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Harnessing Collective Intelligence to Address Global Climate Change

Global climate change, caused by human-generated greenhouse-gas emissions, is perhaps the most pressing and important problem currently facing humanity. It is also unique by virtue of being a truly systemic problem of vast complexity: it affects every one of us, and is directly affected by every one of our actions. Like nothing else, the climate crisis calls upon us to engage in effective collective decision making on a global scale.

At the same time, the spectacular emergence of the Internet and associated information technology has created unprecedented opportunities for new kinds of interactions, via email, instant messaging, news groups, chat rooms, blogs, wikis, podcasts, and the like. As the well-known examples of Wikipedia and Linux illustrate, it is now possible to combine the work of thousands of knowledgeable and interested individuals in ways that were completely impossible a few years ago.

But these technologies have not yet been used to deal effectively with our global problems. Our societal conversations about controversial topics like global climate change are often strident and unproductive. And we have no clear way to converge on well-supported decisions concerning what actions, both grand- and ground-level, humanity should take to solve these problems.

In this paper we argue that it is now possible to harness computer technology to facilitate "collective intelligence"—the synergistic and cumulative channeling of

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the vast human and technical resources now available over the internet—to address systemic problems like climate change. What is needed, we believe, is a new kind of web-mediated discussion and decision-making forum.

Our focus is on a possible use of such a system with a particularly high social return: drawing on the best human and computational resources available to develop government policies about climate change. We will begin with stories about how different kinds of people could participate in such a global conversation. Then we'll briefly describe some of the technologies that would make such a conversation possible.

STORIES OF A POSSIBLE FUTURE

Today, governmental policy-making is complex, cumbersome, and slow. Experts can talk past each other, while experts and policy-makers have unproductive conversations. News media summaries are necessarily incomplete. Agreements between countries are especially difficult. And many intelligent members of the general public are passionate about these issues (on various sides) but see no way to contribute other than activism or changes in their own personal consumption.

Now, imagine a time a few years from now, when a new kind of on-line forum exists to help deal with these problems. Imagine that this forum is called the Climate Collaboratium. And imagine that it is used around the world, by thousands of people on all sides of the issues—experts, policy analysts, legislators, and concerned citizens—to collectively develop and debate scenarios to respond to global climate change.

Here are some stories from that possible future—purely fictional characters in real organizations, involved in activities that are on the cusp of feasibility:

Future Story 1. **A Scientific Expert**

As a graduate student in MIT Prof. Susan Lim's lab, one of Steve McKinnon's responsibilities is to report the lab's new results on the Climate Collaboratorium website. Today is an especially important day for the lab. *Nature* magazine has just published an article from Lim's lab estimating that the Southern Ocean's absorption rate for carbon dioxide is a surprisingly low 0.11 gigatons of carbon per year.

Steve goes to the section of the Collaboratorium website that summarizes the key arguments about many issues related to global climate change. He finds the *issue* called "What is the carbon dioxide absorption rate in the Southern Ocean?" and adds a new *position* stating the new result. Then, to support the new position, he adds an *argument* that briefly summarizes the *Nature* article and includes a link to its on-line version. This information is now easily available to anyone in the world who cares about this issue.

The positions that people had entered previously for the issue almost all had higher values than the new position. Most of the positions had been rated by a group of ocean scientists, including Prof. Lim, and the most highly rated previous position (endorsed by 39% of the experts voting) was an absorption rate of 0.33

gigatons of carbon per year. Because of the reputation of Lim's lab and the precision of their new measurement technique, Steve is confident that many of these experts will change their ratings over the next few weeks, and the new position he has just entered will become the most highly rated one.

Steve could stop there for today, but he is curious how much effect this new result will have on the overall climate situation. To test this, he goes to another part of the Collaboratorium that shows complete *scenarios* for what is likely to happen under different policy choices and other assumptions. He looks at two widely followed scenarios: (1) the "business as usual" scenario maintained by the MIT Program on the Science and Policy of Global Change reflects what will likely happen over the next 100 years with no significant changes in current policies and lifestyles; (2) the "Sierra Club" scenario, maintained by the Sierra Club, reflects a set of assumptions about aggressive policy and lifestyle changes by people and governments around the world.

