Collapse Informatics: Augmenting the Sustainability & ICT4D Discourse in HCI

Bill Tomlinson[1], M. Six Silberman[2], Don Patterson[1], Yue Pan[3], and Eli Blevis[3]

[1]University of California, Irvine, CA, USA, {wmt, djp3}@uci.edu

[2]Bureau of Economic Interpretation, San Francisco, CA, USA, six.silberman@gmail.com

[3]Indiana University, Bloomington, IN, USA, {panyue, eblevis}@indiana.edu

ABSTRACT

Research in many fields argues that contemporary global industrial civilization will not persist indefinitely in its current form, and may, like many past human societies, eventually collapse. Arguments in environmental studies, anthropology, and other fields indicate that this transformation could begin within the next half-century. While imminent collapse is far from certain, it is prudent to consider now how to develop sociotechnical systems for use in these scenarios. We introduce the notion of collapse informatics—the study, design, and development of sociotechnical systems in the abundant present for use in a future of scarcity—as a complement to ICT4D and mitigation-oriented sustainable HCI. We draw on a variety of literatures to offer a set of relevant concepts and articulate the relationships among them to orient and evaluate collapse informatics work. Observing that collapse informatics poses a unique class of cross-cultural design problems, we sketch the design space of collapse informatics and provide a variety of example projects. We explore points of connection and distinction between collapse informatics and sustainable HCI, ICT4D, and crisis informatics. Finally, we discuss next steps and comment on the potential value of collapse informatics work even in the event that collapse never occurs.

Author Keywords

Sustainable HCI, collapse, sustainability, mitigation, adaptation, ICT4D, cross-cultural design

ACM Classification Keywords

H5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous. K4.m. Computers and Society: Miscellaneous.

General Terms

Design, Human Factors, Theory.

CHI'12, May 5–10, 2012, Austin, Texas, USA.

INTRODUCTION[1]

History documents the rise and fall of many complex societies. Large human civilizations form over long periods of expansion, sometimes lasting centuries; however, most civilizations that have ever existed have collapsed [6,31]. The archaeologist Joseph Tainter defines collapse as "a rapid, significant loss of an established level of sociopolitical complexity" ([31], p. 7). In his parlance, "rapid" means "no more than a few decades" ([31], p. 4). Collapse manifests as the loss of the hallmarks of political complexity, namely: *"a lower degree of stratification and social differentiation; less economic and occupational specialization, of individuals, groups, and territories; less centralized control; that is, less regulation and integration of diverse economic and political groups by elites; less behavioral control and regimentation; less investment in the epiphenomena of complexity, those elements that define the concept of 'civilization': monumental architecture, artistic and literary achievements, and the like; less flow of information between individuals, between political and economic groups, and between a center and its periphery; less sharing, trading, and redistribution of resources; less overall coordination and organization of individuals and groups; a smaller territory integrated within a single political unit"* ([31], p. 4).

We live in a world that includes the first global civilization. Despite the relatively continuous growth that this civilization has experienced over the past two centuries (or, perhaps, because of it), it is plausible that this civilization may someday enter a period of decline. Many scholars have suggested that this decline may have already begun, or may begin within the next several decades [6,31].

The collapse of global civilization, whether imminent or not, would carry enormous costs that novel research may be able to reduce. It is time to consider how the CHI community can help civilization react to, and perhaps plan for, global collapse.

In this paper, we propose that there is a need for research in *collapse informatics*—the study, design, and development

[1] Portions of the document adapted from several non-archival publications, specifically: [2,25,29].

of sociotechnical systems in the abundant present for use in a future of scarcity. The term ICT4D—or Information & Communications Technologies for Development—already denotes a well-established area of inquiry, referring to the role and potential effects of ICT in helping the so-called developing world, the 'development' of which is part of our collective global fate. In HCI, under the banners of sustainable interaction design, sustainable HCI, and green IT, there is much literature targeted at mitigating the forces—especially social-behavioral forces—that also threaten standards of living around the globe. This work to date has focused primarily on mitigating the possibility of climate change effects, although some of the sustainability work specifically included in this present paper has stated the need to focus on adaptation as well [2]. Collapse informatics, then, is the third in this trilogy of concerns, focusing on the role and potential effects of ICT in dealing with changes—however induced—that create massive shifts in the way humanity must adapt to survive in its environments—political, social, and ecological. Collapse informatics is broader than notions of adaptation in the general literature on sustainability, since the concern is for preparation and adaptation to change, whether induced by climate change or other forces.

Just as the Americans with Disabilities Act produced innovations that had far-reaching social benefits beyond simply helping those with disabilities, collapse informatics may well produce innovations that are broadly useful, for example, in localized collapse situations, disaster-preparedness and response, or in ICT4D, even in the event that the global community is able to sustain itself indefinitely. Moreover, the study of mechanisms of preparation for and adaptation to collapse has important implications for the discourse on sustainable interaction design/HCI, and ICT4D. Through this research, we envision the possibility of a future characterized by scarcity and shrinking opportunity, and seek to make that future a better place.

COLLAPSE IS NOT APOCALYPSE

If collapse is potentially in our civilization's future, it is relevant to consider how soon and in what styles, collapse may occur. Hollywood movies (e.g., *Carriers*, *28 Days Later*, *The Terminator, 2012*) and survivalist fiction (e.g., [26]), often focus on very rapid collapse, occurring on the scale of days or weeks—an apocalypse.

While rapid and powerful events such as nuclear attacks may cause events to unfold in a way that merits the term "apocalypse", and while various "tipping point" phenomena [6,14] may cause non-linear changes to occur very rapidly (as is common in ecosystems), Tainter [31], geographer Jared Diamond [6], and others note that collapse frequently occurs more gradually. In the popular press recently, there has been discussion of a "double dip recession" [23]; collapse could well take the form of an "N-dip recession."

