ACCELERATE

Building Digital Models to Navigate the 21st Century's Ecological and Social Systems

Abstract

Humanity created, captured, copied, and consumed more than 64 trillion gigabytes of data last year. This deluge of information is being used to try to model the world around us in unprecedented detail. That includes complex systems like cities, ecosystems, and the climate. Going forward these models will become increasingly intermeshed, creating sprawling socioecological simulations that can provide policymakers with invaluable foresight on the outcomes of economic, environmental and social policies. While those simulations, often referred to as "digital twins", can provide knowledge about the potential evolution of a system, big data and machine learning approaches have so far failed to capture the full complexity of real-world situations and different feedback loops. Finding ways to combine models with different scales and purposes and ensuring that today's biases and prejudices are not baked into them, will require a sustained interdisciplinary effort that includes full engagement among citizens.

- Many initiatives for "digital twins" have been recently launched. To what extent will these initiatives be able to reproduce the complexity of real-world systems?
- Can we combine models of physical reality with those simulating more intangible social phenomena?
- How reliable are today's leading models and how can policy makers use them wisely?
- How can we ensure models used to guide policy are transparent, equitable and explainable?

Participants

Moderated by:

Chris Luebkeman, Leader, Strategic Foresight Hub, Office of the President, ETHZ, USA

With:

Maurice Borgeaud, Head, Department Science Applications and Future Technologies, Directorate, Earth Observation Programmes, European Space Agency, Switzerland

Sean Cleary, Executive Vice-Chair, FutureWorld Foundation; Member, Advisory Board, Carnegie Artificial Intelligence & Equality Initiative; Managing Director, Centre for Advanced Governance; Member, GESDA Diplomacy Forum, South Africa

Neil Davies, Director, University of California's Gump South Pacific Research Station on Moorea (French Polynesia); Research Affiliate, Berkeley Institute for Data Science; Vice President, Tetiaroa Society, USA

Dirk Helbing, Professor, Computational Social Science, Department of Humanities, Social and Political Sciences; Affiliate, Computer Science Department, ETHZ; Member, GESDA Academic Forum, Germany *(remotely)*

Mami Mizutori, Special Representative of the United Nations Secretary-General for Disaster Risk Reduction; Head, UNDRR; Member, GESDA Diplomacy Forum, Japan

Philippe Gillet, Chief Science Officer, SICPA; Former Vice President, EPFL, France

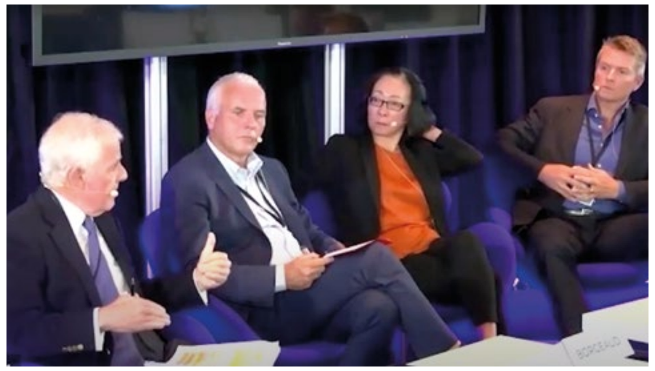
Highlights

A campaign run by the United Nations Office for Disaster Risk Reduction (UNDRR) sums up how human-caused problems increasingly affect our home planet: "There is no such thing as a natural disaster." The slogan also points to how factors such as fossil fuels, nationalism, disregard for developing countries, poverty and urban sprawl all degrade the environment and cause more frequent and intense calamities. "Human beings are now becoming the problem of most of the things in the world of disaster and risk," said Mami Mizutori, a veteran diplomat who heads the agency, emphasizing that 30 million people were displaced by disasters last year, triple the ten million people displaced by conflict. She acknowledged natural hazards like earthquakes and tsunamis, but pointed to humankind's poor stewardship as the cause of more extreme weather events such as storms, floods, and heat waves. "Are they really natural?" she asked. "We do not think so."

These global risks are being studied in digital models and simulations, which can cut across silos of information and data and often include a metric of resilience. To help people prevent hazards from becoming disasters, such models are an "extremely important" tool, Mizutori noted. "Because if we don't know the current situation, the baseline, as well as what happened historically, and what will happen in the future, we won't have good policies to mitigate the risk. And I would think that good models that have the vulnerabilities, the exposure, and the hazards element in it – past, future and importantly current – will really help us understand better what are we living through and what can we do."

