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Designing Interactions to Counter Threats to Human Survival

Abstract This article proposes a new framework for interaction design that contends explicitly with the challenges of implementing sustainable development in the real world. It first examines the interactions between and among the *Four Systems* – nature, human, cyber, and artificial – which impact every single aspect of human existence. Human activity in pursuit of perpetual economic growth has become a threat to human survival. Redressing the balance among the Four Systems will require a radical shift in human ways of living, both individual and collective. However, there are many, mostly human-related factors preventing people from taking effective action at either level. These factors can be categorized as visibility, motivation, collaboration, and adherence issues. To better face these challenges, this article argues that *Sustainable Social Interaction Design* – a new design agenda – should be encouraged. It involves designing and managing a sustainable human world using the ideas, methods, and tools of interaction design to stimulate and maintain positive interactions within the Four Systems. The cyber system, which involves interactive systems that function at the societal level, offers novel possibilities to facilitate such an agenda. This article further argues that Interactive Hybrid Communities, which combine the virtual and the real worlds together, can contribute significantly to incubating sustainable interactions, as they can intensify communication, include multiple levels of actors, consolidate connections, reinforce feedback, and facilitate consensus.

Keywords
The Four Systems
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The Four Systems and Their Interactions

Throughout history, the great challenge of human beings has been to separate themselves from nature to create and develop civilizations.[1] During the course of transforming the natural world into a more habitable environment, human beings created the world of the artificial. Modern humans tend to interact with the natural world through the world of the artificial – tangible or intangible – which has made it the carrier and manifestation of human civilization. The development of human society led to the intimate interaction of human, artificial, and natural systems. Interactions among these three systems defined much of human existence, including the economic, social, and cultural aspects of human life.

Since the 1940s, the cyber system has gradually come into being. The dramatic development of information and communication technologies – including mobile networks, big data, cloud computing, deep learning, and artificial intelligence (AI) – has allowed a highly interconnected cyber world to gradually emerge out of the artificial world. This cyber system has begun to interact with human beings, artifacts, and nature almost as an autonomous counterpart to the other three major systems. The growth of the cyber system has greatly enriched the means and meaning of interactions on our planet. These interactions between and among what this article calls the *Four Systems* – nature, human, cyber, and artificial – impact every single aspect of human activity, life, production, and existence. Figure 1 shows the evolution of the Four Systems.

1 Humanity was originally a young and insignificant species in the natural system. In his work *Dragons of Eden*, Carl Sagan explains that if the history of the entire universe had lasted one day, human beings would have been born the minute before midnight, and human civilization would have emerged in the final second of that day. Carl Sagan, *Dragons of Eden: Speculations on the Evolution of Human Intelligence* (New York: Random House, 2012), 11–19. For a graphic visualization of the cosmic calendar, visit http://www.cosmiccalendar.net/.

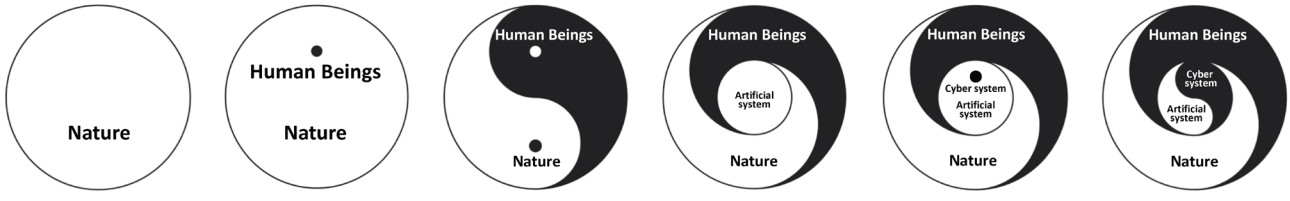

Figure 1 The evolution of the nature, human, cyber, and artificial systems. Copyright © 2018 Yongqi Lou.

I make no claim that these systems are objective realities; instead, they are subjective cognitive frameworks that allow us to understand and interact with the dimension of the world they describe. The very concept of "system" is a structural reference. All four of these systems matter to human beings. Each requires distinct bodies of knowledge to be understood – and so do the interactions amongst them.

Different disciplines tend to focus on distinct subject matters within one of the Four Systems. The subject matter of the natural sciences covers all of physical existence – including humans and their physical creations – with respect to the laws of nature. The social sciences chiefly study the interactions within the human system (for example, psychology and sociology) and those between humans and the artificial (economics is concerned with the production, distribution, and consumption of goods and services, for example). As the artificial world prospered, more disciplines were established and dedicated to studying aspects of the artificial system – engineering, architecture, and urban planning, to name a few. Even newer disciplinary branches have developed that look into aspects of the cyber system, such as the computer sciences.

Viewing the world as four interacting systems (Figure 2) is essentially a human-centered perspective. Imagined from the standpoint of nature, we see that human beings are but one species among hundreds of millions that live on Earth. Plant and animal species also create tangible and intangible products and consume their share of our environment's resources. To nature, grand human achievements are no different from an anthill, or the vast, invisible web beneath the soil created by millions of mycorrhizal fungi and the roots of trees and plants. We, and our artifacts, are part of nature.

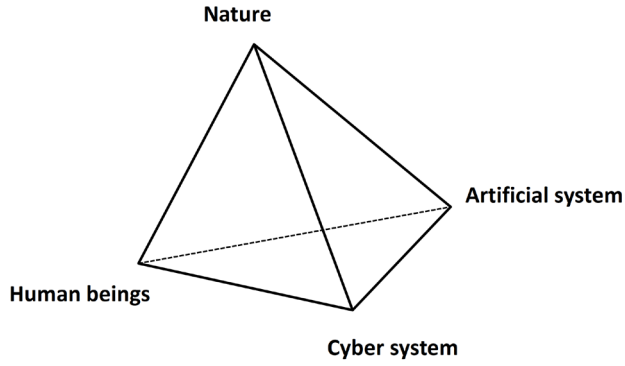

Figure 2 The interactions of the Four (nature, human, cyber, and artificial) Systems. Copyright © 2018 Yongqi Lou.

Only through human eyes do human beings, human-made artifacts, and the cyber world enabled by artificial intelligence appear to rise above the continuum of nature – the universe. Distinct from and yet connected to nature, these systems have become major agencies deeply involved in the interaction between humans and nature – and one that is fundamental to the sustainability of the human species on the planet earth.