TIMING OF COLLAPSE

When, exactly, collapse may begin is difficult to predict with precision. Many scholars tie the collapse timeline to our primarily fossil fuel-based energy supply. "Recent history seems to indicate that we have at least reached declining returns for our reliance on fossil fuels, and possibly for some raw materials," writes Tainter ([31], p. 215). He continues: "[a] new energy subsidy is necessary if a declining standard of living and a future global collapse are to be averted." One barrel of oil does an equivalent amount of work to 25,000 hours of human manual labor [18]; it is the subsidy and externalized costs from this vast resource that makes our current ways of living possible. The term "peak oil" has entered popular parlance to describe the point at which global oil production reaches its highest point and then enters a period of decline. There is some debate over the timing of this phenomenon; some researchers say it has already occurred, others that it will occur within the next several decades. If collapse is tied to dwindling supplies of fossil fuels, collapse may well be in the offing.

Diamond also argues that environmental problems that could cause civilization-scale collapse will manifest within the century. "[A]t current rates most or all of the dozen major sets of environmental problems … will become acute within the life-time of young adults now alive" ([6], p. 513). These kinds of predictions are made as well by Lovelock (e.g., [14]). Lovelock's notion of Gaia Theory, which holds that the Earth is a self-regulating system, has been cited in the HCI literature [6,13] in the context of describing the controversies surrounded his theories. The much less controversial Intergovernmental Panel on Climate Change (IPCC) ([24], p. 7, Figure SPM.5) states that we are very likely to reach a tipping point by 2040 with respect to global warming/climate change unless we are able to reduce our GHG emissions to 1999 levels by the year 2015.

Taken together, these sources suggest that collapse could begin within the next several decades. If it does, it is likely to usher in profound changes.

EFFECTS OF COLLAPSE

In this document we use the term 'civilization' to mean a large, complex society, where a society is a collection of cooperating individuals (or smaller such collections). A civilization including cooperation between globally distributed individuals or collections can be described as a 'global civilization'. With these definitions we can describe a 'collapse of global civilization' as the transition from a state of affairs in which such cooperation exists to one in which it no longer exists. (Note: No moral valuation is intended by our use of the term 'civilization'.)

Diamond and Tainter describe numerous examples of collapse across the history of human civilizations, and point to scarcities of many kinds, including dramatic shortfalls in food, energy, and raw materials. In a scarce, post-collapse future, we may see crumbling infrastructures as well (e.g., power, manufacturing, government regulation). In the "Inside Risks" column in *CACM*, Horning and Neumann note that "[c]ivilization and infrastructure are intimately intertwined. Rising civilizations build and benefit from their infrastructures in a 'virtuous cycle.' As civilizations decline, their infrastructures decay—although unmaintained vestiges, such as roads and aqueducts, may outlive them" ([12], p. 112). In the wake of collapse, the largest level of human organization is likely to be a smaller social unit than the current global civilization [31]. We may see scarcities of energy in the wake of peak oil, and scarcities of other resources as a result of reduced global trade. The lack of infrastructures, energy sources, and trade would likely impact food supplies for a large portion of the world population, who either do not raise their own food, or do so relying on imported water, seed, fertilizers, pesticides, and other supplies. Taken together, these kinds of civilizational repercussions would bring about non-trivial lifestyle changes for many people.

ICT AND COLLAPSE

This paper focuses on the potential contribution that the field of HCI can make in preparation for and adaptation to collapse. Computer-based ICT systems are among the most powerful tools humanity has ever created; understanding how to design ICT and sociotechnical systems to enable social wellbeing in times of collapse could benefit many.

There has been some discussion of collapse in the computing community (e.g., [22]). Within HCI specifically, Blevis and Blevis [6] have written about the need to emphasize adaptation in addition to mitigation. They write: *"We are at a crossroads where the logic that applies is the logic of hoping for the best and preparing for the worst—that is, we need to continue our efforts to develop digital interactivity to induce people and societies to engage in behavioral changes that reduce our greenhouse gas emissions, and we also need to develop digital interactivity that allows us to prepare for and adapt to climate change under the possibility that we will reach a tipping point, or the possibility that we have already done so"* (p. 26).

Wong has discussed the need for a broadening of the scope of research in order to have effects that are sufficiently impactful to address the gravity of the crises facing human civilizations [37]. In Wong's view, researchers "should also consider … the design context to be a world radically altered by environmental damage; solutions that fit into today's lifestyles risk irrelevance" ([37], p. 1).

Silberman and Tomlinson have described a need for "apocalypse-related … approaches to technology design" ([29], p. 1). They consider how HCI research may be relevant to contexts characterized by a "rapid, significant loss of sociopolitical complexity which in itself constitutes an event whose impacts exceed the responsive capacities of [those] affected" ([29], p. 1).

Despite these initial forays by HCI researchers into the space of research relating to collapse and similar phenomena, we as a discipline have largely failed to appreciate the need to design and build technologies that may be of use on the "downward slope" of social complexity. This paper seeks to bring together ideas from these early works with research in other fields to articulate the concerns, goals, assumptions, and concepts of this emerging genre of HCI research. We use the term "genre" following DiSalvo *et al.* [7], who describe genres as "common frameworks that structure how researchers define [a problem] and structure what is an appropriate solution" (p. 1975). While we believe collapse informatics constitutes a substantive departure from the approaches developed thus far in sustainable HCI and ICT4D, we recognize the risks of "carving up" the intellectual terrain, or proliferating subfields unnecessarily.

