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The Dream of Controlling the World – And Why It Is Failing

Dirk Helbing ML (Zurich, Switzerland)[1]

Abstract

If we just had enough data, could we optimise the world and run it like a 'benevolent dictator'? The answer is no. The attempt to build a digital crystal ball to predict our future and a digital scepter to control it is destined to fail, no matter how powerful the information systems we build are. Even though we have moved from a time when there was too little data for evidence-based decisions to a time in which one can make data-driven decisions, there is still a gap between the complexity of the world and the data we have on it. And this gap is rapidly broadening. Though our computational powers are exponentially increasing, they cannot keep up with the increase in complexity! I call this problem the 'complexity time bomb'. Fighting complexity is a lost battle if we do not learn how to use complexity to our advantage by turning from centralised to distributed control and from a top-down to a bottom-up approach that supports self-organisation and self-governance.

In his 2008 essay *The End of Theory*, *WIRED* author Chris Anderson[2] formulated a dream: the truth, he argued, would reveal itself if we just had enough data. Then, the right course of action to improve the world would directly follow from the data. Therefore, governments and companies have recently collected huge piles of data. Secret services are monitoring every citizen in increasing detail, and a number of companies are doing this too. So, are we beginning to see Chris Anderson's dream come true? Can big data yield the best possible decisions? Does it allow to rule the world like a 'wise king' or 'benevolent dictator'?

Every day, companies such as Google and Facebook conduct millions of behavioural experiments on us to figure out how we can be nudged to click a certain link or buy certain products. Increasingly, we are becoming remotely controlled beings, and this novel approach to governance is becoming more and more interesting for politics, too (Thaler 2009, Sunstein 2016). It turns out that nudging can change our behaviour, but it has failed to make us healthy and slim and nice to our environment. So, today's nudging is not as efficient as its inventors would like it to be. But stronger reinforcement mechanisms such as personalised pricing are constantly being developed.

China is even testing a citizen score, a personal number that represents your obedience; if you do something desirable, you will get plus points, but if you deviate from the expectations of those who rule, you will get minus points.[3] A similar secret service programme called 'Karma Police' is run in Great Britain. In conclusion, today basically everything you do is

1 Swiss Federal Institute of Technology, Zurich, Switzerland.
2 See Anderson 2008.
3 See Stanley 2015, *Big Data* 2016.

being tracked: the links you click,[4] what your political opinion is and whether it supports that of the government, whether you pay your loan on time, or whom you interact with. All that data is being evaluated and can determine what kind of job you get, what interest rate you receive, and also what countries you are allowed to travel to – that is the plan, at least in China.

This is Orwell's 1984 combined with Huxley's *Brave New World*. Certainly, top-down systems like these can force people to do certain things. Maybe one could even make entire societies behave in certain ways, if people are likely to oppose the intended changes were to be removed using a 'predictive policing' approach. This is being discussed, too, and algorithms to determine who might do something wrong or might disturb the public order have already been developed. So we are pretty close to a totalitarian society in which you do not need to violate a law to be put to prison – the likelihood or the possibility that you might disturb the plan of the government might be enough. These algorithms also take into account your social contacts, your friends, and your neighbours. Even if your behaviour is perfectly okay, the behaviour of your friends or neighbours could mess up your entire life. I do not think this is the kind of society we would like to live in.

The technological revolution has brought our society to a crossroads, where we need to make up our minds and decide what our digital future should look like (Helbing 2016a, 2015c). Data-driven versions of various historical forms of government can now be built: fascism 2.0 (a totalitarian 'Big Brother' society and 'brave new world'), communism 2.0 (a state that believes it knows what is best for us and would impose it on us – the 'Big Mother' society), feudalism 2.0 (the 'Big Other' society [Zuboff 2015], also known as 'surveillance capitalism' run by global IT corporations). Of course, we could also build a democracy 2.0 – a participatory society that empowers people and fosters collective intelligence.