Such risk prediction models are one example of the trend that started a few years ago around the use of so-called "digital twins" with complex systems like cities, ecosystems and climate. For example, Maurice Borgeaud, an engineer responsible for science, applications, and climate at the European Space Agency, said his agency, the European Commission, European Organization for the Exploitation of Meteorological Satellites (EUMETSAT), and European Centre for Medium-Range Weather Forecasts (ECMWF) all started examining the use of digital twins about two years ago with forestry and food systems. The project, now called Destination Earth (DestinE), aims to develop a high precision digital model of Earth to monitor and simulate natural phenomena and related human activities.

Some of these tools are being built to deal with global issues, but others are needed at a local scale, too, said Neil Davies, an evolutionary geneticist. About eight years ago, while at ETHZ, he created a digital twin – then called an "island digital ecosystem avatar" – of Mo'orea, an island just off the coast of Tahiti in French Polynesia. The idea was to build a decision support tool that was rooted in science data, and to build in disaster resilience, so that local governments could better prepare and respond. With disaster reliance becoming an increasingly important issue, the question of building climate resilient communities is taking on added urgency.



Those models are particularly useful for dealing with the construct of an Anthropocene era, roughly since the end of World War II, in which humans now have more effect on the environment than the environment affects humanity, creating a vicious and destructive cycle, according to Sean Cleary, reinforcing Mami Mizutori's assertions . An author and lecturer on global corporate strategy with combined expertise in business and diplomacy, Cleary said that "now what we can see all around us in terms of challenges, from pandemics to wildfires in Siberia, to methane emissions, to extreme weather right across all parts of the globe, to the threat to island communities, demands a response. Unfortunately, we can't experiment at scale in the real world. If we could, maybe we'd be able to solve some of these things. But the last 20 months of COVID suggests that we're not terribly good at that. We battle to play catch up when we are caught unawares by a crisis upon us. And the logic behind digital twins, the logic behind digital simulations is potentially to give us anticipatory capability that enables better responses at different scales, enabling society at large, human society, national governments, multilateral institutions of different sorts, to anticipate risk in the context of disaster associated with hazard and vulnerability and exposure, in appropriate ways to work out what we ought to do about it." To Cleary, the advantage of digital twins is that they represent "experimental landscapes within which we attempt to explore what may happen under particular conditions, alternative scenarios in that respect, and what contributions humanity in different ways is making towards these particular problems, and what might be done through policy in order to address those challenges". "That's the logic of this discussion. Now, there are also huge limitations."

These limitations go from being "obstructed by biases, randomness, turbulence, chaos theory, and many other things", said Dirk Helbing, a professor and physicist. "Creating an accurate digital twin for material structures, which change all over time, is easy. However, it will probably never be possible to produce an exact digital twin of life on Earth, or of our body, or of our health. And we need, therefore, to expect uncertainty. We need to have a complexity science approach on machine learning. The biggest modern machine learning models publicly known today try to learn a trillion parameters or so. However, sometimes simpler models have more predictive power and less data." And when it comes to building in an AI-powered intelligence system that could help solve the sustainability problems of the planet, that could be risky, he said, because the system "might figure out that the easiest solution would be depopulation. It might trigger an apocalyptic scenario, even though a better future for everyone might exist."

Not everything can be modelled, said Cleary, but "if we do not have a landscape in which to explore, we are not likely to be able to anticipate and respond appropriately". Davies said the most important thing is access to data needed to feed models, which depends on politics and diplomacy. "If you want really to make progress in this field, you will have to share information here," said Borgeaud, agreeing with Davies. "Since 2008, with the Copernicus satellites, we have a full, free and open data policy. This completely changed the way that people are using the data. And it should be the same for models: hiding some of them will not help to move forward."

For Helbing, it is important to have open models that can be challenged. "This is how we make progress in science," he said. "Besides, having a pluralistic approach of models is always beneficial" because combining them often brings better results than using each model individually, as shown with tsunami prediction models. "But altogether, uncertainty will remain," said Helbing. "That means we need to learn to be more flexible, adaptive and responsive as part of what we need to build in terms of the participatory resilience capacity of our systems. We should not plan for systems that will not change over time, but rather design for systems that can flexibly adjust to the circumstances."

The simulations "simply demonstrate how much we don't know," Davies said, after pointing out another aspect of the model he is developing in Mo'orea. "We're starting at the very, very small scale and connecting it to all these data that are coming from satellites. And today, we're kind of launching into a second phase. So, this is an opportune time which tries to connect the science more to society and sort of renames the initiative a little bit as now a sort of collective intelligence infrastructure for democratic ecological action. It's a collective intelligence idea. We need to go much faster to implement that now. And that needs to be implemented from the bottom up as well as from the top down," he said. "We need to share the data, and what we learn about ourselves, with others. Because we can learn from the misfortunes that might happen to others."