It is worth noting that ICT may also play a prominent role in *bringing about* collapse. ICT is a force multiplier and has hastened the development of the various environmental issues that surround us [33]. With regard to the recession in the late 2000s, *CACM* editor Moshe Vardi argues that "information technology played a major role in the crisis" ([34], p. 5). Recalling points made by Tainter, Vardi offers: "A common thread to these disasters is that our financial system has reached a level of complexity that makes it opaque even to the 'high priests of finance'" ([34], p. 5). Vardi gives examples showing how ICT is linked to economic complexity. And then he makes the link to collapse explicit: "if a massive electromagnetic pulse wiped out our computing infrastructure, our society would face a catastrophic collapse" ([34], p. 5).

ICT is a powerful form of technology. Because of ICT's great power, and because it is deeply embedded in global industrialized civilization, understanding how it may be of service in a potential collapse is of critical importance.

Many people in the modern world look at the past several hundred years of fairly steady growth, and see growth as eternal and unconditionally desirable. Growth has led to higher standards of living in many areas, and, as an idea, is supported by the bulk of major governments and corporations of the world. However, continuous growth is, by definition, not sustainable indefinitely.

The bulk of ICT innovations in the past half-century reflect an implicit expectation of perpetual growth. Infrastructures will expand, markets will grow, and materials will become more readily available. Recently, "green" technologies have begun to consider that it might be desirable to have civilization plateau, and achieve a sustainable steady state or dynamic equilibrium [4,5].

Civilizational collapse is the condition for which this paper seeks to help civilization prepare. Thoughtful development of computing technologies, and the removal of certain technologies as well, are methods of preparing. The goal is to adapt to potential futures that may involve collapse, rather than preserving the "business as usual" that may, in fact, be hastening collapse.

SCOPE, CONCEPTS, AND CONCERNS

Software engineering researcher Douglas Schuler suggests that "[w]hether or not humankind successfully navigates itself away from the rocky shoals it faces will depend to no small degree on whether the right type of sociotechnological infrastructure is conceptualized, developed and used" ([27], p. 63). Collapse informatics seeks to build this sociotechnological infrastructure.

Adaptation and Mitigation

Adaptation describes changes in a system's structure or behavior in response to changes in its external environment (e.g., [38]). When the systems under study are humans or groups of humans, we can focus on adaptations to practices for fulfilling human needs. The economist Manfred Max-Neef argues that the fundamental human needs are subsistence, protection, affection, understanding, participation, idleness, creation, identity, and freedom [17]. This particular list is not essential to collapse informatics, but a distinction between finite, broadly relevant (if not universal) needs and culturally idiosyncratic, arbitrarily extensible wants must be made in some way to predict the likely goals of users in the face of collapse.

In global climate change discourse, "adaptation"—the mobilization of effective responses to the effects of environmental change (e.g., climate change) is complementary to "mitigation," the *a priori* reduction of the magnitude of change by reducing the causes of change (e.g., greenhouse gas emissions). Mitigation reduces the need for future adaptation, if it occurs soon enough and with sufficient scale to avoid a tipping point. But, if change becomes inevitable and begins to occur (i.e., as opportunities to mitigate are foregone or mitigation efforts fail), prevention is no longer possible and adaptation is required. Further, because adaptation takes time, it is necessary to begin adapting even before changes occur in order to be successful. Climate science predicts that a certain amount of global warming and sea level rise will occur as a result of past emissions [16,21,36]. While mitigation remains important, the need for a certain amount of adaptation is already assured.

Vulnerability and Adaptive Capacity

The work of adapting *a priori* to expected effects of global change can be described in terms of reducing vulnerability and increasing adaptive capacity. Amy Luers *et al.* [15] note that it is hard to discuss with precision the 'general' vulnerability of a system, and instead study vulnerability in terms of variables that relate to the well-being of the system (p. 257). For example, in studying a farming community one might investigate the vulnerability of crop yields to climate change. In studying a city one might investigate the vulnerability of food availability to changes in oil prices.

Luers *et al.* define vulnerability in terms of (a) the sensitivity of the system's well-being (or its proxy) to changes in the value of the environmental variable in question and (b) the proximity of the system to a threshold below which the system is said to be 'damaged.' Specifically, large changes in well-being resulting from small changes in the environment are indicative of high vulnerability, as is proximity to the damage threshold [15] (pp. 257-8).

Luers *et al.* define adaptive capacity as "the extent to which a system can modify its circumstances to move to a less vulnerable condition." Quantitatively, it is the difference between a system's current vulnerability and its vulnerability under some condition to which it could shift. This does not include adaptations already made in response to past disturbances; those adaptations are represented by the system's current vulnerability. Adaptive capacity indicates changes that could be made to reduce vulnerability to future disturbance ([15], p. 259). Vulnerability describes actual conditions; adaptive capacity describes possible conditions.

These concepts describe two categories of work that supports adaptation to collapse: reducing vulnerability and increasing adaptive capacity. We aim to reduce vulnerability of fulfillment of fundamental human needs to the disturbances we expect in association with global change (climate change, sea level rise, degradation of ecosystems and their services, etc.). Once existing adaptive capacity has been exploited, adaptive capacity must be increased to further reduce vulnerability. One component of adaptive capacity is knowledge; we cannot change our ways unless we know how. Thus increasing adaptive capacity entails, among other things, gathering and developing knowledge relevant to fulfilling fundamental human needs in various contexts despite the disturbances of global change. Reducing vulnerability means helping interested parties deploy that knowledge. There are different appropriate times for work in these two categories. To the extent that increasing adaptive capacity has low opportunity costs — and this may hold for much of the 'knowledge work' involved — it can be undertaken even in situations of uncertainty. Reducing vulnerability to changes in one variable, however, may increase vulnerability to changes in others. Thus the appropriate action depends on our degree of certainty about what the future holds. Research on decision making under uncertainty abounds in the policy, business, decision theory, and computer science literatures and is likely to be of value in choosing between possible adaptations.

