we become. The more complex we become, the larger the class of problems that we are able to solve. It is no wonder, then, that we revere and call *wise* a person who sees from a larger perspective. Likewise, it is no wonder that we derive meaning and joy from experiencing ever-larger perspectives.[14]

[14]One could say that humans yearn to experience themselves as the whole. Recall that successful complex adaptive systems, especially those that are already sufficiently complex, tend to become more complex in a

Thus, relative to those we know today, future social choice systems better at solving problems might:

1. Encourage self-reflection
2. Promote systems thinking
3. Celebrate wisdom.

8 Indicators for optimized systems

Eleven design motifs were discussed in the previous section that might be found in future, more optimal social choice systems. They are gathered here, categorized into two groups (with obvious overlap):

1. Primary characteristics:
   (a) Decentralize decision-making power
   (b) Expand engagement
   (c) Reward cooperation
   (d) Increase transparency and the flow of information
   (e) Employ broad motivations
   (f) Operate near criticality
2. Characteristics of supportive education programs and social norms:
   (a) Nurture critical thinking
   (b) Value self-honestly
   (c) Encourage self-reflection
   (d) Promote systems thinking
   (e) Celebrate wisdom.

A discussion of possible indicators for each of these characteristics could fill several papers. Some indicators would be subjective, some objective. Some categorical, some real-valued. Data might come from surveys and polls, networked Internet-of-Thing devices, tax records, point-of-sale units, and many other sources. The work of selecting, validating, and applying indicators remains open, but some straightforward possibilities are briefly discussed. A bit more is said about indicators of criticality. The rest is left for future work.

virtuous cycle. Ultimately, all human challenges amount to the challenge of knowing the world—of building perfect internal models of the world. But the only perfect model is the world itself. To know the world perfectly is to be the world.

8.1 Common and uncommon indicators

Examples of straightforward indicators include income and wealth inequality measures, of which there are several. Also straightforward would be indicators of education programs. These might include the number of teachers, classes, or funding volumes.

Beyond these examples, and indicators of wellbeing already in use by census, public health, or other government agencies, indicators of optimality might be more atypical. As a case in point, an individual participating in a relatively optimal economic system should feel engaged. A necessary condition for feeling engaged is to feel that participation is meaningful. To be meaningful, participation must fulfill core needs, such as the ones that Max-Neef identifies.

Consider a person that wishes to help others. Perhaps he would like to teach children, a job that the community deems as important. It should be the case that the economic system provides adequate funding for him to excel as a teacher, to be the best teacher he can be. If it does not, and if he and other teachers are frustrated in their positions, then something is wrong.

If it should happen that there are already more teachers than the community needs, then the economic system should engage his energies in a somewhat different position that would also allow him to express his desire to help others, and so would be meaningful to him. If no meaningful work can be found, then something is wrong.

From this example, one can imagine economic system indicators that address such topics as motivation, engagement, fulfillment, and meaning.

A similar example could be constructed for a governance system. If an individual is involved, she should feel that her voice is heard, that the system is fair and transparent, and that all involved are treated with respect. Moreover, the procedure should produce widely supported solutions, not just hair-thin majority decisions. Although the details of systems will differ, a well-designed system is again engaging and participation meaningful. Thus, one can imagine governance system indicators that address topics such as fairness, transparency, justice, problem solving, honesty, and cooperation, as well as engagement and meaning.

Although still not typically collected by government agencies, much work has been done in recent years in developing survey instruments that can capture traits and internal states like frustration, joy, and wisdom [81, 121, 122]. Similar types of approaches could be used to develop instruments for some indicators of social choice system optimality. Guidance, such as provided by the Organization for Economic Co-operation and Development on subjective wellbeing, could be useful [123].

8.2 Criticality indicators

Remarkably, widely different complex systems, across diverse natural and social domains, tend to display a common set of structural similarities [124, 125, 126, 127, 128].

These include a high clustering coefficient (the formation of communities within a network), short path lengths (most nodes can be reached by a path that travels though only a small number of other nodes), and power-law or scale-free degree distributions (degree is the number of connections at a node).

It appears as well that structure and dynamics are closely related. For example, diversity in information processing dynamics for artificial networks appears to be maximized for those structures that are maximally complex [129]. In general, self-organized criticality is thought to maximize both structural and dynamical complexity [53, 58], and so problem-solving capacity.

Thus, in theory at least, the comparative degree or quality of self-organized criticality in social choice systems could be indexed by a range of structural and dynamic measures. Measures of complexity itself could also be applied, many of which have been developed in statistical mechanics, information theory, and other fields [130, 131]. Much work remains to be done to develop appropriate criticality indicators for social choice systems.

