# The Dream to Control the World – and Why it is Failing

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# The dream to control the world – and why it is failing

**Dirk Helbing, ETH Zurich**

**Abstract: If we just had enough data, could we optimize 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. Even though we have moved from a time, when there was too little data for evidence-based decisions, to a time, where one can make data-driven decisions, there is still a gap between the complexity of the world and the data we have about 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 centralized to distributed control, and from a top-down to a bottom-up approach that supports self-organization and self-governance.**

In his 2008 essay "The end of theory" WIRED author Chris Anderson[1] 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 behavioral 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 governance approach is becoming more and more interesting for politics, too.[2] It turns out that nudging can change our behavior, but it has failed to make us healthy and slim and to be nice to our environment. So, todays nudging is not as efficient as its inventors would like it to be. But stronger reinforcement mechanisms such as personalized pricing are constantly being developed.

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

[1] See: Chris Anderson. (2008). The End of Theory: The Data Deluge Makes the Scientific Method Obsolete, *16*(7). Retrieved from https://www.wired.com/2008/06/pb-theory/

[2] R.H. Thaler and C.R. Sunstein, Nudge: Improving Decisions about Health, Wealth and Happiness (Penguin, 2009); C.R. Sunstein, The Ethics of Influence: Government in the Age of Behavioral Science (Cambridge University, 2016).

[3] See: Jay Stanley. (2015). China's Nightmarish Citizen Scores are a warning for Americans. Retrieved from https://www.aclu.org/blog/free-future/chinas-nightmarish-citizen-scores-are-warning-americans ; Big Data, meet Big Brother: China invents the digital totalitarian state. Retrieved from http://www.economist.com/news/briefing/21711902-worrying-implications-its-social-credit-project-china-invents-digital-totalitarian

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 get 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 likely to oppose the intended changes would 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 been developed already. So we are pretty close to a totalitarian society, where 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, your neighbors. Even if your behavior is perfectly ok, the behavior of your friends or neighbors 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 how our digital future should look like.[5] 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 would believe to know what is best for us and would impose it on us – the "Big Mother" society), feudalism 2.0 (the "Big Other" society,[6] 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 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, 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 also in France. Democracy has become pretty unstable. And 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.

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[4] Revealed: The 48 organisations that can see your entire online browsing history, even if you delete it, Mail Online (Nov 25, 2016). Retrieved from http://www.dailymail.co.uk/sciencetech/article-3971214/The-48-organisations-entire-online-browsing-history-delete-it.html ;
Browsers nix add-on after Web of Trust is caught selling users' browsing histories, The Register (Nov 7, 2016). Retrieved from https://www.theregister.co.uk/2016/11/07/browsers_ban_web_of_trust_addon_after_biz_is_caught_selling_its_users_browsing_histories/ ; Apple iCloud Hoards 'Deleted' Browser History Going Back More Than A Year, Forbes (Feb 9, 2017). Retrieved from http://www.forbes.com/sites/thomasbrewster/2017/02/09/apple-safari-web-history-deleted-stored-icloud/#632df5322439

[5] D. Helbing, Why we need democracy 2.0 and capitalism 2.0 to survive. Jusletter IT (25. Mai 2016); D. Helbing, Societal, Economic, Ethical and Legal Challenges of the Digital Revolution: From Big Data to Deep Learning, Artificial Intelligence, and Manipulative Technologies. Jusletter IT (21. Mai 2015).

[6] S. Zuboff (2015) Big Other: Surveillance Capitalism and the Prospects of an Information Civilization. Journal of Information Technology 30, 75–89. Retrieved from https://papers.ssrn.com/sol3/papers2.cfm?abstract_id=2594754

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[7] (the ability to deal with shocks and other unexpected developments), for high innovation rates, and collective intelligence.[8] I am convinced that co-creation, co-evolution, collective intelligence, self-organization and self-governance, considering externalities (i.e. external effects of our actions), will be the success principles of the future.

**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 now called "values by design" or "ethically aligned design". IEEE has recently drafted guidelines in this direction,[9] and Elon Musk shares this perspective too. He has invested 1 Billion US-Dollar into the OpenAI initiative, to make artificial intelligence an instrument for everyone.[10] In the meantime, Amazon, Apple, Facebook, IBM, and Microsoft have decided as well to work on the development of moral Artificial Intelligence.[11] Even Pope Francis has spoken up. He demands a Europe 2.0, a new European humanism, and asks: "What is up with you humanistic Europe, you defender of human rights, democracy and freedom."