The human-centeredness of this perspective inevitably directs our attention beyond artifacts to include interactions between the human, artificial, cyber, and natural systems enabled by or centered on those artifacts. These interactions are addressed by various design practices.

1. The interactions between the human system and the artificial system form the bedrock of many traditional design practices, including visual communication design, product design, and environmental design. Later on, service design and human-machine interface design emerged. Within these design areas, artifacts serve as *intermediaries* that facilitate human-thing and inter-human relationships.
2. The interactions between the artificial system and the cyber system are the focus of smart system design, for instance, the Internet of things (IoT) system. At the core of this discipline are cyber-physical systems (CPS) studies, which focus on the communication, integration, and interaction of physical and software components connected to and controlled by a computer network system.[2]
3. Human-in-the-loop models integrate human beings into the cyber-physical system. Taking interactions between the human, artificial, and cyber systems into account not only adds one more player to the cyber-physical system, but also significantly increases the complexity of the system by fueling the systemic operation with a new driving force.[3] Technically speaking, design in this area concerns effective human-machine collaboration.[4] In addition, the interaction between human world and cyber world (the world of artificial intelligence) raises new ethical concerns which may impact the entire human community. Such ethics are integral in laying the foundation for designing for complex sociotechnical systems.
4. Most existing interaction design practices and studies focus on interactions between the human, artificial, and cyber systems, but rarely consider that nature or the planet Earth is a system with limited resources on which human survival depends. Some (such as the Club of Rome) have claimed that resource limits will be the central constraint for the development of humankind.[5]

Re-situating various human interactions with our surroundings within nature – as a system, the environment, and a set of conditions – will have a profound impact on interaction design at all levels and bring to light new design principles.

2 For example, see Edward A. Lee, "Cyber Physical Systems: Design Challenges," in *11th IEEE Symposium on Object Oriented Real-Time Distributed Computing (ISORC)* (Los Angeles: IEEE, 2008), 363–69, available at http://doi.ieeecomputersociety.org/10.1109/ISORC.2008.25.

3 Gunar Schirner, Deniz Erdogmus, Kaushik Chowdhury, and Taskin Padir, "The Future of Human-in-the-Loop Cyber-Physical Systems," *Computer* 46, no. 1 (2013): 36–45, DOI: https://doi.org/10.1109/MC.2013.31.

4 Kyle J. Behymer and John M. Flach, "From Autonomous Systems to Sociotechnical Systems: Designing Effective Collaborations," *She Ji: The Journal of Design, Economics, and Innovation* 2, no. 2 (2016): 105–14, DOI: https://doi.org/10.1016/j.sheji.2016.09.001; John M. Flach and Kyle J. Behymer, "From Designing to Enabling Effective Collaborations," *She Ji: The Journal of Design, Economics, and Innovation* 2, no. 2 (2016): 119–24, DOI: https://doi.org/10.1016/j.sheji.2016.12.004.

5 Ernst Ulrich von Weizsäcker and Anders Wijkman, *Come On! Capitalism, Short-Termism, Population and the Destruction of the Planet—A Report to the Club of Rome* (New York: Springer Nature, 2017), DOI: https://doi.org/10.1007/978-1-4939-7419-1.

6 John Thackara, *How to Thrive in the Next Economy: Designing Tomorrow's World Today* (London: Thames and Hudson, 2015), 10.

7 Ibid., 17. Also see Tom Murphy, "Can Economic Growth Last?," *Do the Math*, July 14, 2011, accessed October 20, 2018, https://dothemath.ucsd.edu/2011/07/can-economic-growth-last/.

The Human World is Facing an Existential Crisis

Human activities have made a significant impact on the natural world. Over the past three hundred years, humans seem to have conquered nature and rule the world in which they live. To a great extent, progressive efforts to transform natural resources into the material basis of productivity and human development have gone through a continuous process of intensification. In a (very simple) way, the economy represents our production, distribution, and consumption activities, which depend on resources and energy extracted from nature. Figure 3 shows the changes in the Dow Jones Industrial Average (DJIA) from 1918 to 2018. Despite fluctuations in the growth curve during economic crises, global economic development has exhibited continuous growth. Indeed, we seem to take for granted that the economy will always be in a state of perpetual growth. However, "growth of anything tangible, or energy consuming, cannot continue indefinitely in a finite university."[6] "Exponential economic growth on a physical planet contravenes basic laws of physics and mathematics."[7] There is a crucial ceiling that limits all possibility for expansion[8] – limits on resources and environmental capacity. In the past, optimists believed that ceiling was far in the distance and our potential for growth nearly unlimited. Today, thanks to scientists' persistent research and warnings, we have begun to grasp the limits to growth with increasing clarity.

In a 2009 edition of the journal *Nature*, Johan Rockström and his colleagues[9] from the Stockholm Resilience Centre set forth a framework for "nine planetary boundaries": a set of environmental control variables whose fluctuations can and will have an impact on our species' survival. Each boundary delimits a safe operating space "within which human beings can continue to develop and thrive for generations to come."[10] According to their research, there are tolerable limits to 1) stratospheric ozone depletion, 2) loss of biosphere integrity (biodiversity loss and extinctions), 3) chemical pollution and the release of novel entities, 4) climate change, 5) ocean acidification, 6) freshwater consumption and the global hydrological cycle, 7) land-system change, 8) nitrogen and phosphorus flows to the biosphere and oceans, and 9) atmospheric aerosol loading.[11] In 2015, that same research group published an updated article[12] in the journal *Science* stating that four boundaries had been crossed as a result of human activity: climate change, loss of biosphere integrity, land-system change, and altered biogeochemical cycles (phosphorus and nitrogen). Of these four, two involve what the scientists label core