To increase adaptive capacity is to increase the number of options. To reduce vulnerability to changes in a particular variable is to change our way of life to reduce the costs of anticipated disturbances associated with that variable.

The question of time is central to this work. It takes time to change a way of life, even for an individual. How long might it take for an entire city to develop local food production in anticipation of rising oil prices? At least years; perhaps decades. Thus if we think that severe disturbances are decades, not centuries, away, it makes sense to begin increasing adaptive capacity now.

COLLAPSE INFORMATICS AS A STRATEGIC DESIGN PROBLEM

The core challenge of collapse informatics involves designing sociotechnical systems in our present context, even though the primary usage of these systems will occur in a very different situation. Essentially, collapse informatics is a cross-cultural design problem.

However, whereas most cross-cultural design efforts span two communities that are contemporary but spatially and culturally distinct (e.g., designers from one country attempting to design systems for users in a different country), the cross-cultural design problem in collapse informatics spans two communities that may exist in the same location but are temporally and culturally distinct (e.g., designers in the present attempting to design systems for their future selves and families in a time of scarcity). What makes this effort particularly challenging is that it is impossible for a researcher or designer to engage with the anticipated users and seek to understand their needs and ways of viewing the world in which they live, or engage in action research (cf. [11]). This is not to say that typical cross-cultural design is easy; meeting and interacting with the people for whom we design is different from understanding their needs and desires. But in most cross-cultural design it is at least logically possible to attempt to establish understanding, work with users to evaluate prototypes, and iterate on designs. In collapse informatics the imagined users are not yet in the imagined context of use (collapse). They may not have even been born yet.

Collapse informatics focuses on the difference in availability of resources and infrastructure between when systems are designed and when they may be used. These systems are designed in times of relative abundance in many places around the world, building on the wealth of resources and expanding infrastructures brought about by fossil fuels and globalization. In present times, we have the cognitive surplus [28] to design systems for purposes beyond immediate survival, and the excess materials and energy to bring these systems to fruition.

Not all sociotechnical interventions involve building and deploying systems. Fry's notions of "redirective practice" (e.g., using a push mower instead of a gas powered lawn mower) and "acts of elimination" (e.g., replacing lawns with small scale crop gardens or wildflowers) [10] instead point to the potential need to remove components of complex sociotechnical systems. In Tainter's analysis [31], complexity itself sets the stage for collapse; therefore, reducing complexity in sociotechnical systems while maintaining their viability could be an important means both of avoiding collapse and of creating systems that are viable post-collapse. Understanding how our research may be most effectively brought to bear on this suite of concerns, whether through the introduction of new technologies or the elimination of problematic ones, is an important consideration of the proposed project.

To design these interventions, and begin exploring how they interact with human civilizations, we return to Max-Neef's concept of basic human needs [17]. Understanding how sociotechnical systems may support and provide for these needs in a sustainable way in a time of scarcity is the core of the collapse informatics design problem.

Despite the possibility of widely-shared human needs, we also recognize the existence of many different social, biological, and biogeographic contexts (e.g., [8]). What serves a human need in one culture (even a collapsed one) may be very different than what serves the same need in a different culture. What serves a need across various ecological habitats differs as well, especially as climate changes make ecologies dynamically unstable.

Finally, collapse informatics systems should also operate in future scenarios characterized by minimal, intermittent, and/or alternative infrastructure—or even "anti-infrastructure," such as a local despot who takes most things of value for his or her own use.

RELATION TO OTHER GENRES OF HCI RESEARCH

Collapse informatics is both a separate concern and a part of the discourse for sustainable HCI, ICT4D, crisis informatics, and potentially other genres within and outside HCI. (See Figure 1.) These genres aim to increase human well-being. But their operating contexts and orienting assumptions are different to those of collapse informatics.

Sustainable HCI has been mainly focused on mitigation,

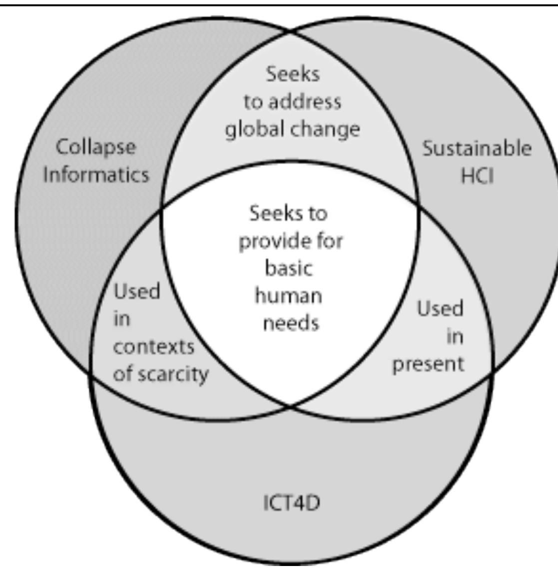

Figure 1: Collapse informatics has a great deal in common with sustainable HCI research and ICT4D.

and tends to assume that the infrastructures relied on by most interactive technologies will persist as the risks incurred by current unsustainable practices become urgent challenges to well-being and survival. Collapse informatics distinguishes itself from this work by its orientation to adaptation rather than mitigation and by imagining those infrastructures as at risk, and subject to design and redesign, rather than as stable elements of the environment [30].