Mizutori said she recognized the usefulness of scientific digital twins, but found that "models are useful as long as there is a literacy in the communities to translate that into policies. Otherwise, we can have fantastic models, but it won't work". Luebkeman said that might be "something where GESDA can help". Policymakers are not following the science, said Mizutori, exacerbating a vicious circle of disasters, response and recovery. Another problem – which is about the digital divide between North and South – is: "if good policy makers in the South want to listen to the science but have neither the capacities nor the funding to do so, how do we overcome this? If we don't, on the global scale, we are not going to make it." To address these issues, Cleary proposed creating something like an observatory of such models, entailing three elements. The first is to allow transparency in capturing the initiatives that are being undertaken, and to include a much wider set of data and information from a variety of organizations (from the International Monetary Fund through the UNDP, WHO, WMO) that feed decision-making. He also proposed adding more oversight of the process and making greater efforts to ensure citizens are actively involved. "The second element is to have some measure of oversight into this process itself, because otherwise, you cannot build the trust, you cannot do the interrogations, you cannot clarify the missions that are at stake," he said. "One approach is to have, into this observatory, a science lens, a policy lens and finally a public lens, to allow for public participation." The third element flows from that latter lens: This observatory shall try "to ensure citizen engagement, through a digital agora. We can enable that digitally nowadays, we can enhance the trust around understanding, and potentially make a constructive contribution to the evolution of sensible policies."

Takeaway Messages

Digital twins function as experimental landscapes that let scientists analyse risks, support decision-making and foster disaster resilience, which is becoming important to adapt to climate change.

The critical thing is not to imagine that scientists are going to be able to model everything and then to be able to draw definitive conclusions.

There are limitations from being obstructed by biases, randomness, turbulence, chaos theory. It will probably never be possible to produce an exact digital twin of life on Earth, or of our body, or of our health. And we need, therefore, to expect uncertainty.

A digital avatar project in French Polynesia, rooted in open science, was aimed at helping local governments better prepare, respond, and build climate resilient communities. Such projects use a collective intelligence infrastructure to possibly spur democratic ecological action.

The transition to open science and a full, free and open data policy have spurred many digital twin initiatives and is vital for such models.

Models are useful as long as there is a literacy in the communities to translate their results into policies. Otherwise, the most fantastic models will remain helpless.

An observatory could be put in place to 1) capture existing initiatives of "digital twins", 2) include some oversight in the process to increase trust and 3) ensure citizen engagement, through a digital agora.

Additional content

THE “4P” APPROACH, by Neil Davies

Focusing on the goal of helping communities, Neil Davies explained that his approach was largely inspired by medicine, and the so-called “4Ps”. For him, good digital models must be the result of an approach that is:

1/ Personalized

“Every person is different, with a different genome. In the same sense, every place is also different.”

2/ Predictive

“One needs to understand all of the diversity in place, in order to make predictions under different scenarios. This, in order to be...”

3/ Preventive

“We need prevent outcomes so we can maximize wellness, and not just treat sickness [talking about medicine].”

4/ Participatory

“Not only do we need to take some agency in our own health, because if we are all going to monitor our own health we need to take control of that to some extent. But also we need to share the data and what we learn about ourselves with others. Because we can learn from the misfortunes that might happen to others. We can learn ‘I have that kind of genome too, and if you had a bad reaction to that drug it’s useful for me to know that because I might have the same genomic signature and that helps me’.”

“So we try to apply that systems biology approach to social ecological systems. This is for the health of places, people, and natural systems,” he explained

Digital twins (digital models of the world or parts of it): 12 statements, by Dirk Helbing

1/ On data

It has become an attractive idea to create digital twins of everything, including the Earth, the climate and the human body. While the benefits of this approach may be huge, it is also important to realize the limitations. For example: attempts to create an exact digital copy of the world are obstructed by biases, randomness, turbulence, chaos theory, and many other things. This needs to be kept in mind. All in all, we must realize that a data-science rather than a data-driven approach is needed.

2/ On complexity

Creating an accurate digital twin for material structures, which change little over time, is easy. However, it will probably never be possible to produce an exact digital twin of life on Earth, or of our body, or of our health. We are faced with fundamental challenges and measurement limits when models of complex dynamical systems are built. We need, therefore, to expect uncertainty. We need to have a complexity science approach.

3/ On machine learning

The biggest modern machine learning models publicly known today try to learn a trillion parameters or so. However, sometimes, simpler models have more predictive power; less data, or even noisy data, can sometimes generate better models. No matter how many variables are being considered, however, there are many orders of magnitude of interaction effects which are not captured, hence neglected. This can produce a wrong picture and bad forecast, which can be dangerous.