In both scenarios, Steve goes to the issue for which he just added a new position, and indicates that he wants to adopt the new position. This automatically creates two new scenarios (shown as "children" of the scenarios with which he started). Then Steve clicks the "Simulate now" button and watches the new results appear. Even though Steve had worried that the results might have been even worse, the new simulations both show increases relative to the starting scenarios of only about .02 degrees Celsius in the global average temperature in 2100, with relatively minor effects on global economic output, adverse weather events (like hurricanes), and estimated quality of life.

Of course, the "Simulate now" option uses many rough approximations in its calculations. Full-scale simulations, using much more detailed calculations, can take days to run even on today's computers. But Steve thinks these new results are important enough that he clicks the button to "Request full simulation" for both new scenarios. He is pretty confident that either the MIT center or one of the other universities with full-scale simulations will be intrigued enough to run his new scenarios and generate much more detailed (and believable) predictions that incorporate Steve's new data.

Future Story 2. An Advocate

Sarah Schmitt is the Director of Policy Analysis for the United States Climate Action Partnership (USCAP), an alliance of businesses and environmental groups including Boston Scientific, BP, General Electric, General Motors, and Shell.

Starting about 18 months ago, Sarah and her staff led the creation of a set of detailed scenarios in the Climate Collaboratorium showing the consequences of USCAP's proposed program for capping emissions and then letting organizations buy and sell emission permits among themselves ("cap and trade"). Most of the people working on these scenarios were not actually employees of USCAP. Some were employees of USCAP member organizations paid to do this as part of their job, but many were volunteers—students, retired scientists, environmental hobbyists, and Wikipedia contributors—attracted to the USCAP scenarios because they seemed particularly promising.

The scenarios included detailed scientific assumptions about population growth, emissions rates for different kinds of vehicles, upper atmosphere chemistry, and so forth. But most of the people developing the USCAP scenarios were not computer programmers or climate change scientists themselves. Instead, they were able to build their scenarios by just selecting combinations of positions that had already been entered by specialists in different disciplines.

Sarah and her staff were happy to see that most of the simulated results of the USCAP cap-and-trade program were good under all the plausible combinations of different scientific assumptions. In fact, after USCAP endorsed these scenarios, over 80,000 other Collaboratorium users also endorsed them as their preferred alternatives.

Despite many conversations over the years, the US Chamber of Commerce is still not a member of USCAP. In fact, the chamber has tried to represent the interests of its many small-business members by developing a competing set of scenarios in the Collaboratorium. Today Sarah's staff has just shown her a new set of scenarios which they think incorporate the key elements of both the chamber and the USCAP scenarios.

After seeing the new scenarios, Sarah decides to recommend to her boss that USCAP propose them to the chamber. Of course, this will all take some negotiating. But Sarah is convinced that some form of these new scenarios will be enough to bring the chamber on board.

And when that happens, the Chamber of Commerce will bring with it the endorsements of over 50,000 members who have given their Collaboratorium proxies to the Chamber of Commerce. With these new endorsements, the USCAP scenarios will become—at least for a while—the most highly ranked scenarios in the entire Collaboratorium!

Future Story 3. A High School Student

Dinesh Rao is a high school student in Mumbai, India. He first heard of the Climate Collaboratorium in his honors science class last year. One of the class's homework assignments was to use a simple entry-level simulation in the Collaboratorium and find a combination of parameters that would reduce the atmospheric concentration of carbon dioxide to less than 350 parts per million by the year 2100.

Dinesh's teacher had also asked the students to study the most highly rated arguments on both the "yes" and "no" positions for the issue "Should we rely on unknown future technological advances to solve climate problems that would be expensive to address today?" Unlike many of the positions in the Collaboratorium, this one is a philosophical issue, not directly tied to specific parameters or other simulation elements in particular scenarios. But this issue has attracted a lot of attention, and the arguments on both sides of the issue are very well developed.

Dinesh found the climate change work so interesting that this year he joined a student team in the FIRST Climate Change competition. FIRST is a US-based non-profit founded to inspire young people's interest and participation in science and technology. For years, it has organized competitions where teams of high school students build robots, and it has recently started a new competition based on the Collaboratorium.