9 Research and development of social choice systems

9.1 Wellbeing Centrality

A large amount of computer simulation, system design, survey instrument validation, public polling, and other preparatory work could begin at universities today with adequate funding. But after sufficient preparatory work is completed, the bulk of the effort will necessarily involve field testing, with associated data collection and analysis. The prudent approach is to conduct experiments with willing partners at the local (e.g., community, city or county) level rather than national level.

The local level presents a near-ideal environment for field testing new social choice systems. The work could be done by relatively small research groups, at relatively low cost, and in co-existence with existing systems. In most democracies, and under certain restrictions, systems could be tested without any legislative action, not even local legislative action. This would be particularly true if testing occurs using membership clubs. Here, participants are volunteers that organize and manage a local civic club. A number of club-like community currency systems already exist in Western nations [132, 24, 133]. In the United Kingdom, some municipalities have organized a community currency system [134]. These systems are not, however, part of a coordinated, global scientific effort to examine relative optimality of social choice systems. That effort is nascent.

By testing social choice systems in local areas, risks to the larger society are minimized. Further, risks to the participating community can be mitigated in a variety of ways. In the ideal, researchers and communities would design trials to be safe-to-fail. Given that many local areas face difficult economic and other hardships, some populations might welcome the opportunity to participate in a trial. As part of the recruiting process, results from computer simulations and previous trials, if they exist, could help inform a community of potential outcomes, benefits, and risks.

Taken as a whole, the research program described here suggests a new multidisciplinary program that I term *wellbeing centrality*. As mentioned, it spans the design, testing, promotion, and operation of social choice systems that place wellbeing measurement, evaluation, forecasting, and deliberation at the center of decision-making activities. The term is rather unique (29 hits on Google, for example). I chose a unique term to better serve as a keyword for literature searches. Currently, there is not a commonly accepted keyword under which diverse academic, civil society, political, business, and artistic efforts related to system optimality or system design might be categorized.

As I envision it, the wellbeing centrality program and data collection and analysis effort for field trials would be coordinated over all locations where testing and system implementations occur. The goal is to assess and monitor relative optimality of systems, and this requires that standardized (harmonized) data be available for multiple systems. In the ideal, a central or networked data repository would exist to facilitate research, with access restrictions and other measures to protect privacy.

Other aspects of the data collection and analysis effort would be quite different than those of typical government census programs and the UN Sustainable Development Goals program, even if some of the same variables are used in surveys. First, the scale of data collection is different. Here the focus is on local areas, rather than on a nation as a whole. Second, collection is conducted by a local population and its research partners and affiliates, rather than by a national government. Third, in the ideal, a good portion of the data is longitudinal microdata. That is, data span a variety of variables collected over time from the same individual. Such data are relatively rare today, and would be priceless for scientific analysis.

Fourth, besides automated collection of data from local environmental, economic, or other sensors, the effort for collecting data from humans is ideally aimed at the question, *What is your story?* Here, *story* is meant to convey all the meaningful aspects of a person's or organization's situation with regard to a topic. For example, if one were to ask a person face-to-face "Are you currently employed?" the answer might well be conversational, rather than yes/no. Perhaps the person works in two different capacities, and the motivations for doing so involve several outside factors. In the future, it should be possible to implement communication technologies that would allow a participant to communicate the meaning of her story in an engaging and efficient way, yet result in data suitable for modeling and assessment, and so be of maximum benefit to the community. That is, a story told must also be heard.

Fifth and last, data is collected as close as practical to real-time. For some variables, this might mean daily. Near-real-time data collection and analysis would not only assist the scientific effort, but also provide near-instant feedback to the community, allowing it to adjust its system as needed to obtain desired outcomes.

9.2 LEDDA Framework

A prototype wellbeing-centrality project is the Local Economic Direct Democracy Association (LEDDA) framework, in early development. The framework is a local economic system designed to function in parallel with existing systems. The initial description is provided in the book *Economic Direct Democracy* [7]. The framework displays several of the design motifs identified in this paper as capable of improving problem-solving capacity. These include distributed decision-making power through income equality, a cooperative financial system, high transparency, and because income are secure, high, and equal, a broadening of motivation for economic behavior.

Conceptually, a LEDDA is a membership-based, community development association open to all resident individuals, business, nonprofits, and other organizations in an area. Because money functions as a democratic voting tool in this framework, a LEDDA acts to achieve a high and equal income for every member family. Over time, say, 10–30 years depending on circumstances and community desires, economic voting power becomes evenly distributed.