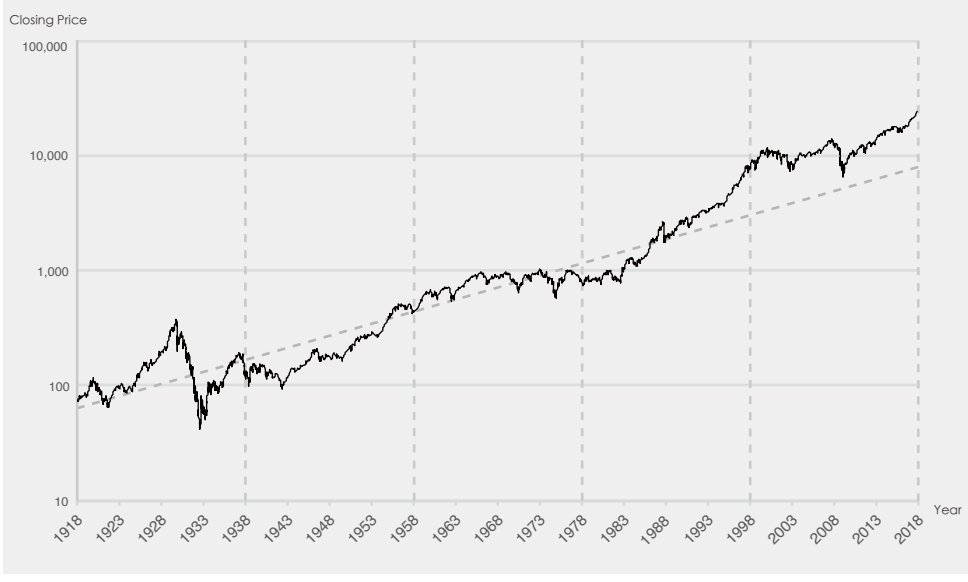

Figure 3 Changes in the Dow Jones Industrial Average from 1918 to 2018 (price-weighted). Data source: Wind www.wind.com.cn/. Diagram by Chen Li. Copyright © 2018 Yongqi Lou.

8 In its recently published report, the Club of Rome discussed in detail the contradictions between an exponentially growing set of claims (technology, economy, etc.) and the finite pool of natural capital. von Weizsäcker and Wijkman, *Come On!*, 44–55.

9 Johan Rockström et al., "A Safe Operating Space for Humanity," *Nature* 461, no. 7263 (2009): 472–75, DOI: https://doi.org/10.1038/461472a.

10 Stockholm Resilience Centre, "Planetary Boundaries Research," *Stockholmresilience.org*, accessed October 22, 2018, https://www.stockholmresilience.org/research/planetary-boundaries.html.

11 Stockholm Resilience Centre, "The Nine Planetary Boundaries," *Stockholmresilience.org*, accessed October 22, 2018, https://www.stockholmresilience.org/research/planetary-boundaries/planetary-boundaries/about-the-research/the-nine-planetary-boundaries.html.

12 Will Steffen et al., "Planetary Boundaries: Guiding Human Development on a Changing Planet," *Science* 347, no. 6223 (2015): 1259855, DOI: https://doi.org/10.1126/science.1259855.

boundaries: climate change and biosphere integrity. They suggest that significant changes to such a core boundary can destabilize the planet directly. They conclude that these problems will eventually limit the development of the human species.

The relationship between humanity and nature has become fraught with crisis and challenge.[13] Consensus on this issue has been solidifying among scientists for decades; for example, the *1992 World Scientists' Warning to Humanity* begins with "Human beings and the natural world are on a collision course."[14] The current crisis means that the planet will become unsuitable for human habitation.[15] The issue is not the life or death of the planet itself. It is the life or death of the human species. The earth has existed for 4.6 billion years. While many species have disappeared over time, the earth continues to exist. Hence, when we talk about sustainability, our challenge is not to address an ethics of value, but rather an ethics of survival. For humans, it is an existential crisis. The goal of sustainable development is to ensure that the human species has the capacity for survival. Achieving this aim in the long run means being able to live on as a species, and at the same time continue the sustainable production of meaning making.

Every element of physical existence on Earth is a component interacting with every other element within the natural system. All interactions in the natural system follow natural laws. Studying such interactions and predicting their consequences is the domain of the natural sciences. If we look at that crisis through the lens of interactions among the Four Systems, we find the core issue: the balance among them is (severely) disturbed. Human activity in pursuit of economic development and growth seems to threaten human survival, and has perhaps pushed the human world beyond the safety zone. Scientists may point out planetary level effects, but the (human) causes remain under the surface – every single problem relates to our ways of living, producing, and satisfying our needs for health, food, housing, sanitation, education, and maybe most important of all, a meaningful existence. Every dimension of human well-being is now under the microscope.

An ancient Chinese proverb says, "Let him who tied the bell on the tiger take it off." Among the Four Systems, human beings comprise the only system capable of acting with subjective autonomy (so far). If we want to contribute to rebalancing interactions among the Four Systems, human beings need to act differently. This transition involves redefining the criteria of what constitutes a "good life" and our well-being. New interactions must employ restorative models for growth and development, including reducing the pace of material consumption, reducing harmful emissions, seeking alternative energy resources, improving environmental purification capacity, and making the linear economic model circular. Most importantly, redressing the balance will require a radical shift in human ways of living.

Collective Behavior Change, and the Barriers Preventing It

Imbalance among the Four Systems poses a threat to our survival. To reestablish equilibrium, we must truly understand the catastrophic consequences brought on by unsustainable patterns in human activity and then change the way we interact with each other and, as the human system, how we interact with the other systems.

Long-held beliefs in modern consumerist societies are aptly conveyed by such axioms as "fast is better than slow," "expensive is better than cheap," "big is better than small," and "convenience now is better than gratification later." All these represent criteria, values, and principles that relate more broadly to the notion of *quality*, which must be redefined for the current context.

In terms of modern, democratic nation-states, this transformation is about enabling people to live, work, and otherwise act in accordance with values that enhance the sustainable development of humankind, rather than those established

13 For example, see Rachel Carson, *Silent Spring*, 40th Anniversary ed. (Boston: Houghton Mifflin, 2002); Union of Concerned Scientists, "World Scientists' Warning to Humanity (1992)," available at https://www.ucsusa.org/about/1992-world-scientists.html#.W4Jsw5MzYnU; William J. Ripple et al., "World Scientists' Warning to Humanity: A Second Notice," *BioScience* 67, no. 12 (2017): 1026–28, DOI: https://doi.org/10.1093/biosci/bix125.