If we do not pay attention now, we could lose freedom and self-determination, human dignity, assumed innocence, fairness and justice, pluralism, democracy, participation, and most likely peace and many of our jobs. This is not just a theoretical threat. We have seen how easily democracies can be turned into other forms of government. It happened in Hungary. It is happening in Turkey, in Poland, and in France. Democracy has become pretty unstable, so it is time to speak up and defend it. Because I still believe it is the best system if we just upgrade it with digital means.

Privacy, human rights, and the division of power are important to sustain peace. Self-determination promotes creativity and innovation. Pluralism and diversity are the basis of societal resilience (Helbing 2015a, b) (the ability to deal with shocks and other unexpected developments), for high innovation rates, and collective intelligence (Page 2007). I am convinced that co-creation, co-evolution, collective intelligence, self-organisation, and self-governance, considering externalities (i.e. external effects of our actions), will be the success principles of the future.

1. Upgrading Democracy with Technology

I am not against the use of technology such as Big Data and Artificial Intelligence – on the contrary. However, I am arguing for a different use of technology – a way of use that is

4 Revealed by Beall 2016, Martin 2016, Fox-Brewster 2017.

now called 'values by design' or 'ethically aligned design'. IEEE (Institute of Electrical and Electronics Engineers) has recently drafted guidelines in this direction (*IEEE* 2016), and Elon Musk shares this perspective too. He has invested one billion US dollars into the OpenAI initiative to make artificial intelligence an instrument for everyone (Mack 2015). In the meantime, Amazon, Apple, Facebook, IBM, and Microsoft have decided as well to work on the development of moral artificial intelligence (Hern 2016). Even Pope Francis has spoken up. He demands a Europe 2.0, a new European humanism, and asks: "What has happened to you, the Europe of humanism, the champion of human rights, democracy and freedom?"

It is a wrong understanding of society to believe that the truth will emerge from big data and a benevolent dictator approach will produce the best results. Even though the economic development of Hungary is strongly data-driven, and Viktor Orbán seems to consider himself a benevolent dictator, Hungary has fallen back economically. It started off as the leading eastern European country and ended up last in the rankings. Since Turkey is governed in an autocratic way, its economic situation has been deteriorating too. A world-wide data-driven analysis by Heinrich Nax and Anke Schorr confirms that democratic forms of governance create economic benefits (Nax and Schorr 2015).

Now, why is today's data-driven control not working so well? It sounds so intuitive: more data yields more knowledge, and more knowledge implies more power and success. However, optimisation creates in fact a decelerating growth curve. At some point in time the optimal state is reached and you cannot get beyond it. It is the wrong paradigm for society. The right kind of paradigm would be based on creativity, co-creation, and co-evolution, which is expected to produce an accelerating, exponential growth curve because it is not restricted to innovating within the current system (as the optimisation approach is), but it innovates the system too (i.e. it also comes up with totally new, 'disruptive' solutions which are outside of today's system).[5] Figure 1 shows the development of the world economy since 1991. It is really saturated as you would expect for an optimisation approach. This is the problem and we need to pursue a totally different approach now – based on an open and participatory information and innovation ecosystem.

It turns out that even though the information technology sector has exploded, it has not created the overall macro-economic growth that was expected. The current approach has also not solved our biggest problems yet, which are climate change, the financial, economic and public spending crisis, conflicts and wars, mass migration and terrorism, which may all result from today's lack of sustainability. That means likely future resource shortages if we do not change the current economic system from a consumption-oriented system based on linear supply chains towards a circular and sharing economy, which would be able to provide a high quality of life for more people with less resources.

So, something is wrong with today's top-down control approach, which is dominated by a few IT monopolies. This approach works like a data-driven version of the command economy – something that obviously has not worked very well in the past due to the lack of flexibility and creative freedoms. Interestingly, if you look at the top ten list of the most liveable cities in the world, for many years, none of the big IT-nations has been represented

5 The Limit to Growth study, Global 2000, and other studies trying to anticipate our future have concluded that, in a world of limited resources, an economic and population collapse would occur, no matter how the simulation parameters are chosen. This means that the system of equations must itself be changed, meaning that we need to innovate and change the system.