The framework consists of eight integrated components. One is a local monetary system, and another is a local financial system, the Crowd-Based Financial System (CBFS). I refer to these together as the Token Exchange System (TES). The *token* is a transparent local electronic currency that circulates alongside the national currency. Thus, the TES is a bi-currency system. The CBFS consists of loan, subsidy, donation, and nurture arms. The first three provide interest-free, zero-cost financing to local for-profit and nonprofit member organizations. The nurture arm provides income assistance to members who are unemployed or not in the workforce.

An agent-based, stock-flow consistent [135] model of an idealized TES situated in a US county has been published [8]. The model is illustrative, not predictive. The simulation spans roughly 30 years, starting from semi-realistic conditions based on US Census and other data. For example, tax rates resemble real tax rates, and starting income distributions resemble real distributions. I intend that the model serve as a steppingstone toward future, more sophisticated efforts. Stock-flow consistency rules out certain flaws in design logic at the modeled resolution and opens the door to higher resolution studies.

By the end of the simulation, mean and median family incomes of members have more than doubled to reach a final target of 110,000 tokens and dollars (T&D). For purposes of the simulation, one token equals one dollar in purchasing power. Ninety percent of families in the county have joined the LEDDA because it is in their best financial interest to do so. Full (99%) employment is achieved and poverty is eliminated.

The 110,000 T&D target represents post-CBFS income—pre-tax income after mandatory contributions to the CBFS are made. At simulation's end, the post-CBFS income of every member family is about equal to the 90th percentile of family income at the start of the simulation. The dollar portion (65% of final income) is about equal to the US national average family income.

For this community of 100,000 adults, roughly 2.5 billion T&D flow through the CBFS annually to fund local organizations. Roughly 3.5 billion T&D flow through the CBFS to provide nurture support to members who are unemployed or not in the workforce. As mentioned, this CBFS funding arm helps ensure that all member families attain the same income level.

Simulation results for a high-unemployment scenario have been presented in abstract form [136]. The scenario starts at 30 percent unemployment, such as might be caused by expanded use of robotics. Again, full employment is achieved within a 30-year simulation period, and incomes for all member families rise to the initial 90th percentile of starting incomes. By the end of this simulation, more than 50 percent of the workforce is employed by the nonprofit sector. A real LEDDA could choose any target partition of the workforce, among other targets.

An interactive model of an idealized TES at steady-state conditions is available on the Internet [9]. Whereas agent-based models can illustrate how a TES might progress year by year, starting from initial conditions, the simpler steady-state model illustrates currency flows in a mature system at equilibrium, perhaps 15 to 30 years after initiation. By altering parameters and choosing different targets and starting conditions, users can gain a better understanding of how desired currency flows might be achieved.

10 Conclusions

Given the long list of super wicked problems that societies face, it seems wise to ask if the decision-making systems used to solve problems and organize activity are sufficient for the task. If they are not, and no alternative designs are developed and tested, then societies could expect conditions to deteriorate. Human potential would not be realized, and the collapse of social and environmental systems, even within several generations, would not be an unrealistic outcome.

It appears that current social choice systems are sub-optimal relative to need. The rather straightforward remedy is to ask the following question: Of all conceivable social choice system designs, which ones might be most optimal, and by what criteria? The natural audience for such a question is the science and technology sectors and the academic community, which can bring the latest advancements in medicine, technology, psychology, public health, ecology, complex systems, and other fields to bear in developing and testing answers. Ideal partnerships would include all major sectors of society.

After a sufficient amount of preliminary work has been conducted, including computer simulations and public outreach, the natural theater to conduct field testing of new or greatly improved designs is willing local communities. This could allow parallel testing of different designs in multiple locations across the globe, by relatively small research groups, at relatively low cost and risk, in co-existence with existing systems, and without new legislative action. Successful systems that demonstrate benefits might spread laterally to new local areas.

The LEDDA framework, a prototype wellbeing-centrality local economic system, is in early development. This system of economic democracy displays several of the design motifs identified in this paper as capable of improving problem-solving capacity. These include distributed decision-making power through income equality, a cooperative financial system, high transparency, and because incomes are secure, high, and equal, a broadening of motivation for economic behavior.

The LEDDA framework is just one example of the many possibilities for improved social choice system design. The task of innovation, and the intended purpose of the wellbeing-centrality program, is to discover those designs that best reflect actual human nature and needs, including the need to develop and express wisdom. Frustration, joy, anxiety, and contentment are among the gauges by which success can be measured.

11 References

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