14 Union of Concerned Scientists, "World Scientists' Warning (1992)."

15 For example, see David Wallace-Wells, "The Uninhabitable Earth: Famine, Economic Collapse, a Sun that Cooks Us: What Climate Change Could Wreak—Sooner than You Think," *New York Magazine*, July 9, 2017, accessed October 22, 2018, http://nymag.com/intelligencer/2017/07/climate-change-earth-too-hot-for-humans.html?gtm=top&gtm=top; Adam Frank, "Earth Will Survive. We May Not," *New York Times*, June 12, 2018, https://www.nytimes.com/2018/06/12/opinion/earth-will-survive-we-may-not.html.

16 There is some (heavily cited) research by one author stating that it is the conduct and decisions made by large organizations and policymakers that is responsible for ongoing climate changes, and that seeking to alter individual behaviors rather than those of large structures will not substantively contribute to our collective ability to mitigate climate change. See Elizabeth Shove, "Beyond the ABC: Climate Change Policy and Theories of Social Change," *Environment and Planning A* 42, no. 6 (2010): 1273–85, DOI: https://doi.org/10.1068/a42282. Shove's work was itself subject to debate from her colleagues. See Lorraine Whitmarsh, Saffron O'Neill, and Irene Lorenzoni, "Climate Change or Social Change? Debate within, amongst, and beyond Disciplines," *Environment and Planning A* 43, no. 2 (2011): 258–61, DOI: https://doi.org/10.1068/a43359; for Shove's response, see Elizabeth Shove, "On the Difference between Chalk and Cheese—A Response to Whitmarsh et al's

by contemporary economic standards. This strategy requires collective behavioral changes by human beings acting consciously as one of the Four Systems. These changes also depend on reshaping the interactions between the Four Systems toward a new equilibrium – a sustainable world for humanity.

Let us consider the human system first. Our decision making is often based on purely human goals related to political, economic, and social conditions. In the personal decision-making process, emotions, values, and instrumental rationalities all influence the choices we make. Different with individual decision, collective behavioral changes will involve large-scale systemic and societal actions.

We usually use two approaches to bring about change. One is to work from the top-down via institutional and organizational forces such as national and local government and business enterprise; the other is to drive change from the bottom up, via reflective regulation.[16] Humans are not living beings with needs to be satisfied wholesale. We must learn to use our subjective initiative to guide behavior toward appropriate, commonly-shared goals. This capacity involves the critical, ethical and moral component of the personality, what Freud proposed as the superego.[17]

Implementing large-scale changes depends on the effectiveness of any measures taken – especially their collective uptake. This means action at the systems level, including redesigning the system itself; and, at the same time, spurring on individual action, which means changing everyday behaviors. But there are many, mostly human-related factors preventing people from taking effective action at either level.

The first of these is the *failure to see*. We are in trouble. This message is not new at all, but most people simply ignore it. This is a visibility issue. For instance, while it is generally accepted that world scientists largely reached consensus on climate change a decade ago,[18] the global warming debate still rages. People are apparently unable to perceive the depth of the environmental crisis. Why?

- It is difficult to see the whole system – we have blinkered perceptual frameworks. While we humans have an amazing capacity to process information, our cognitive climate change databases are woefully incomplete. "Our whole society has been rendered cognitively blind by a metabolic rift between man and the Earth."[19]
- Out of sight means out of mind. Given the long-term inequity in global economic development, most people living in the North are insulated from the negative impact of their activities, because they are happening somewhere else.[20]
- The signals of the crisis are too weak, or its unfolding too slow, for many outside the scientific community to perceive. Limited by our narrow sensory capacity, figures, percentages, and media coverage are too abstract for us to grasp their importance.
- We have no emotionally convincing way to communicate the dimensions of the crisis between the human world and the natural world.

The second factor is our *failure to take action*. This is a motivation issue. Even though a growing number of people have begun to acknowledge the impact of human activities on the environment, there is still a massive gap between recognizing that impact and taking concrete steps to mitigate the damage we continue to cause. This is possibly due to our not wanting to sacrifice our quality of life, or a feeling of being overwhelmed, or because we lack the channels and platforms needed to effect the radical changes our species and planet so desperately needs.

The third factor is our *failure to collaborate*. Beyond individual responses, producing effective changes at the scale needed will require a coordinated, inclusive

Comments on 'Beyond the ABC: Climate Change Policy and Theories of Social Change,'" *Environment and Planning A* 43, no. 2 (2011): 262–64, DOI: https://doi.org/10.1068/a43484. Here is a measured response to the debate more generally that distinguishes between individual behaviors and "emissions-related behaviors," see Charlie Wilson and Tim Chatterton. "Multiple Models to Inform Climate Change Policy: A Pragmatic Response to the 'beyond the ABC' Debate," *Environment and Planning A* 43, no. 12 (2011): 2781–87, DOI: https://doi.org/10.1068/a44404. This debate notwithstanding, the UN IPCC report published October 8, 2018 calls for changes on an unprecedented level if we are to limit environmental change catastrophe, leading some to claim that governments have the "moral obligation to act." See IPCC, "Summary for Policymakers of IPCC Special Report on Global Warming of 1.5°C Approved by Governments," news release 2018/24/PR, October 8, 2018, https://www.ipcc.ch/news_and_events/pr_181008_P48_spm.shtml; and Jonathan Watts and Matthew Taylor, "World Leaders 'Have Moral Obligation to Act' After UN Climate Report," *The Guardian*, October 8, 2018, https://www.theguardian.com/environment/2018/oct/08/world-leaders-have-moral-obligation-to-act-after-un-climate-report.

17 Roy Schafer, "The Loving and Beloved Superego in Freud's Structural Theory," *The Psychoanalytic Study of the Child* 15, no. 1 (1960): 163–88, DOI: https://doi.org/10.1080/00797308.1960.11822573.

18 Naomi Oreskes, "The Scientific Consensus on Climate Change," *Science* 306, no. 5702 (2004): 1686, DOI: https://doi.org/10.1126/science.1103618.

19 Thackara, *How to Thrive in the Next Economy*, 154–55.

20 Jared Diamond, *Collapse: How Societies Choose to Fail or Succeed* (London: Penguin, 2011).

response from and for all levels of society,[21] from the top down and the bottom up, *together*. The lack of mechanisms to promote and implement changes impacting sizable segments of society limits our capacity to resolve the crisis.