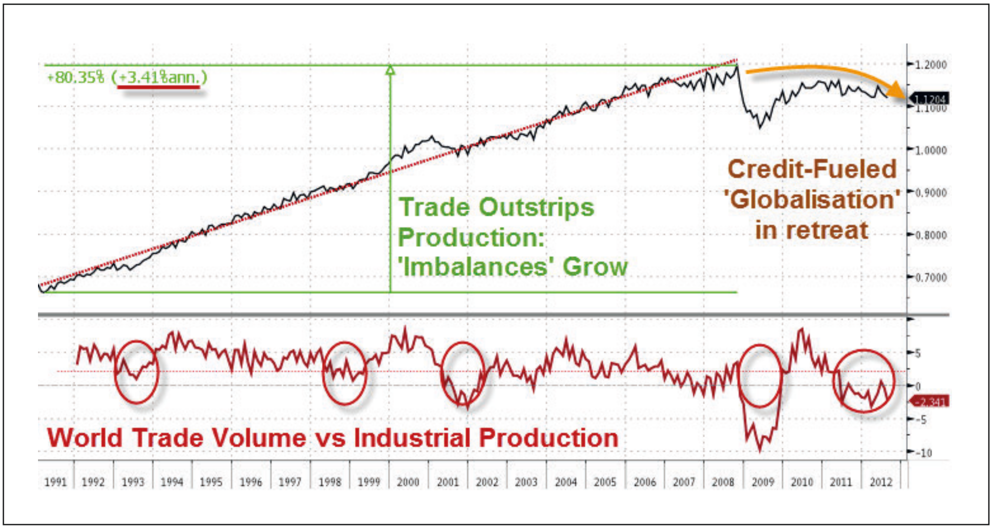

Fig. 1 The volume of world trade has reached saturation in the past decade (Source: LONG 2012).

on it. It is therefore no surprise that a recent event on 'disrupting cities through technology', which included all relevant stakeholders, concluded that the concept of smart cities as fully automated, data-driven structures has failed (*Wilton Park* 2017a, b). Society is not a machine (HELBING 2017). Therefore, I advise that we use big data, but use it in a different way – not in the sense of a 'black box society' (PASQUALE 2016), but in favour of an open and participatory information ecosystem (HELBING 2015d). The idea of a much more participatory and inclusive approach is now spreading in many countries, including the United States, as the 'Open Letter on the Digital Economy' shows.[6]

Even though we have an exponentially increasing processing power – doubling approximately every 18 months according to Moore's law[7] – the overall data volume is increasing even faster. It is currently doubling every twelve months (SCHILLING 2014). This means that, within just one year, we produce as much data as in all the years before, in the entire history of humankind. As a consequence, the gap between the data we produce and the data one can process is opening up more and more. Therefore, there is a kind of 'dark data' that can never be evaluated, which means that we need science to decide what data to process and how. So science is back, in contrast to what Chris ANDERSON and his followers have claimed.

Another important point is the quickly increasing connectivity of our world. Basically, we are connecting companies and people more and more, creating a combinatorial explosion of complexity (see red factorial curve in Fig. 2). It overtakes the data volume, which means that top-down control will work decreasingly well as time goes on. In fact, if you have listened to the talks of the last World Economic Forums, the conclusion is basically this: "We have

6 Open Letter on the Digital Economy. Available at: http://openletteronthedigitaleconomy.org (last accessed: 10. May 2017).