ICT4D has been mainly focused on increasing standards of living in 'developing' countries, often by importing or adapting technologies created and used in 'developed' countries. This work can increase human well-being in the short and medium term and is therefore deeply important. But the use practices and infrastructures surrounding most of these technologies, developed in countries whose economic growth has been made possible by abundant fossil fuels [32], may not be sustainable in the long term (i.e., decades to centuries). Collapse informatics distinguishes itself from ICT4D by considering long term scenarios of global change, in which the infrastructural conditions in current high-consumption countries begin to look more like those currently prevalent in 'developing' countries, and the continued appropriation of non-local resources and associated notions of externalized costs are no longer supported by post-collapse global conditions.

The nascent field of crisis informatics is also concerned with saving life and maintaining well-being in the context of dramatic change. These are urgent, difficult, and important design challenges, especially given the possibility that disasters will increase in frequency and severity as global change unfolds. Thus collapse informatics overlaps with this work, but here again distinguishes itself by taking a longer and broader view. Disasters are bounded in space and time; by designing to support users in disaster contexts we can assume that (a) the disaster will end and (b) users in the disaster context can be supported by users outside it (with access to functioning infrastructure). In collapse informatics work, the new conditions are not necessarily bounded in space or time; in collapse scenarios, infrastructure failures are likely to be spatially extensive and for all practical purposes permanent.

EVALUATION

A critical question when designing systems for a future that has not yet come to pass is "How do you know it will work?" The question of evaluation looms large over collapse informatics work.

Key elements of a proposed approach to collapse informatics evaluation can be drawn from the history of collapse. Two core ingredients frame our approach to evaluation: smaller social group size and unreliable infrastructure. The approach is this: create models and/or conduct real world experiments with willing participants in which certain constraints are placed on a person or group's existence, and explore the viability and usefulness of the proposed design or actual working system in that context. For example, if one model of collapse entails no electricity, then any system that relies on electricity is a failure. If another entails the lack of reliable federal or state governments, the bulk of civil services will no longer be available. Existing measures of quality of life [9] and assessments based on basic human needs [17] may then be used to assess the implications of collapse informatics research projects used in these circumstances.

In addition to evaluating the success or failure of a particular system, these models may be used to generate questions (cf. [1]), principles, heuristics, and indices [30] to help understand the set of relevant issues more fully. Researchers may also consider what kinds of emergent and network effects may be valuable or problematic in a range of collapse contexts.

We acknowledge that evaluation is a difficult and rich topic of critical importance to collapse informatics, and fertile ground for future work in this area.

EXAMPLES

To explore the range of potential collapse informatics projects, first we include a somewhat detailed sketch for an application in progress called "The Climate Change Habitability Index," to serve as an example of the type of interactive technology application we have in mind. Next, we include a series of ideas for applications and contexts targeted to motivate near-future collapse informatics research.

The Climate Change Habitability Index

The Climate Change Habitability Index (CCHI) is a design exercise and catalyst to a program of ongoing research. The idea of the CCHI is to allow ordinary individuals—rather than just climate scientists—to understand the state of the world in terms of habitability at particular places. In the face of climate change, individuals will need to be able to use the CCHI and other measures to answer questions such as: (a) *can I continue to live where I am living,* (b) *where can I move if I can't continue to live where I'm living,* and (c) *how many people can the place where I live sustainably support, if where I live continues to be habitable?* The CCHI needs to be stated in a way that is as easily understood by ordinary people as other summary reporting such as weather forecasting.

Definition

The CCHI is defined abstractly as a metric that can be stated in ordinary language and diagrams which allow people to answer the above three questions related to sustainability and adaptation to climate change about particular places on Earth.

By "*can I continue to live where I am living*," we mean to ask if a place is habitable enough for people to live in accordance with water and food supplies, health conditions, and the habitability of coastal environments in particular and other environments in general.

By "*where can I move if I can't continue to live where I'm living*," we mean to ask which places are habitable or have better, more sustainable living affordances respective of the five factors identified by the IPCC ([24], p. 16, Figure SPM.2)—namely water, coasts, food, health, and ecosystems. This question relates to a person's ability to understand the habitability of where she or he lives now and to make plans for moving in the future, if necessary.

By "*how many people can the place where I live sustainably support, if where I live continues to be habitable*," we mean to ask how can we inform policies and decisions related to migration and absorption of immigrants in a manner that promotes peaceful and orderly sustainable practice in the face of the potential and realized effects of climate change.

The CCHI aims to provide a metric to enable everyone from individuals to intergovernmental bodies to plan for the dynamic and orderly migration and absorption of populations as climate change alters the suitability of various regions of the planet for sustainable habitation. Finally the notion of making the habitability index as highly accessible as a notion like "temperature" is co-requisite to the social imperative to provide for the safety and security of every person and creature whose life or home may be impacted by climate change events and effects.

Initial Design for the CCHI

We are designing a tool to support the summarization of the suitability of any particular place for habitation as a dynamically changing metric corresponding to historical, current, and predicted states of water systems, ecosystems, food supplies, coastal conditions, and health conditions, as well as the likelihood of hazard events. Interactivity of the habitability index may be presented using cloud-based technologies, such as layers implemented as part of the "Google Earth" or "Google Maps" APIs, or other GIS systems. Figure 2 shows the essential interactivity elements we imagine are needed to support interactivity with the CCHI representation as a cascading summary of more detailed data. Our design is deliberately minimalist and it is easy to image a gray scale version as a matter of accessibility. The regions defined in the map denote a cumulative summary of the risk factors indicated by the risk factor icons.