The fourth factor is our *failure to persevere*. There is much evidence that we are demonstrating positive change throughout the world. Yet, these changes are often abandoned after some time. Whether at the individual or collective scale, sustainable actions are easy to start, but very difficult to continue. For bottom-up projects, the challenges are even more serious.

These factors can be categorized as ***visibility***, ***motivation***, ***collaboration***, and ***adherence*** issues. All demand radical changes in human interactions, both individual and collective. But, the human system cannot change on its own. The visible, motivated, collaborative, and continuous human interactions that will lead to a more sustainable future on the planet Earth are situated in a wider environment – the interconnected, interdependent, interactive dynamic created by all four systems.

In the following sections, I will elaborate on how design can contribute to addressing these challenges by creating new interactions within societies (the human system) and between the human and the artificial, cyber, and natural systems. In particular, I highlight the role that the interaction between the human and cyber systems can play in this transition.

We are, by nature, capable of transforming our world. However, even if radically changing our societal behavior in ways that reflect an ethos of sustainability is to our collective benefit, we still have difficulty working collaboratively and consistently towards the necessary transitions. There is a massive disconnect between our being cognizant of the facts and our being (collectively) willing – and able – to implement change. As Karl E. Weick noted, "There is agreement that they are big problems. And that's the problem."[22]

What Design Can Do, and Be

Whenever we have the intention to improve something, we use design to make it so. Herbert Simon said it best: "Everyone designs who devises courses of action aimed at changing existing situations into preferred ones."[23] All of humanity is facing the very real possibility that our home will become uninhabitable. It is high time we engage with design and design thinking to deal with this existential challenge. So, what can design do, in terms of changing our collective behaviors?

Design has no subject matter of its own; its scope is potentially universal.[24] A plethora of theoretical discussions explain the focal expansion of design from tangible things to interactions or relationships between various actors. Among them, human-centered design approaches[25] offer a most influential perspective. For example, Don Norman introduced User-Centered Design (modified as Human-Centered design later on) in *The Psychology of Everyday Things*, suggesting that designing enjoyable products requires putting "human needs, capabilities, and behavior first."[26] Richard Buchanan[27] enriches this idea by linking the view of product elements (considering form, materials, function, and manner) with the view of the form of product experience (including the useful, usable, and desirable dimensions). Therefore, design mediates the intent of the manufacturer and the expectations of the users within a given natural, social, and cultural environment. Design can be used to alter the interaction context – and the ways humans interact with each of the Four Systems.

Every transition is a decision making process that human beings can alter by design, especially by design that aims to influence willpower and emotions. A human-centered approach allows designers to address situated issues of visibility, motivation, collaboration, and adherence. For example, communication design

21 Adrian Smith, Jan-Peter Voß, and John Grin, "Innovation Studies and Sustainability Transitions: The Allure of the Multi-Level Perspective and Its Challenges," *Research Policy* 39, no. 4 (2010): 435–48, DOI: https://doi.org/10.1016/j.respol.2010.01.023; United Nations Department of Economic and Social Affairs, *World Economic and Social Survey 2013: Sustainable Development Challenges* (New York: United Nations, 2013), vi, accessed October 17, 2018, http://www.un.org/en/development/desa/publications/world-economic-and-social-survey-2013-sustainable-development-challenges.html.

22 Karl E. Weick, "Small Wins: Redefining the Scale of Social Problems," *American Psychologist* 39, no. 1 (1984): 40–49, DOI: https://doi.org/10.1037/0003-066X.39.1.40.

23 Herbert A. Simon, *The Sciences of the Artificial*, 3rd ed. (Cambridge, MA: MIT Press), 111.

24 Richard Buchanan, "Wicked Problems in Design Thinking," *Design Issues* 8, no. 2 (1992): 16, DOI: https://doi.org/10.2307/1511637.

25 Martin Maguire, "Methods to Support Human-Centred Design," *International Journal of Human-Computer Studies* 55, no. 4 (2001): 587–634, DOI: https://doi.org/10.1006/ijhc.2001.0503.

26 Don Norman, *The Psychology of Everyday Things* (New York: Basic Books, 1988); Don Norman, *The Design of Everyday Things*, revised ed. (New York: Basic Books, 2013), 8.

27 Richard Buchanan, "Design Research and the New Learning," *Design Issues* 17, no. 4 (2001): 3–23, DOI: https://doi.org/10.1162/07479360152681056.

can enable people to grasp problems by clearly visualizing information and amplifying its signals; product design can create suitable artifacts and tools to enhance people's capacity of reforming the world; environmental design can create and cultivate real life conditions enabling desirable human action; strategic design can provide systematic methods to intervene in the existing system for a long-term goal; systems design can help to bring about changes at holistic levels; and so on.

Design can unlock hidden opportunities to create value, but more importantly, it can also create meaning and enable others to do so. These meanings are a powerful vector for social change. Satisfying human needs is the first principle of the human-centered design approach. Failing to recognize that this approach has its (natural and environmental) limits is going to be our downfall. Nevertheless, designs can and do enable people to exchange their physical needs for spiritual rewards. Consider high-heeled shoes, for example. They cost money, hurt the wearer's feet, and make walking difficult. But people wear them despite all this for the sake of beauty. Moreover, as was remarked to my colleague Michael Lissack by one high heeled shoe wearer, "Without my heels, I am not me; it is someone else walking around in flats." This demonstrates that people are willing to sacrifice the material in pursuit of the non-material – and that sometimes, the sacrifices they are willing to make are sizeable if they perceive the reward to be worthwhile.

Imagine that sustainability – low consumption, low energy consumption, dramatically less polluting behaviors – were to become fashionable and desirable (its significant material benefits notwithstanding). This might lead many to make sacrifices that they have not thus far. According to Yuval Harari,[28] (homo) sapiens' distinctive cognitive capacity for fiction helps us cooperate in large numbers. Fashion and religion are both good at persuading people to perceive and believe in metaphysical values, and are also good at using design to create the stories and experiences that form large-scale systems of human cooperation. Using design processes to create a new, more appropriate reward system is a potentially promising direction.

Most problems in the human world do not have clear boundaries; they are difficult to define and delimit, and tend to lack coherent structures. On top of this, people's views and values – and hence the solutions they propose – are generally quite diverse. While most established disciplines in natural and social sciences ground their inquiries within certain boundaries – they seek to develop knowledge about actors and interactions in specialized systems – design is increasingly concerned with interactions arising at the intersection of all Four Systems. This interdisciplinary focus – integrating knowledge from various fields for new productive purposes[29] – was evident long before the emergence of the cyber system. Even within the long tradition of artifact-focused craftsmanship in design, the process and resulting products were also shaped by considerations about how artifact should interact with people and their surroundings in order to realize its purpose.