7 Moore's law. In: Wikipedia. Available at: https://en.wikipedia.org/wiki/Moore's_law (last accessed: 10. May 2017).

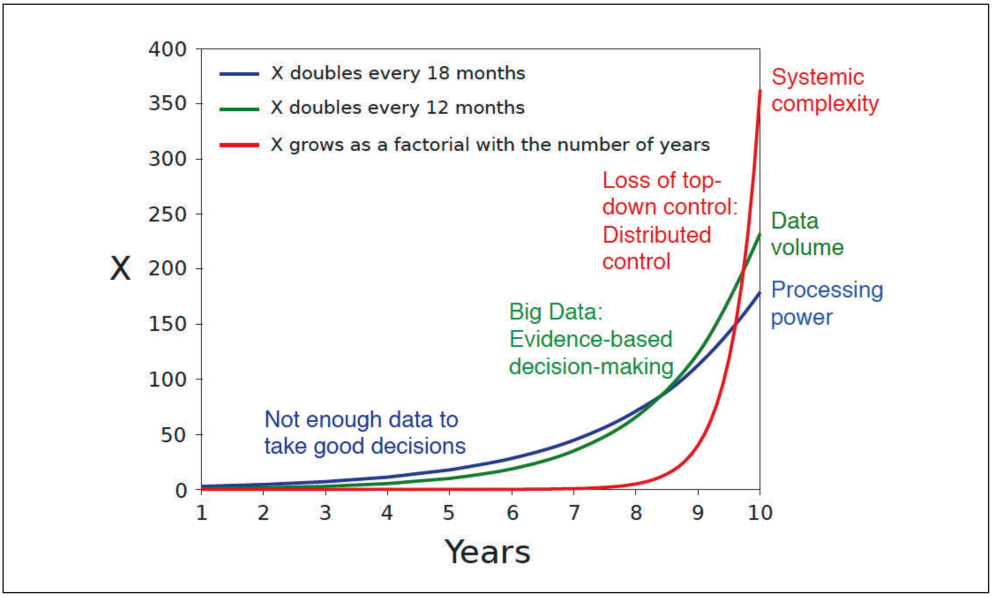

Fig. 2 Two exponential curves and a factorial curve, schematically illustrating the increase in computational processing power, overall data volume, and systemic complexity (Helbing et al. 2015b).

lost control of the world". Therefore, we need a new control paradigm – one that is based on distributed control and the subsidiarity principle (which implies significant levels of self-organisation and self-regulation).

We really need to understand complex systems much better, and we need digital platforms to support a self-organised coordination in a highly complex and diverse world. Society cannot be steered like a car. It is not a mechanical system. It is an evolutionary system in which the behaviour of its parts is adapting and changing, interactions matter a lot (or even dominate the system behaviour), and noise is important (Helbing 2008, 2012). In complex systems, interactions can produce unexpected outcomes and emergent phenomena such as 'phantom traffic jams' or stop-and-go waves (Helbing 1998). Even if you had a perfect mass surveillance system and could read the minds of all people, you could not prevent the traffic jam. You would just see it happen. However, we have mathematical formulas that allow us to understand these stop-and-go waves and how they come about.

Surprisingly, perhaps, there is no need to know much about psychology, and we do not need to read minds. The only thing that matters is the interactions between cars. These imply that, above a certain density threshold, small variations in speeds will be amplified, which creates a domino effect that causes a situation nobody wants (Helbing 2001). Note that the drivers in this experiment are all people who use modern technology and have all the data that seems to be necessary to accomplish the task. They are also well educated – they have driver's licenses and they want to avoid traffic jams. Nevertheless, traffic jams are still happening. This traffic flow problem is a prime example for systems that are unstable – there are many of them. When confronted with such systemic instabilities, things can go totally wrong, even if you have the very best intentions (Helbing 2013). The occurrence of cascading effects is a typical reason for the loss of control. Another example is the financial crisis, where a good performance of the individual actors could not avoid a global meltdown (*British Academy* 2009). When Lehman Brothers went bankrupt, this created a cascade of bankruptcies all over the United States. Hundreds of banks failed, causing losses of hundreds of billions of dollars.

Let me give a further example. We recently did a decision experiment in the lab, where we could predict an incredible 96 % of all decisions (Maes and Helbing 2016). That is unheard-of accuracy in social experiments. Still the deterministic model that produced these accurate predictions was unable to predict the aggregate, macroscopic outcome well. That means the overall results were quite different. The next surprise was that when we added some noise to the deterministic model, making the microscopic model predictions of individual behaviours less accurate, the macroscopic outcome was much better.

The reason why adding noise can produce more accurate macro-predictions is that small deviations from deterministic behaviour can trigger cascading effects that cause completely different kinds of outcomes. Consequently, to get a good aggregate picture, we do not need to know every individual behaviour. We do not need mass surveillance, as the aggregate picture is the only thing that a policy maker needs to care about.