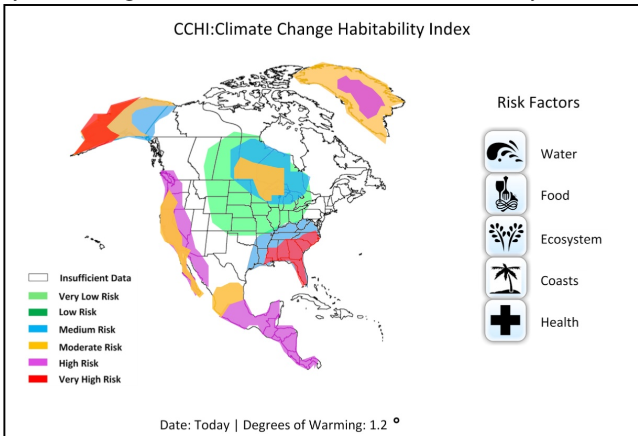

Figure 2: CCHI view on a specific day given a specific amount of warming. (*Not real data—For illustrative purposes only.*)

Time & Temperature

Another two essential features of CCHI are time and degrees of warming (or cooling). Our purpose is to allow people to see historical trends and future predictions about how climate change affects the Earth over periods of time. People need to be able to see what the Earth may look like when the average temperature increases by a specific amount which in the IPCC summary diagrams ([24]) ranges from 0 to 6 degrees Celsius of warming. Two degrees Celsius of warming is generally considered to be the dangerous tipping point. Based on the assumptions of the IPCC reports, we define year 2000 to be the base point and set the temperature change to be 0 for 2000 ([24]).

The CCHI seeks to provide access to data about the current and possible future habitability of particular regions [6]. Making this information readily available to ordinary people will increase the likelihood that the evacuation and absorption of populations in the face of climate change will be orderly and peaceful.

Application Ideations and Context Scenarios

The following are unimplemented "fictional abstracts" for research projects that serve as ideas we hope others will take up, or which we ourselves will investigate in future work. These ideas/scenarios illustrate the range of what may be possible in terms of collapse informatics.

Predicting and Preparing

Designing ICT Systems for Post-Collapse Deployment: Most current ICT systems are designed for deployment in contexts much like those in which they were developed – industrialized, stable, infrastructure-rich, and communication-enabled. In the case of civilizational collapse, though, the lack of infrastructure and other resources may make deployment of these systems challenging – there may not be access to the most recent version of a system, or critical updates, or server-based license management systems. This project would develop a new class of ICT systems – "collapse-compliant systems" – that are designed for use after the industrialized context has begun to decay. For example, collapse-compliant systems should be 1) always ready (the most recent version must be locally cached with some regularity); 2) critically useful (explicitly serve a physiological or psychological need of humans or some other species); and 3) robust (must contain source code or some other mechanism for repair/adaptation). A Wikipedia dump that locally auto-archives a subset of articles based on user-specified keywords and total file size would be one example of a collapse-compliant system. An online community could emerge around this and other collapse-compliant systems, so that interested individuals and organizations could benefit from each other's preparedness.

Modeling Survivable Whole Life Systems: Many researchers (e.g., Max-Neef [17]) suggest that humans have an assortment of basic needs. In any viable, long-term survival scenario, all basic human needs must be met. This project would simulate an arbitrary-sized population of human-like agents and examining the interdependencies among individuals and their various needs. For example, two agents may reciprocally provide affection for each other, but compete with each other for subsistence in the context of scarce food resources. By modeling basic human needs, this system may allow individuals and institutions to plan more effectively for both emergency and everyday lifestyles.

Visualizing Collapse Via Markers of Social Complexity: This project would create a means of monitoring and visualizing key indicators of the collapse process. The system would track metrics such as unemployment rates, bond ratings, border security, governmental solvency, and incidence of martial law; integrate these factors via a user-customizable algorithm; and present the results via a dynamically-updated interactive visualization. Enabling the citizenry to monitor and predict the process of collapse may enable broader preparedness for the reduction of social complexity.

Peak ICT: Peak oil will usher in profound changes across many facets of society. Since ICT systems rely extensively on fossil fuels for their creation and operation, these systems are likely to be heavily affected by declining fuel availability. Barring a new power source to replace fossil fuels, eventually ICT will reach a point where the maximum information storage, manipulation, and transmission will be reached ("Peak ICT"), and human civilizations will enter a time of declining information availability. While studies suggest that people preferentially expend scarce resources ICT over many other things (even, sometimes, food), and therefore Peak ICT may lag behind Peak Oil by some months or years, an awareness of the likelihood of Peak ICT may be helpful for both individual and institutional planning efforts. This project would explore the characteristics, timing, and implications of Peak ICT.

Surviving and Thriving

Local Smart Grids: A great deal of research has explored the use of smart electrical grids for increasing energy efficiency, and tracking energy usage for a variety of other purposes. However, the bulk of this research focuses on centralized grids used by large-scale institutions such as power companies or universities. Despite this focus, many of these advances may be able to be applied to local power contexts such as off-the-grid communities and self-sufficient survival retreats. These contexts tend to have much more stringent constraints on power; as such, they would benefit greatly from intelligent power tracking and management. This project would explore how sensing, measurement, and control techniques developed for large smart grids may be adapted to help local smart grids address canonical concerns in renewable energy such as the intermittency problem, in which energy sources such as solar or wind power vary dramatically based on cloud cover, time of day, etc.

Tracking Post-Collapse Food Sources: One of the most basic human needs is reliable access to food sources. However, vagaries of climate, seasons, access, and other factors may compromise this access. While researchers have previously explored ways of dynamically mapping the flows of materials through product supply chains outside collapse contexts [3], this project would seek to create an interactive system for monitoring a diverse array of food resources. The system could feature arbitrary ranges for various resources, with user-specified fuzziness of boundaries, and blendable confidence values to manage resource information from multiple sources. By providing a central and shareable way to track food sources, this system could be of significant use both to individuals foraging repeatedly in a given range, and to communities wishing to benefit mutually from shared food-gathering experiences.