Design today faces far greater challenges than merely satisfying individuals' needs and is operating within an ever-expanding context. Every single one of humanity's most pressing challenges involves vast numbers of societal stakeholders and institutions. These challenges take place within a complex web of intermingled technologies and operational hierarchies. The effects produced by the networked, nonlinear interactions among all the moving parts in our complex sociotechnical system are constantly emerging. If design is going to turn away from mere creation towards addressing humankind's biggest problems, it needs to explore a brand-new culture. As one of many trials, in 2014 at Tongji University, a small group of scholars started a joint initiative called "DesignX," which aims to explore knowledge required by designing for complex sociotechnical systems.[30]

Sustainable development is a prime example of a complex sociotechnical

28 Yuval Noah Harari, *Sapiens: A Brief History of Humankind* (New York: Random House, 2014).

29 Buchanan, "Wicked Problems in Design Thinking."

30 Donald A. Norman and Pieter Jan Stappers, "DesignX: Complex Sociotechnical Systems," *She Ji: The Journal of Design, Economics, and Innovation* 1, no. 2 (2016): 83–106, DOI: https://doi.org/10.1016/j.sheji.2016.01.002.

system challenge. From a strategic point of view, implementing sustainable development goals sets us on a course towards a better future; from a practical standpoint, sustainability suggests transformations to existing development models. Redesigning the relational aspects and interactions among the Four Systems will enable a restorative transformation and relief from the existential threats to human survival. This mission opens a new agenda for design: *Sustainable Social Interaction Design*.

Despite our ever-evolving technical means, the essential dimensions of interaction design have not changed – it remains "relationship-based design," from the perspectives of human experience and feedback. The technological revolution endows interactional relationships, experiences, and feedback with new forms and content. Today, in the mainstream of interaction design, there is a focus on the idea that satisfying people's desires and meeting their needs by expanding human capacity. As we come to understand the crisis we face in reshaping the relationship between the human world and the natural world, we must additionally consider environmentally forced interactions from the perspective of system safety. Such considerations lead us to question the very concept of ever expanding capacity. *Sustainable Social Interaction Design* involves designing and managing a sustainable human world by using the ideas, methods, and tools of interaction design to stimulate and maintain positive interactions within the Four Systems. It treats the relationship between human activities and the natural world as an interrelated system. The goal of this design practice is to recalibrate our entire complex world by directing collective human behavior toward sustainability. To be effective, it needs to impact at the societal scale and to work in conjunction with economic and political systems.

The Promising World of the Virtual

Interest in complex sociotechnical systems is nothing new. They have been the subject of intense scrutiny for more than 70 years. There is an extensive literature that includes work by Peter Checkland,[31] C. West Churchman,[32] and many others in both the information systems and soft systems thinking communities[33] and the interaction community – Lucy Suchman's work in *Plans and Situated Actions*[34] comes to mind. In addition, there has been significant work in design theory and practice at places like MindLab[35] or the Helsinki Design Lab (closed but not forgotten).[36]

But what makes this topic relevant again, is because of the development and implementation of information technology, which has significantly extended the definition of what constitutes the sociotechnical.[37] Interactions between the human system and the natural system gave rise to the artificial system, which in turn led to the emergence of the cyber system: information, communications, and digital technologies (devices, platforms, applications, and so on) and the Internet. We have made great strides in artificial intelligence, big data, open data processing, cloud computing, deep learning, and swarm intelligence. Massively networked computer systems make it possible for us to collaborate on larger scales and thereby address more complex sociotechnical problems from multiple directions simultaneously. Complex problem resolution efforts are more rapid and more effective when actors at every level work together – when, as Nancy Roberts says, "we get the whole system in the room."[38] Thanks to a combination of developments in gamification, visualization, and artificial intelligence, highly technical or specialized problems that were once the remit of researchers and stakeholders behind closed doors can now be put into the hands of thousands of people working together toward problem resolution. A seminal example of this is the online protein folding game FoldIt,[39] which leverages input from online gamers to solve

31 Peter Checkland, *Systems Thinking, Systems Practice* (New York: John Wiley & Sons, 1981).

32 C. West Churchman, *The Design of Inquiring Systems: Basic Concepts of Systems and Organization* (New York: Basic Books, 1971); C. West Churchman, *The Systems Approach and its Enemies* (New York: Basic Books, 1979).

33 For example, see Peter Checkland and Jim Scholes, *Soft Systems Methodology in Action* (Baffins Lake: John Wiley & Sons, Inc. 1999).

34 Lucy A Suchman, *Plans and Situated Actions: The Problem of Human-Machine Communication* (Cambridge, UK: Cambridge University Press, 1987).

35 See https://www.mindlab.ie/about-us/ for more information.

36 The Helsiki Design Lab helped government leaders see the "architecture of problems." It helped decision makers view challenges from a big-picture perspective, and provided guidance toward more complete solutions that considered all aspects of a problem. For more information, see http://www.helsinkidesignlab.org/.

37 von Weizsäcker and Wijkman, *Come On!,* 44–49.

38 Nancy Roberts, "Wicked Problems and Network Approaches to Resolution," *International Public Management Review* 1, no. 1 (2000): 13, available at http://journals.sfu.ca/ipmr/index.php/ipmr/article/view/175. Roberts attributes this idea to physicist and philosopher David Bohm's *On Dialogue* (Cambridge, MA: Pegasus Communications, 1990).

39 Seth Cooper et al., "Predicting Protein Structures with a Multiplayer Online Game," *Nature* 466, no. 7307 (2010): 756, DOI: https://doi.org/10.1038%2Fnature09304; Firas Khatib et al., "Crystal Structure of a Monomeric Retroviral Protease Solved by Protein Folding Game Players," *Nature Structural & Molecular Biology* 18, no. 10 (2011): 1175, DOI: https://doi.org/10.1038/nsmb.2119.

tricky molecular biology problems. A more recent (and pertinent) example is Google's Environmental Insights Explorer, a citizen science tool created to fight climate change.[40] We can adjust the relationship between humanity and nature, and achieve measurable impact, via design.