With Albert Einstein, I would like to say: “We cannot solve our problems with the same kind of thinking that created them”. Most of the big unsolved problems of the globe are those related to systemic instability. This ranges from unstable supply chains to economic booms and recessions and breakdowns of cooperation to tragedies of the commons, from electrical blackouts to financial crises, and from crime to war.[8] To improve the state of the world, we need explanatory models. In many cases, complexity science, based on non-linear interactions between a complex system’s components (such as individuals and companies), has delivered a new understanding of these problems, where the conventional ‘linear thinking’ fails to work.

In fact, it is possible to explain even counter-intuitive macro-phenomena from ‘micro-level’ interactions, as is common in physics. Moreover, by changing the interactions, many problems occurring in complex systems can be solved. There are numerous nice success stories in complexity science for this. In the following, I will discuss some of my own work.

My research started with pedestrian and crowd dynamics (Helbing and Johansson 2010). In pedestrian flows, as people interact with each other, they create self-organised macro-phenomena such as lanes of uniform walking direction where different directions of motions are separated from each other. This can be simulated in a computer. It takes just the higher relative velocity between people moving in opposite directions to produce the lane formation phenomenon. Traffic signs, police men, or laws are not required for this. But lane formation is not the only self-organisation phenomenon we found. We also discovered oscillatory flows at bottlenecks, stripe formation in two crossing flows, and clogging phenomena at bottlenecks, when fleeing crowds try to evacuate themselves (Helbing et al. 2000).

Besides pedestrian models, models for traffic flows, logistics, and supply networks, disaster spreading and response, social coordination and cooperation, opinion formation, the emergence of social norms and social preferences, as well as models for the spreading of crime, conflict, diseases, knowledge, and culture have been developed.[9]

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8 For further information see: www.coss.ethz.ch/publications.html and https://scholar.google.de/citations?user=ebrNfPAAAAAJandhl=enandoi=ao (last accessed: 10. May 2017).

9 Brockmann and Helbing 2013, Schich et al. 2014; for further information see: www.coss.ethz.ch/publications.html (last accessed: 10. May 2017).

Some of this work has also been applied in practical contexts. The following provides an incomplete list:

– A pedestrian software for crowd and evacuation simulations was developed based on the social force model of pedestrian motion discussed below. The software is now commercially available and internationally distributed. It has, in the meantime, supported the planning of the Formula One Grand Prix in Abu Dhabi, the North Melbourne Station, and various arenas and mass events all over the world.
– Based on an application of the 'slower-is-faster effect' observed in pedestrian crowds, certain steps in the semiconductor production of Infineon Technologies could be improved, which has increased the throughput by 30 % (Helbing et al. 2006).
– The observation of self-organised oscillations of pedestrian flows at bottlenecks inspired a new traffic light control approach based on concepts of emergent coordination and self-control, which is patented (Lämmer and Helbing 2008, Helbing and Lämmer 2012). The practical performance of this approach has been successfully tested in the city of Dresden.

2. The Social Force Model

In the following, I will discuss just one kind of model which has helped to understand and solve complex real-world problems (Helbing et al. 2015a): the social force model. Different kinds of models – from agent-based, to cellular automata, to gas-kinetic, fluid-dynamic, and stochastic – have been developed for various other kinds of problems.[10] The social force model can explain all the above-mentioned observations (lane formation, oscillations at bottlenecks, stripe formation, and the clogging phenomenon of escaping crowds at bottlenecks). The model has been inspired by physics but adapted to social behaviour. It is based on an equation of motion and an acceleration equation. The latter contains several different force terms that represent different motivations of a pedestrian, for example to adjust their speed, to walk into a certain desired direction of motion, or to keep some distance to other people, as reflected by repulsive forces.