Optimizing Arbitrage in Dynamic Barter Markets: In the absence of governmental infrastructure and stable currencies, it may be difficult to establish reliable exchange rates among various barter goods. Prices may vary across vendors in a market context, or across time in a series of interactions with one or more vendors. This project would build a computational system for optimizing trading policies in both concurrent and iterated exchanges. The system could take as input the available exchange rates in as many interactions are available, in whatever commodities are available. It would then seek to create transitive mappings across multiple commodities, as well as to perform predictive modeling of likely values of various commodities. The results of these calculations would be used to suggest optimal trading strategies and exchange rates. By optimizing arbitrage policies, this system could provide users with a competitive advantage in an unregulated and low-information-exchange market setting.

Currency, Infrastructure, and Societal Gatekeeping: Societies require the storage of value using media of exchange such as currencies in order to enable the easy transfer of seasonal and localized work across time and distance. Currencies typically require exchange participants to trust the issuer of the currency as well as the validity of the physical currency itself. The infrastructure of currency, however, enables the central authority to act in other gatekeeping roles as well. For example, flows of money across national borders are restricted, tax structures can be enforced, and a primary crime can be effectively punished on the basis of tax evasion as a secondary crime. When the trust in the centralized authority of the physical currency fails, not only does the currency system fail but so do the gatekeeping roles as well. This project would examine sources of trust in alternative digital currencies and how they span the digital-physical border. The examination would be done in light of how existing gatekeeping roles could be restructured and reimagined.

WHAT IF COLLAPSE NEVER COMES?

As has been evidenced time and time again across history, humans have a remarkable supply of ingenuity. Therefore, we may well avert collapse through a new energy source, geoengineering, the colonization of space, or some other as-yet-unconsidered approach. If collapse is somehow avoided, or delayed to the point where it's not yet relevant to give it much thought, won't the work on collapse informatics have been wasted?

We propose that no, the work will not have been wasted, for two main reasons. First, as was discussed in the previous section, collapse informatics has much in common with other HCI work. The overlap among projects and approaches among these genres makes a large portion of any research findings that may arise from collapse informatics efforts broadly relevant.

To offer a specific example, following publication of the results of the World3 model in the widely-circulated *Limits to Growth* [20], the 'Bariloche Group' of Latin American systems modelers offered the following critique: "The view that global crises will occur in the future reflects a parochial, developed-world perspective. For two-thirds of the world's population, crises of scarce resources, inadequate housing, deplorable conditions of health, and starvation are already at hand" ([19], p. 45). Given these crises, a subset of collapse informatics research efforts may be usefully adapted for use in other cultures and contexts.

Second, one of the key concepts of collapse informatics is designing sociotechnical systems with basic human needs at the heart of the process. Many research projects and commercial undertakings focus instead on perceived needs or manufactured needs, which then leads to a proliferation of complexity in many people's lives. This complexity not only hastens our progress toward collapse [31], but it also potentially compromises our quality of life. Humans evolved to deal with much narrower suites of issues than those that currently confront us [33]; the vast complexity of many people's lives may contribute to a lack of societal wellbeing via cognitive overload [35]. By seeking to foster more direct paths to meeting human needs, collapse informatics may also find new ways to make people happy.

FUTURE WORK

There are several main domains of future work that are relevant to collapse informatics. First, more work is needed to understand the details of how previous studies of collapse and various collapse scenarios may influence the goals and processes of collapse informatics as a genre of research.

Second, there are abundant potential projects in this area, across a wide variety of human needs, contexts, and habitats. The selection of fictional abstracts above provides just a small sampling of the wide range of potential research efforts that could be undertaken, and that could help improve human quality of life in collapse contexts.

Third, the question of how best to evaluate collapse informatics projects is of critical importance. The particular challenges of this class of cross-cultural design problem make evaluation an exciting area for future research.

Finally, there may be ways that collapse informatics can lay the groundwork for research outside of HCI pertaining to collapse, providing new kinds of collapse-compliant infrastructures that support efforts in other domains. To use a term from economics, computers are powerful "general purpose technologies" – their ability to amplify human efforts could have a profound effect on a range of other disciplines.

CONCLUSION

This paper is based on the possibility that global industrial civilization may enter a period of collapse, rather than indefinitely continuing the growth that has been its hallmark for much of the past two centuries. We propose that it is now appropriate for CHI researchers to begin exploring how our discipline may help to address the problems that would be likely to arise in such a scenario.

In this paper, we have defined collapse informatics as encompassing the study, design, and building of ICT and sociotechnical systems in the abundant present for use in a future of scarcity. Work in this area would seek to serve basic human needs, situated in particular contexts and habitats. We have drawn connections between collapse informatics and existing areas, offered initial thoughts on how research in this area may be evaluated, and provided a selection of potential projects that would be relevant to this domain.

While we see collapse as an unfortunate potential future, it is one that humanity's current ways of living make increasingly likely. There are many efforts afoot across many disciplines to enable sustainability; however, these efforts are often diametrically opposed to the culture of growth and consumption that pervades industrialized society. Perhaps by thinking now about life after collapse, we may both prepare ourselves for such an outcome, and also make that outcome less likely.

ACKNOWLEDGMENTS

The authors wish to thank the reviewers for their helpful feedback. We also thank Bonnie Nardi, Shunying Blevis, Sam Kaufman, Chit Meng Cheong, Rebecca Black, the Donald Bren School of Information and Computer Sciences, and the California Institute for Telecommunications and Information Technology. This material is based upon work supported in part by the

National Science Foundation under Grant No. 0644415 and by the Alfred P. Sloan Foundation.