The emergence and spread of the cyber system offers novel possibilities for humans to think, observe, and act at both the individual and collective levels. Where once we had difficulty gaining a larger picture of the extent and impact of our activities, we now have *greater transparency through data and algorithm technologies*. Data detection, mining, processing, and analysis tools and algorithms enable us to better see and understand the dynamics of human behavior and gain valuable feedback about complex system operations and potentialities. Open data means that public and private organizations can leverage big data in pursuit of targeted long-term environmental solutions. Social computing research and applications – based on cognitive science, intelligent science, and complex science – greatly enhance our ability to analyze and manage social and economic activity, and therefore our ability to tackle complex sociotechnical challenges.

Another potentiality in the cyber system is its ability to *enhance connectivity between the Four Systems* – potentially leading to increased system resilience,[41] both physical and non-physical, especially via active research into cyber-physical systems.[42] Using embedded computers, network monitoring, and cybernetic control, the Internet of Things (IoT) enables the interconnection of the artificial, nature, and human systems – where the cyber systems act as the nervous system. With human-in-the-loop models, we can not only orchestrate and monitor the interactions among systems, but also to more effectively realize complex sociotechnical goals based on collective social behavior and norms. In other words, we can adapt larger initiatives to better fit local communities and local cultures, which may lead to more widespread uptake.[43] This opens a new window for us to adjust the relationship between the "coupled human and natural system (CHANS)" through design.[44]

A third potential inherent in the cyber is the power of artificial intelligence to *learn the situation, predict eventualities, provide feedback, and even make decisions*. The city of Hangzhou is now using Alibaba's ET City Brain to improve traffic management. City Brain is a cyber system that unifies the integrated computing platform, the urban data resource platform, the artificial intelligence service system, and the open IT service platform as a whole to forecast real-time traffic, optimize traffic flow, and detect traffic incidents.[45] The latest developments in artificial intelligence, such as Google's DeepMind, combine deep learning and context enhancement to achieve large scale data responses. This combination of research and learning has enabled us to migrate a model developed for big data into smaller data scenarios. In this way, artificial intelligence has begun to shed its heavy dependence on big data. Importantly, thanks to artificial intelligence and social computation, people can "see" feedback, "predict" the impact of a certain action, and "manage" a complex system via artificial intelligence – something that we have never been able to do before, especially on the social scale.

Overall, the cyber system both enriches the interconnections and interactions among all four system, and has the potential to hold the Four Systems as a whole. It can be connected to each system via specific mechanisms, feedback loops, platforms, and so on. It is a living example of Arthur Koestler's holon – something that is simultaneously both part and whole.[46] Cyber systems can help the world be linked through real-time big data monitoring, data mining, and data visualization systems in ways that more clearly communicate the condition of social and natural systems on Earth. As such, the cyber becomes the intermediary between the human, artificial, and natural worlds. Through this intermediary, the signals of large scale societal changes – such as sustainable development initiatives at the

40 Robinson Meyer, "Google's New Tool to Fight Climate Change," *The Atlantic*, September 25, 2018, https://www.theatlantic.com/technology/archive/2018/09/google-climate-change-green-house-gas-emissions/571144/. For more information, see https://insights.sustainability.google/.

41 Yacov Y. Haimes, "On the Definition of Resilience in Systems," *Risk Analysis* 29, no. 4 (2009): 499, DOI: https://doi.org/10.1111/j.1539-6924.2009.01216.x; Igor Linkov et al., "Changing the Resilience Paradigm," *Nature Climate Change* 4, no. 6 (2014): 407, DOI: https://doi.org/10.1038/nclimate2227.

42 Ragunathan (Raj) Rajkumar et al., "Cyber-Physical Systems: The Next Computing Revolution," in *DAC '10: Proceedings of the 47th Design Automation Conference* (New York: ACM, 2010), 731–36, DOI: https://doi.org/10.1145/1837274.1837461.

43 "Michael Schrage on Innovation," *Ubiquity: Information Everywhere* 2004, no. 12 (2004), available at https://ubiquity.acm.org/article.cfm?id=1040565.

44 Marina Alberti et al., "Research on Coupled Human and Natural Systems (CHANS): Approach, Challenges, and Strategies," *The Bulletin of the Ecological Society of America* 92, no. 2 (2011): 218–28, DOI: https://doi.org/10.1890/0012-9623-92.2.218.

45 "ET City Brain," Alibaba-Cloud, accessed November 29, 2018, https://www.jfdaily.com/news/detail?id=67901.

46 Arthur Koestler, *The Ghost in the Machine*, reprint ed. (London: Hutchinson, [1967] 1990), 48.

systems level – can be transferred to the subsystems and individual elements of each system, and collective actions can be manifested.

Artificial intelligence now participates in and even leads tasks that were once the sole responsibility of human beings. At present, the capability for artificial intelligence to replace humans in decision-making processes is relatively low, and the scope of applications is limited. In the future, however, the potential of artificial intelligence to function as an autonomous system competing with humans is huge. Human beings are gradually relinquishing part of our power to manage the world, transferring that power to the cyber world. How that part of power can be properly and ethically used is nevertheless a major issue in terms of its impact on human beings. This challenges the assumption that human beings are the only actors capable of making decisions or undertaking actions that have the force of decisions. Moreover, things endowed with artificial intelligence will claim their rights as they acquire independent consciousness. One can imagine, in a similar vein, if the trees in the Amazon jungle could think and act, their sustainable development strategy might be to limit the spread of human beings as their biggest threat. Perhaps in the near future, intelligent machines will also take part in political life as the result of a symbiotic contract.[47]

Hybrid Community Building as the Incubator of Sustainable Interactions and Social Innovation

Subjective initiatives of human beings are the main, if not the only, motivating power among the Four Systems. I concur with Margaret Mead, who said, "Never doubt that a small group of thoughtful, committed citizens can change the world; indeed, it's the only thing that ever has."[48] But how can we help these groups become visible, connected, and empowered? We need a community! Community is a society of people who share similar values, interests, cultures, identities, norms, and visions. Today's virtual communities – forged on social media, MMORPGs, wikis, content sharing sites, and so on – challenge the norms established by traditional communities such as family, residential area, company, organization, or government. The very existence of the Internet supports Jürgen Habermas's definition of the public sphere as a "virtual or imaginary community which does not necessarily exist in any identifiable space," including the physical.[49] Anthony Giddens calls this *disembedding*[50] – "the 'lifting out' of social relations from contexts of interaction and their restructuring across indefinite spans of time-space." The reality formed by the virtual is a fact. In my view, the emergence of the virtual is not a problem in itself – it actually extends our capacity for social interaction, and our ability to manage complicated issues by engaging multiple stakeholders and facilitating consensus – the real problem is the separation of the virtual and real worlds!