The goal of this competition is to come up with climate change scenarios that are both plausible and desirable. To be plausible, a scenario has to use positions that have probabilities of at least 50% as rated by FIRST-approved experts in the relevant subjects. To be desirable, a scenario should include the smallest possible increase in global average temperature, and the highest possible value for global economic output and estimated quality of life.

Dinesh's team is working on a detailed scenario that includes massive use of telework (including telephone, email, and advanced videoconferencing) to replace most daily commuting and business travel. Dinesh and a couple of his teammates are excellent computer programmers, so they are writing some new software modules for the simulation itself. Two other teammates are artists developing a video enactment of what life would be like for a Mumbai call center worker under this scenario. Dinesh's team has already won several awards in the Mumbai competition, and he thinks they have a good chance of winning more in the Indian national competition.

Dinesh also knows that last year, many elements from the scenario developed by a winning high school team in California were later adopted by the Conservative Party in the U.K., and he dreams that his team's work may someday be as influential.

Future Story 4. **An Open-Source Software Developer**

Matt Shields works in Santa Clara, California, designing integrated circuits for Cisco. He loved programming in college, but now he doesn't get much chance to write software at work. So for several years, he has spent some time at night and on weekends contributing to the Linux open source software project.

Matt is also passionate about environmental issues. He drives a hybrid car, recycles everything he can, and recently has been thinking about getting involved with some kind of environmental activism. When he heard about the Climate Collaboratorium, he knew it was for him! Here was a place where he could use his programming skills, indulge his passion for software, and try to make the world better, all at once.

The current version of the most widely used Collaboratorium simulator divides world economic activity into five major regions. For the last six months, Matt has been working on new software modules that will allow people to subdivide these regions into much smaller units (such as countries, states, and cities). Matt had a clever idea about how to do this, and he's now almost through debugging the new software he wrote. With a little luck, he hopes to get his new modules accepted by the Collaboratorium software committee and included in an official software release sometime next month. And he hopes that soon after that, people all over the world will be using his software to develop more detailed models of their own cities and regions.

One of Matt's friends recently got a job offer from Google, based in part on the volunteer programming work he had done on the Collaboratorium. Matt is happy with his current job, so he's not looking to copy his friend. But he sometimes daydreams about a day—many years from now—when he can tell stories to his grandchildren about how, in his twenties, he helped saved the world from a global climate catastrophe.

Future Story 5. A congressional staffer

Mary Dominguez is a senior legislative assistant for U.S. Sen. Karen Williams (Democrat, Colorado). Mary is responsible for all the environmental legislation in Sen. Williams' office; for the past couple of years she has been monitoring changes in the Climate Collaboratorium fairly frequently. She has noticed that shifts in Collaboratorium endorsements are often good predictors of how public opinion polls will change several months later.

Recently she noticed a significant increase in endorsements for tighter limits on a cap-and-trade program in the U.S., so she decides to talk to Sen. Williams about how this new information should influence the environmental bill the senator is currently drafting with a Republican colleague.

HOW COULD ALL THIS BE DONE?

The stories you have just read are not impossible fantasies. With a suitable combination of technological support and on-line community building, all could feasibly be realized. Three primary types of technology would be required: (1) on-line argumentation systems; (2) computer simulations; and (3) collective decision-making tools.

On-line Argumentation Systems

Today's on-line discussion forums, blogs, and chat rooms do a good job of encouraging lots of people to express their opinions and share them widely. But these systems are not very good at supporting evidence-based, logical deliberation: the quality of contributions can vary enormously. Discussions of controversial issues are often hijacked by a narrow set of "hot" issues or "loud" voices. The same basic ideas may be entered many times in slightly different ways in different places. And it is difficult to find the most important comments on a specific issue embedded in many other topics.