It is a wrong understanding of society to believe that 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 off last. 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 as well that democratic forms of governance create an economic benefit.[12]

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[7] D. Helbing (2015) Responding to Complexity in Socio-Economic Systems: How to Build a Smart and Resilient Society? Retrieved from https://papers.ssrn.com/sol3/papers2.cfm?abstract_id=2583391 ; D. Helbing (2015) Wie wir eine smarte, krisenfeste, digitale Gesellschaft bauen können, Nova Acta Leopoldina NF 122, Nr. 410, 209-243.

[8] S.E. Page (2008) The Difference: How the Power of Diversity Creates Better Groups, Firms, Schools, & Societies: How the Power of Diversity Creates Better Groups, Firms, Schools, and Societies (Princeton University).

[9] IEEE, Ethically Aligned Design (2016). Retrieved from http://standards.ieee.org/develop/indconn/ec/ead_v1.pdf

[10] Elon Musk, Silicon Valley Elite Launch 'Open' Artificial Intelligence With $1 Billion (Dec 11, 2015). Retrieved from http://www.forbes.com/sites/ericmack/2015/12/11/elon-musk-sam-altman-peter-thiel-others-launch-open-a-i-with-1-billion-donation/#d4041f063efc

[11] 'Partnership on AI' formed by Google, Facebook, Amazon, IBM and Microsoft (Sep 28, 2016). Retrieved from https://www.theguardian.com/technology/2016/sep/28/google-facebook-amazon-ibm-microsoft-partnership-on-ai-tech-firms

[12] H.H. Nax and A.B. Schorr, Democracy-Growth Dynamics for Richer and Poorer Countries (2015). Retrieved from https://papers.ssrn.com/sol3/papers2.cfm?abstract_id=2698287

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, optimization 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 optimization 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).[13] Figure 1 shows the development of the world economy since 1991. It really saturated as you would expect for an optimization 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.

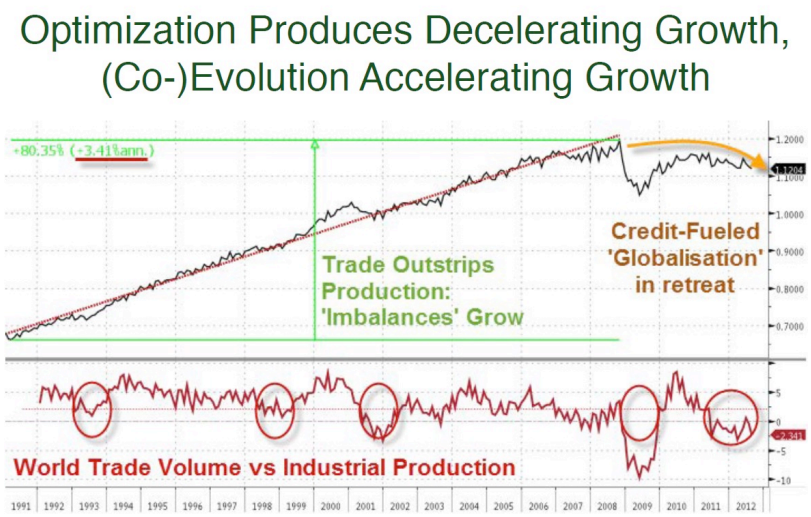


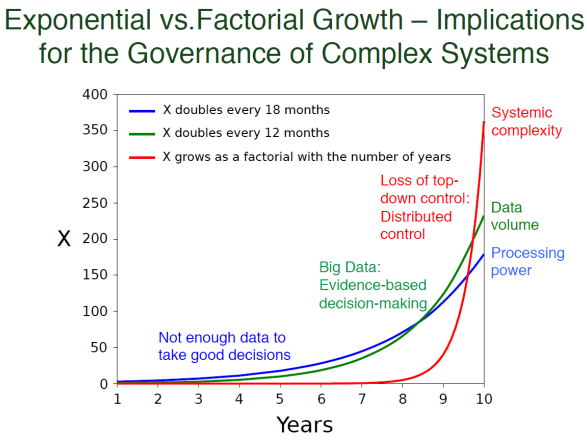

Figure 1: The volume of world trade has saturated in the past decade (Source: Risk Drivers – Global Trade Outstrips Industrial Production by Gordon T. Long, http://www.gordontlong.com/2012/Tipping_Points-2012-11-02.htm, last accessed Feb 21, 2017).

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 is 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.

[13] 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.

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 most livable cities in the world, for many years none of the big IT-nations has been represented there. 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.[14] Society is not a machine.[15] Therefore, I advise that we use Big Data, but use it in a different way – not in the sense of a "black box society",[16] but in favor of an open and participatory information ecosystem.[17] 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.[18]

Even though we have an exponentially increasing processing power – doubling approximately every 18 month according to Moore's law[19] – the overall data volume is increasing even faster. It is currently doubling every twelve month.[20] 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 ever more. So there is a kind of "dark data" that can never be evaluated, which means 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.