4/ On artificial intelligence

So far, big data has not made the scientific method obsolete, nor do we have a universal AI. And if we had one, this could still be dangerous. Suppose, for example, one would task an intelligent system to solve the sustainability problems of the planet. It might figure out that the easiest solution would be depopulation. And it might trigger an apocalyptic scenario, even though a better future for everyone might exist. Moreover, as many of today’s AI systems operate like ‘black boxes’, we may not realize some of the harmful effects AI systems are causing.

5/ On optimization

The concept of ‘optimizing the world’ is highly problematic because there is no science that could tell us what is the right goal function to choose: should it be GDP per capita, or sustainability, life expectancy, health or quality of life. The problem is that optimization tries to map the complexity of the entire world to a one-dimensional function. This leads to gross oversimplifications and to the neglection of secondary goals, which is likely to cause other problems in the future. Using a co-evolutionary approach would probably be a better strategy than optimization. And coordination approaches may be more successful than control approaches.

6/ On qualities

A largely data-driven society is expected to perform poorly with regard to hardly measurable qualities that we care about. This includes freedom, dignity, love, creativity, meaning, culture – in short: quality of life.

7/ On innovation

Something like a ‘digital crystal ball’ is unlikely to see disruptive innovations which are not included in the data of the past. Hence predictions could be overly pessimistic and misleading. For example, consider

the forecast of world’s population. According to some future projections, about one-third of the world’s population is claimed to be ‘overpopulation’. These people are in danger of dying early of resource shortages. However, such projections do not sufficiently consider alternative forms of running our economy. Perhaps ‘overpopulation’ is not the main problem, but the lack of economic (re-)organization.

8/ Humans *versus* things

In a highly networked, complex world, where almost everything has ‘side effects’, feedback effects and cascading effects, ethical challenges abound. For example: people should not be managed like things. In times where many argue with ‘trolley problems’ and ‘lesser evils’, if there’s just a big enough disaster, problem, or threat, any ethical principle or law might be overruled, including human rights and even the right to life. Such developments can end with crimes against humanity, and that needs to be avoided.

9/ On dual use

A powerful tool, particularly when applied on a global scale, may cause serious large-scale damage. It is therefore necessary to map out undesired side effects of technologies in their use. Effective measures must be taken to prevent large-scale accidents and dual use. Among others, this calls for decentralized data storage and distributed control. Moreover, transparency and accountability for the use of data and algorithms must be dramatically improved.

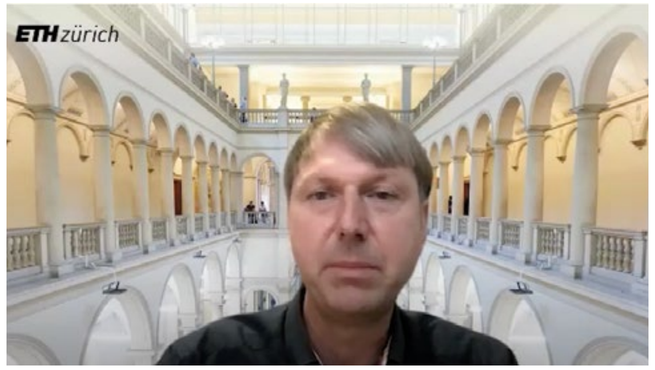
10/ On alternatives

We should carefully consider alternative uses of technology. I very much would like to push for the idea of creating a socio-ecological finance system, that would use the Internet of Things to measure externalities that decisions of people and companies cause. This novel real-time feedback would promote the core evolution towards circular economy and sharing economy. So this would be really oriented at change and action, rather than just observation and prediction.

11/ On governance

As people are increasingly an integral part of socio-technical systems, a technology-driven approach is not enough. We first and foremost need social innovation to unlock the benefits of the digital age for everyone. A platform supporting true informational self-determination is virtually needed. And rather than a ‘war room’ approach, we need a ‘peace room’ approach, which requires, among others, an interdisciplinary, ethical, multi-perspective approach. In other words, a new multi-stakeholder approach to achieve better insights and participatory resilience.

So, in conclusion: smart societies cannot be operated like fully automated machines – and there’s a strong imperative not to attempt it. When designed and operated without sufficient insight, digital twins may create a ‘matrix world’ and technological totalitarianism. But designed and operated it well, digital models of the world – or certain aspects of it – can offer a formidable policy instrument, not only for the management of cities and societies, but also for the co-evolution of evidence- and data-based information ecosystems that can foster a new collaborative relationship between citizens and policy makers. And that’s what we’re aiming for.



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