There are numerous urgent, existential threats confronting humanity today. Climate change is perhaps the most crucial, but it is by no means the only one.[51] The challenge for design research and practice is to inspire entire societies to extend the notion of long-term human benefit to include preserving and protecting sustainability within all Four Systems. If we can build or enable a *hybrid community* combining the virtual and the real worlds, and at the same time, strengthen and enrich the interconnections among the human-nature-artificial-cyber system, we will have an incubator for encouraging responsible behaviors and social interactions. With it, we will be able to nudge (or drive) societies toward sustainable societal changes at larger scales and do so much more easily and effectively. As a new public sphere, an Interactive Hybrid Community can contribute to sustainable collective behavior changes in several ways.

47 Just two and half years after my keynote at ACM/CHI '15 that inspired this piece, Hong Kong firm Hanson Robotics created a female robot called Sophia. Her facial features are highly mobile and expressive, and she is capable of displaying a range of emotions. On Oct. 25, 2017, Saudi Arabia announced her recently acquired citizenship, to mixed reactions.

48 Margaret Mead, *Continuities in Cultural Evolution* (New Haven: Yale University Press, 1964).

49 Marshall Soules, "Jürgen Habermas and the Public Sphere," accessed November 9, 2018, https://www.media-studies.ca/articles/habermas.htm. See also Jürgen Habermas, *The Structural Transformation of the Public Sphere: An Inquiry into a Category of Bourgeois Society* (John Wiley & Sons, 2015), 1–26.

50 Anthony Giddens, *The Consequences of Modernity* (Stanford, CA: Stanford University Press, 1990), 21.

51 Rockström et al., "Safe Operating Space," 472–75; United Nations, "Sustainable Development Goals," accessed October 22, 2018, https://sustainabledevelopment.un.org/sdgs.

Intensify Communication

Why do people not truly grasp the importance of today's complex challenges? The modes and platforms of communication we use today do not clearly present the information required, nor do they enhance the weak signals embedded in the content effectively. A hybrid community will create multiple contexts for coordinated communication. By repeating a message across contexts, we can enable a fuller understanding of the threats we all face, gather inspiration and expertise regarding potential opportunities, and provide for a natural, omnipresent communication that is more persuasive than preaching.

Include Multiple Levels of Actors

Communities have traditionally been clustered according to their interests, values, visions, benefits, or projects. By contrast, the members of the Interactive Hybrid Community will be from every walk of life. The richness of knowledge, social position, and cultural background found in this multi-actor, multi-disciplinary, multi-level community means a variety of perspectives and resources will all be contributing to the social agenda. In this social innovation process, how to reduce the threshold of using technology for all kinds of people is an important topic.

Consolidate Connections

Our present crisis of sustainability is mainly due to connection failures within the subsystems. Technological solutions may be good at creating the "hard connections," but are not good at creating the soft ones, especially emotional connections. For instance, people know the importance of clean energy, but their use of it very much depends on their mindset and daily habit. An interactive hybrid community can enable ideas to navigate and sprout throughout it. It will also empower people to understand, intervene and further reconstruct the system towards a preferred one.

Reinforce Feedback

Having a positive feedback or reward system connected to our actions is key to encouraging people to take, repeat, or prolong a certain action. The hybrid community can help to create multiple non-material incentives that induce people to adjust their behavior. Trends in this direction have already begun – socially networked sustainability apps like JouleBug (energy consumption), Changers CO_2 (well-being and CO_2 management), HowGood (grocery sustainability gauge), and Rippl (sustainable employment search engine) attest to this[52] – but more needs to be done for sustainability to become a socially desirable and even fashionable practice. The goal is for it to become so popular that it reaches critical mass among societies across the globe.

Facilitate Consensus

There are lots of ways to facilitate consensus, among them community building is one of the most effective one. We implicitly understand the power of socialization when we learn community norms as children at home or in school. In doing so, we adapt the norms of a society or community based on common values. Achieving sustainability means multiple compromises. Adequate and effective communication among community members is the key to deeper consensus, which is impossible without the incubator effect of the hybrid interaction environment. For example, with broad support within a community, a proposal to shift culture away from exclusive possession and towards sharing can be formulated, accepted, initiated, or withdrawn much more easily.

52 For more information, see https://joulebug.com/, https://changers.com/, https://howgood.com/#/, and https://www.betherippl.com/.

Epilogue

We have major problems and there are major barriers to their resolution. Designers are exactly the sort of people who should be able to tackle these issues. But, to solve these problems, we need a different breed of designers – people trained to understand the ecology, the environment, and the virtual systems that provide appropriate communication and feedback, in addition to people who understand economics and politics, and culture and religion.

Beyond new design experts, we need new design communities. Design should play an active role in the process of Interactive Hybrid Community building, which will greatly contribute to bringing together people, nature, cyber, and artificial systems to form a bottom-up, grassroots force for sustainable social innovation. Together with organizations working from the top down, the community can contribute significantly to shaping humanity's future social, economic, and everyday experiences. It will be an important new opportunity and arena for design.

We also need entirely new principles and approaches. As with any strategy, implementation is key. At no other time in human history has design activism been so necessary. If we do not intervene, the imbalance will continue to spread. We cannot predict the future based on the past. Delaying action for fear that design behavior may be wrong is similar to refusing to eat for fear of choking. The real mistake is not acting or not evaluating the action taken.

When Pandora's Box is closed, new problems do not emerge. Any linear solution that does not take new problems into account can seem untenable. Therefore, to cope with uncertain and unfamiliar territory, we should act while observing, explore through action, and make timely adjustments to our actions through comprehensive feedback while adjusting our goals. This is exactly Mr. Deng Xiaoping's approach to reform – cross the river by feeling the stones!

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