REFERENCES

1. Baumer, E.P.S. and Silberman, M.S. When the implication is not to design (technology). *Proceedings of the 28th international conference on Human factors in computing systems (CHI 2011),* (2011), 2271.
2. Blevis, E. and Blevis, S. Hope for the best and prepare for the worst: interaction design and the tipping point. *interactions 17*, 5 (2010), 26-30.
3. Bonanni, L., Hockenberry, M., Zwarg, D., Csikszentmihalyi, C., and Ishii, H. Small business applications of sourcemap. *Proceedings of the 28th international conference on Human factors in computing systems (CHI 2010)*, (2010), 937.
4. Costanza, R., Cumberland, J.H., Daly, H., Goodland, R., and Norgaard, R.B. *An Introduction to Ecological Economics*. CRC Press, 1997.
5. Daly, H.E. *Toward a Steady-state Economy*. W.H.Freeman & Co Ltd, 1973.
6. Diamond, J. *Collapse: How Societies Choose to Fail or Succeed*. Viking Adult, 2004.
7. DiSalvo, C., Sengers, P., and Brynjarsdóttir, H. Mapping the landscape of sustainable HCI. *Proceedings of the 28th international conference on Human factors in computing systems (CHI 2010)*, (2010), 1975-1984.
8. Dourish, P. What we talk about when we talk about context. *Personal and Ubiquitous Computing 8*, (2004), 19-30.
9. Fayers, P.M. and Machin, D. *Quality of life: the assessment, analysis and interpretation of patient-reported outcomes*. Wiley, 2007.
10. Fry, T. *Design futuring: sustainability, ethics, and new practice*. Berg, 2008.
11. Hayes, G.R. The relationship of action research to human-computer interaction. *ACM Trans. Comput.-Hum. Interact. 18*, 3 (2011), 15:1-15:20.
12. Horning, J. and Neumann, P.G. Risks of neglecting infrastructure. *Comm. ACM 51*, (2008), 112.
13. Laurel, B. Gaian IxD. *interactions 18*, 5 (2011), 38-46.
14. Lovelock, J. *The Vanishing Face of Gaia: A Final Warning*. Basic Books, 2009.
15. Luers, A.L., Lobell, D.B., Sklar, L.S., Addams, C.L., and Matson, P.A. A method for quantifying vulnerability, applied to the agricultural system of the Yaqui Valley, Mexico. *Global Environmental Change 13*, 4 (2003), 255-267.
16. Matthews, H.D. and Weaver, A.J. Committed climate warming. *Nature Geosci 3*, 3 (2010), 142-143.
17. Max-Neef, M. *Human scale development: conception, application and further reflections*. The Apex Press, 1991.
18. McKibben, B. *Eaarth: Making a Life on a Tough New Planet*. Times Books, 2010.
19. Meadows, D. *Groping in the Dark: The First Decade of Global Modelling*. John Wiley & Sons Inc, 1982.
20. Meadows, D.H. *Limits to Growth*. Signet, 1972.
21. Meehl, G.A., Washington, W.M., Collins, W.D., et al. How Much More Global Warming and Sea Level Rise? *Science 307*, 5716 (2005), 1769 -1772.
22. Nelson, T.H. Crush and crash: logic of a terrible tomorrow. *Comm. ACM 40*, (1997), 90-91.
23. Norris, F. Time to Say It: Double Dip May Be Happening. *The New York Times*, 2011. http://www.nytimes.com/2011/08/05/business/economy/double-dip-recession-may-be-returning.html.
24. Pachauri, R.K. *Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. IPCC, 2007.
25. Pan, Y., Cheong, C.M., and Blevis, E. The climate change habitability index. *interactions 17*, 6 (2010), 29-33.
26. Rawles, J.W. *Patriots: Surviving the Coming Collapse: A Novel of the Turbulent Near Future*. Xlibris Corporation, 2006.
27. Schuler, D. Communities, technology, and civic intelligence. *Proceedings of the fourth international conference on Communities and technologies*, (2009), 61-70.
28. Shirky, C. Gin, Television, and Social Surplus - Here Comes Everybody. 2008. http://www.herecomeseverybody.org/2008/04/looking-for-the-mouse.html.
29. Silberman, M.S. and Tomlinson, B. Precarious infrastructure and postapocalyptic computing. *Examining Appropriation, Re-use, and Maintenance for Sustainability, workshop at CHI 2010*, (2010).
30. Silberman, M.S. and Tomlinson, B. Toward an ecological sensibility: tools for evaluating sustainable HCI. *CHI EA '10 Proceedings of the 28th of the international conference extended abstracts on Human factors in computing systems* (2010), 3469.
31. Tainter, J.A. *The Collapse of Complex Societies*. Cambridge University Press, 1990.
32. Tainter, J.A. Social complexity and sustainability. *ecological complexity 3*, 2 (2006), 91-103.
33. Tomlinson, B. *Greening through IT: Information Technology for Environmental Sustainability*. The MIT Press, 2010.
34. Vardi, M.Y. The financial meltdown and computing. *Communications of the ACM 52*, (2009), 5.
35. Walsh, R. Lifestyle and mental health. *American Psychologist*, (2011).
36. Wigley, T.M.L. The Climate Change Commitment. *Science 307*, 5716 (2005), 1766-1769.
37. Wong, J. Prepare for Descent: Interaction Design in our New Future. *Defining the Role of HCI in the Challenges of Sustainability, workshop at CHI 2009*, (2009).
38. Vulnerability, Resilience and Adaptation. 16:25:48.679192. http://ihdp.unu.edu/article/adaptation.