The social force model not only reproduces the observed self-organisation phenomena in a qualitative way. It also passes empirical and experimental tests. For example, we have compared the model with empirical pedestrian trajectories (Johansson et al. 2007) and performed a series of lab experiments (Moussaid et al. 2011, 2009). The obtained knowledge was also applied to study practical problems such as crowd disasters. In the past, for example, several crowd disasters have occurred during the Hajj, the Muslim pilgrimage. For this reason, the Saudi Arabian government asked me and other experts for an analysis of the problem (Haase et al. 2016). During the Hajj, an estimated 1.5 to 3 million people walk from the Holy Mosque in Mecca to Mina, where they perform the 'stoning the devil' ritual. On the Jamarat Bridge in Mina, the temptation by the devil is represented by several pillars. The pilgrims are supposed to demonstrate their resistance to these temptations by throwing little stones ('pebbles') against the pillars. This has caused extremely crowded situations on the Jamarat Bridge in the past, such that crowd disasters happened on average every two to three years. In 2006, a crowd disaster occurred on the open plaza in front of the entrance to the Jamarat

10 For further information see: www.coss.ethz.ch (last accessed: 10. May 2017).

Bridge which happened to be recorded. Our video analysis revealed that there was first a transition from smooth pilgrim flows to stop-and-go-flows, which may be seen as an advance warning signal of potential trouble to come (Johansson et al. 2008).

After this, there occurred a second unexpected transition to crowd turbulence, when the density was so high that pilgrims were erratically pushed around by others in the crowd, probably without intent. There is a transfer of forces from one body to the next, and the forces add up with unpredictable sizes and directions such that the situation becomes uncontrollable, even by many soldiers. Later, we found out that the same mechanism was also the cause of the Love Parade disaster (Helbing and Mukerji 2012). Movies taken by participants of the event showed turbulent waves, as we had expected. These made people stumble and fall on top of each other.

As the occurrence of such deadly crowd disasters is not acceptable, the Saudi Arabian government has built a new Jamarat Bridge in the past years.[11] A five-level-structure with more capacity replaced the old Jamarat Bridge and different ramps leading to the different levels made sure to separate different pilgrim flows. They also put together a team of international experts to help come up with suggestions. A Saudi Arabian expert team responsible for the implementation selected several of them for realisation. One of the suggestions made was to avoid crossing and counter-flows, meaning to implement a unidirectional flow organisation. This has worked safely for many years. The government was very happy with the results and the work received high international recognition. In the following years, I was no longer involved in expert workshops or otherwise. Then, in 2015, a crowd disaster happened, most likely due to the occurrence of crossing flows (Haase 2017).

3. Optimisation Itself Does Not Necessarily Prevent Turbulent Flow in Crowds

In that year, another team was apparently trying to maximise flow and comfort by minimising travel times. This may have led to stronger variations in the density and flow than in previous years and to crossing flows. Despite the optimisation and at least five thousand CCTV cameras, the crowd disaster could not be prevented. So optimisation and surveillance are no guarantee for functionality and safety, as I said before.

One of the neglected problems of optimisation is the right choice of the goal function. In the above case, it seems that travel times were chosen rather than safety (which was optimised in previous years). In the case of our economy, gross domestic product was maximised rather than sustainability. Unfortunately, in many cases one only finds out too late that another goal function should have been chosen.

What is possible, however, is to model the complexity of pedestrian flows with reasonably simple models and to explain what is going on, under what conditions, and why. By now, we can also understand many other troubling self-organisation phenomena. For example, we can predict various kinds of traffic congestion and the travel times associated with them (Helbing et al. 2009). However, we cannot predict the moment when congestion sets in, because this may depend on a random event, such as the overtaking manoeuvre of a truck. Despite this complication, we have been able to develop an analytical theory of vehicle flows that can help to overcome traffic congestion.

11 For further information see: http://web.archive.org/web/20140816222258/ and www.trafficforum.org/crowdturbulence (last accessed: 10. May 2017).