One promising approach for dealing with these problems is using systems for on-line argumentation[1]. As several of the stories above suggest, these systems can help groups define networks of issues (questions to be answered), positions (alter-

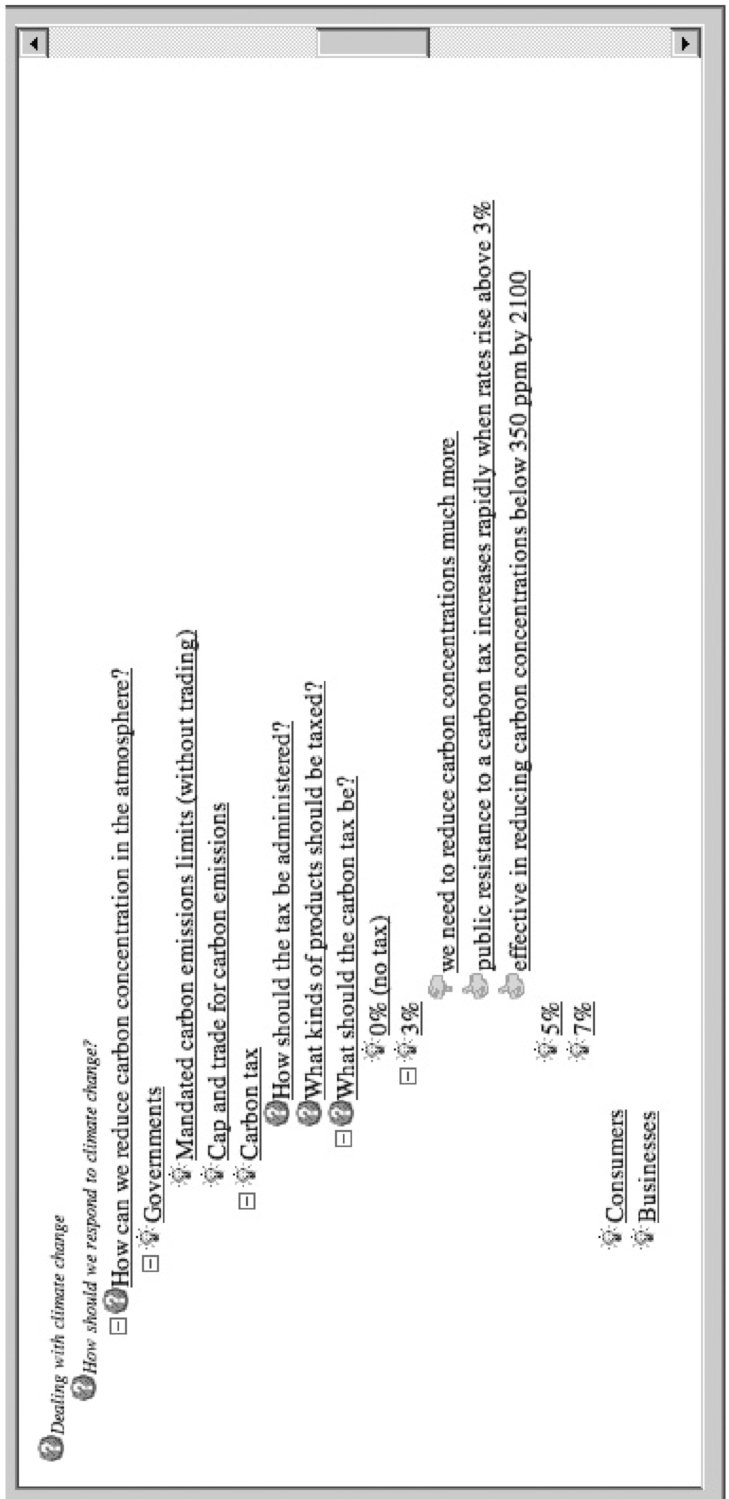

Figure 1. A sample argument structure

native answers for a question), and arguments (statements that support or detract from some other statement) (See Figure 1).

Such tools can help make deliberations, even complex ones, more systematic and complete. The structure implicitly encourages users to express the evidence and logic in favor of the positions they prefer. The results are captured in a compact form that makes it easy to understand what has been discussed to date and, if desired, add to it without needless duplication; this encourages synergy among group members and helps the system accumulate information and opinions across time.