The right approach for this is 'mechanism design', or in this case an adaptive cruise control (ACC) system that is changing the interactions between successive cars (Kesting et al. 2008). In such a way, it is possible to get rid of congestion, even if not every car is equipped with an ACC system. As stop-and-go waves show, self-organisation in complex systems does not necessarily produce desirable outcomes, but we can generate favourable outcomes by changing the interactions. This approach can also be applied to urban traffic. In our self-organised traffic light control, traffic flows control the traffic lights in a bottom-up way rather than the other way around, as it is common today. This approach makes traffic flow much more efficiently than the state-of-the-art control systems, attempting to optimise the flow by a traffic control centre.[12]

We propose to apply a similar approach to social and economic systems. Mechanism design (Maskin 2008) can improve the outcome of social and economic interactions, for example in markets (whose performance depends on the respectively applied auctioning mechanism) (Ferscha et al. 2012). What we need for this is knowledge from game theory, complexity science, or computational social science. In fact, Noble Prize winner Elinor Ostrom has proven with empirical observations that self-governance can be efficient if the institutional design is well-chosen (Ostrom 2015). Therefore, I propose to use personal digital assistants to help us take better decisions (Helbing 2015e). Information systems that support our creativity, innovation, and coordination will also benefit the economy and society altogether. They will improve business models, products and services, cities, and the world. Reputation systems, for example, can influence social interactions in a way that promotes responsible behaviour, cooperation and quality (Diekmann et al. 2014).

Such digital assistants working for us can now be built. We just need to create a suitable institutional framework. 'Digital democracy' is such a framework that allows the knowledge and ideas of many minds to come together and create 'collective intelligence' (Helbing und Pournaras 2015). Massive open online deliberation platforms (MOODs) can support this (Helbing and Klauser 2016).

It turns out that diversity is highly important to come up with good solutions that work for many people (Page 2007, Woolley et al. 2010, Hidalgo et al. 2007). So it is very important to promote value pluralism and to reach a balance of interests ('social forces'), in order to produce solutions that do not just improve a system for a single group. To enable combinatorial innovation and a flourishing, thriving economy, solutions should benefit many groups of companies and people.

In order to support this, my team and I have recently started to work on a digital platform called Nervousnet.[13] It aims to measure the externalities between people and companies and the environment. We can use smartphones and the Internet of Things to do these measurements collectively in a crowd-sourced way. We could then give undesired effects such as noise, pollution, or rubbish a price and desirable things such as cooperation, education, or the reuse of resources a value. With such a system, people could actually earn money for producing data and sharing them with others, as well as for producing positive externalities. This could be the basis of the participatory digital economy that I imagine for the future.

12 For further information see: www.stefanlaemmer.de and www.stefanlaemmer.de/#Literatur (last accessed: 10. May 2017)

13 For further information see: www.nervousnet.info (last accessed: 10. May 2017).

The approach would create multidimensional incentive systems or, if you want, multi-dimensional financial markets, which would help to manage complex systems in a differentiated, multi-factorial way and even to build self-organising or self-regulating systems (Helbing 2016b). Such a multi-dimensional financial system can now be created using blockchain technology. In other words, 300 years after the inception of the concept of the 'invisible hand' presented in the previous talk by Alan Kirman, we can finally make it work by combining the Internet of Things with blockchain technology and complexity science.

Such a system could establish new kinds of incentives which would boost a circular and sharing economy. Thereby, we could mitigate or even overcome the resource crises expected for the future. Rather than implementing a circular and sharing economy by regulations and laws, this approach would create new market forces promoting a more responsible and efficient use of resources and recycling (Helbing 2014, 2016c). In a similar way, one could produce incentives supporting social coordination, cooperation, and peace.

In summary, my vision of the digital economy and society of the future is that of a networked, well-coordinated, distributed system of largely autonomous (sub-)systems. I do believe we should use Big Data, but it should be used in an open, participatory, fair and democratic way. We should also use Artificial Intelligence, but in a symbiotic and ethical way. We should further use incentive systems, but in a multidimensional way. It is also fine to create an operating system for society, but it should provide everyone opportunities for creativity and innovation, for bottom-up participation and co-creation. We need a new societal framework, a finance system 4.0 and socio-ecological capitalism to solve the problems of the future. According to my vision, this digitally upgraded capitalism would also be democratic, so smart technologies alone will not create smart cities and smart nations. It is the combination of smart technologies and smart citizens which creates smarter societies. Let us now build this together!

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