Tools like these have been used successfully for decades in small face-to-face groups with skilled facilitators who help the groups organize their comments into a logical structure. But a critical barrier to the use of these systems is the effort and skill required to structure discussions in this logical way. Fortunately, however, such systems might actually work better at the large scale suggested by the stories above, for a few reasons.

First, the number of distinct issues, options, and arguments in a discussion will grow much more slowly than the number of participants. Thus, after a few of the key issues, positions, and arguments have been entered, it will become much easier to find the places where additional ones should go. Second, in a large, web-based conversation, people who are naturally good at mapping arguments in this logical way will be able to apply their skills more easily over a much larger base of users and comments. Just as some people in Wikipedia spend much of their time copyediting contributions others have made, we expect that some people in a forum like this would spend much of their time improving the logical structure for comments that others have made.

Together, these aspects of structured argumentation systems have the potential to make group deliberation much more productive than ordinary conversations. But the users of such systems are still, in a sense, "just talking." They might, for instance, spend huge amounts of time analyzing and debating issues that are actually trivial in the overall scheme of things. And they have no systematic way of understanding how positions on different issues interact with each other. For example, will the potential benefits of energy-saving light bulbs in US homes be completely overwhelmed by emissions from coal-powered electric plants in China? And if people telecommute from home more often, will the reduced carbon emissions from less commuting be outweighed by increased emissions from more home heating?

The only way to answer questions like these accurately is to use quantitative models to analyze complete scenarios of the whole climate-related system. And that requires another type of technology: computer simulations.

Computer Simulations

Fortunately, many organizations have developed computer simulations that make this possible.[2] These simulations include economic and social factors such as pop-

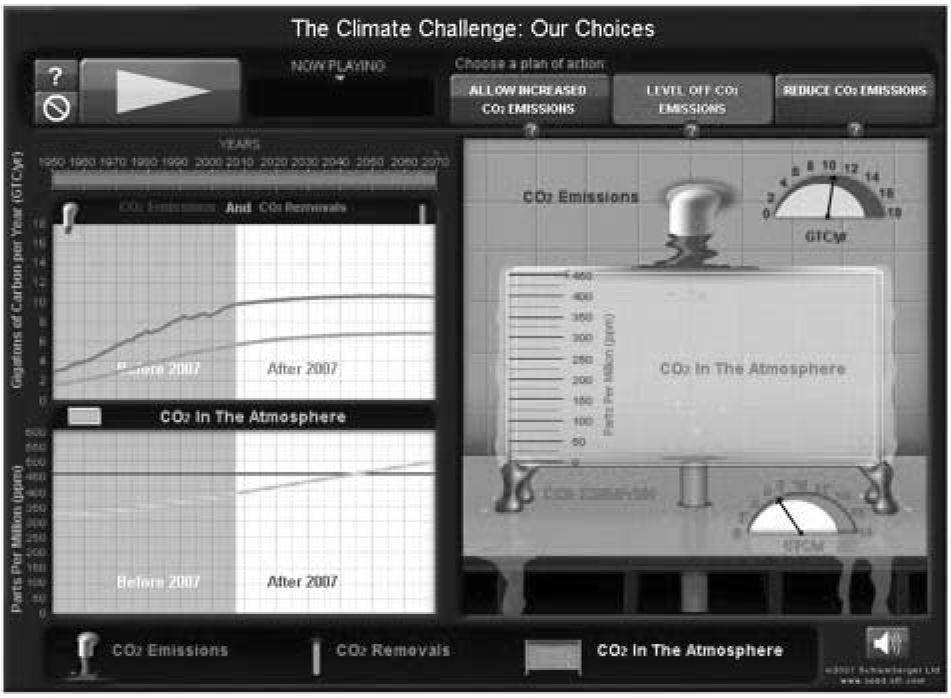

Figure 2. Sample simulation program (from Senge et al, 2007).

ulation levels, transportation usage, residential heating, and manufacturing intensity, as well as physical factors such as carbon emissions, ocean chemistry, and the effects of atmospheric carbon on temperatures at the earth's surface.

In order to run these simulation programs, a set of parameters is needed. Fortunately, as the stories above suggest, the selection of these parameters can be linked to the argumentation system in a natural way. Each parameter in a simulation can be mapped to an issue in the argumentation system, and the different positions for that issue can correspond to different possible values for the parameter. For instance, in the first story above, Steve McKinnon entered a new value for the parameter representing an issue about carbon dioxide absorption rate in the Southern Ocean. Then, after he added the value, both he and others could add arguments, for and against that position.

By choosing positions for all the parameters in a given simulation, users can define scenarios. Then, if they want, they can also ask for these scenarios to be simulated. Simple simulations can be run immediately. If a simulation program requires substantial computer time, the request may need to be approved and the results may not be available for days. In either case, the complete scenario, including the results of the simulation, can then be stored for others to review.

The easiest way to start developing a system like this is with a single, simple simulation program, such as the one shown in Figure 2. But as the stories at the beginning of this article suggest, many alternative simulations—developed by many different people and organizations—could potentially be linked into the same framework. And users of the system could then debate the relative advantages and disadvantages of different simulation programs as they evaluate the overall scenarios being analyzed using these programs. One possible outcome of this effort, therefore, might be a vast library of (somewhat) interoperable and publicly accessible climate-related simulation programs developed by many people all over the world.

Collective decision-making tools

On-line argumentation and computer simulation provide a powerful way to explore many possible models of—and responses to—global climate change. But using these approaches alone runs the risk of just generating and evaluating an ever-expanding set of possibilities, with no way to converge on the most promising. For that, a third type of technology is needed: tools for collective decision-making.

A simple but useful possibility, for instance, is just to let all users of the system vote on the position(s) they favor for each issue. Then, the system can automatically display positions in order of the votes they have received, and it can automatically run simulations every day showing the combined results of the most highly ranked positions.

A slightly more sophisticated possibility is to show votes separately for different kinds of users. For instance, for issues that involve specific scientific expertise (like the Southern Ocean's rate of carbon dioxide absorption), the system might show only the votes from people who have been certified as having expertise in those areas. But for issues involving value choices (such as "How much economic sacrifice should we make today to reduce the probability of substantial sea level rises for our great-grandchildren?"), the votes of ordinary people might count like those of experts.

In some cases, it may also be appropriate to use not just votes, but probability estimates. One promising way to generate probability estimates from a group is to use "prediction markets" where people buy and sell predictions about uncertain future events and are paid only if their predictions are correct. Such prediction markets have been found to be surprisingly accurate in a wide range of situations, including forecasting product sales and US presidential elections[3].

One of the most intriguing possibilities is what might be called "proxy democracy"[4]. With this approach, rather than expecting everyone to vote on all issues, users could give their voting proxies to other individuals or groups whenever they wanted to. For example, you might give your proxy on scientific issues to the Federation of American Scientists while giving your proxy on "values" issues to the Sierra Club. Anyone who has someone else's proxy could, in turn, delegate it further, and you could always see how those who had your proxy voted on your behalf. If you didn't like the way someone used your proxy on a given issue, you could always retrieve your proxy and vote directly on that issue.

Such a system doesn't require people to spend any more time on issues than they want to, but it lets them express their opinions at whatever level of detail they want, from very general to very specific.

As the stories above suggest, proxy democracy also has another desirable property: organizations that want to increase their influence are motivated to negotiate with other groups and to recruit more of their supporters to join the overall discussion forum because that will increase the number of people whose proxies they control.

CONCLUSION

The web-based forum we have described is, simultaneously, a kind of Wikipedia for controversial topics, a Sims game for the future of the planet, and an electronic democracy on steroids. If we could build it, our societal conversation about global warming could go beyond the realm of the all-too-often emotionally-driven yes/no votes about small numbers of simplified alternatives. It could, instead, facilitate reasoned and evidence-based collective decision-making about highly complex issues.

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Endnotes

1. See Moor and Aakhus (2006); Klein and Cioffi (2007).
2. See for example Nordhaus (1994); Dowlatabadi (1995); Weyant (1999); Fiddaman (2002, 2007); Sterman (2002).
3. See, for example, Wolfers and Zitzewitz (2006).
4. See, for example, Malone (2004, p. 65, footnote 21) and http://en.wikipedia.org/wiki/Liquid_democracy.

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