[14] Disrupting cities through technologies. Retrieved from https://www.wiltonpark.org.uk/event/wp1449/ and https://www.wiltonpark.org.uk/wp-content/uploads/WP1449-Report.pdf

[15] D. Helbing, Society is not a machine, optimization not the right paradigm! Retrieved from https://www.edge.org/response-detail/26795

[16] F. Pasquale, The Black Box Society (Harvard University Press, 2016).

[17] D. Helbing, The Automation of Society Is Next: How to Survive the Digital Revolution (CreateSpace, 2015).

[18] Open Letter on the Digital Economy. Retrieved from http://openletteronthedigitaleconomy.org

[19] Moore's law. Retrieved from https://en.wikipedia.org/wiki/Moore's_law

[20] Knowledge Doubling Every 12 Months, Soon to be Every 12 Hours. Retrieved from https://www.linkedin.com/pulse/knowledge-doubling-every-12-david-russell

Figure 2: Two exponential curves and a factorial curve, schematically illustrating the increase in computational processing power, overall data volume, and systemic complexity.[21]

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. That is the red (factorial) curve in Figure 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 basically is: "We have 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-organization and self-regulation).

We really need to understand *complex systems* much better, and we need digital platforms to support a self-organized 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 behavior of its parts is adapting and changing; interactions matter a lot (or even dominate the system behavior), and noise is important.[22] In complex systems, interactions can produce unexpected outcomes and emergent phenomena such as "phantom traffic jams" or stop-and-go waves.[23] 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.[24] 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 a driver's license, 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.[25] 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.[26] When Lehman Brothers went

[21] D. Helbing et al. (1/2016) Das Digital-Manifest. Spektrum der Wissenschaft. Retrieved from http://www.spektrum.de/thema/das-digital-manifest-algorithmen-und-big-data-bestimmen-unsere-zukunft/1375924 ; an English translation can be found here: http://bit.ly/1Xwf3l4

[22] D. Helbing (ed.) Managing Complexity: Insights, Concepts, Applications (Springer, Berlin, 2009); D. Helbing (ed.) Social Self-Organization (Springer, Berlin, 2012).

[23] D. Helbing and M. Treiber (1998) Jams, waves, and clusters. Science 282, 2001-2003.

[24] D. Helbing (2001) Traffic and related self-driven many-particle systems. Reviews of Modern Physics 73, 1067-1141.

[25] D. Helbing (2013) Globally networked risks and how to respond. Nature 497, 51–59.

[26] Letter of the British Academy to Her Majesty The Queen (Jul 22, 2009). Retrieved from https://www.euroresidentes.com/empresa_empresas/carta-reina.pdf

bankrupt, this created a cascade of bankruptcies all over the United States. Hundreds of banks failed, which caused losses of hundreds of billions of dollars.

Let me give a further example. We recently made a decision experiment in the lab, where we were able to predict an incredible number of ninety-six percent of all decisions.[27] That is a kind of 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, which make the microscopic model predictions of individual behaviors 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 behavior can trigger cascading effects that cause completely different kinds of outcomes. As a consequence, to get a good aggregate picture, we do not need to know every individual behavior exactly. 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, from breakdowns of cooperation to tragedies of the commons, from electrical blackouts to financial crises, from crime to war.[28] 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 it is common in physics. Moreover, by changing the interactions, many problems occurring in complex systems can be solved. There are a number of nice success stories of complexity science for this. In the following, I will discuss some of my own work.

My research started with pedestrian and crowd dynamics.[29] In pedestrian flows, as people interact with each other, they create self-organized 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 just takes 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-organization phenomenon we found. We also discovered oscillatory flows at bottlenecks,

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[27] M. Maes and D. Helbing (2016) Random deviations improve micro-macro predictions. An empirical test. Submitted.

[28] See publications at http://www.coss.ethz.ch/publications.html and https://scholar.google.de/citations?user=ebrNfPAAAAAJ&hl=en&oi=ao

[29] D. Helbing, A. Johansson (2010) Pedestrian, Crowd and Evacuation Dynamics. Encyclopedia of Complexity and Systems Science 16, 6476-6495.

stripe formation in two crossing flows, and clogging phenomena at bottlenecks, when fleeing crowds are trying to evacuate themselves.[30]

Besides pedestrian models, the author and his team have developed 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.[31]

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%.[32]
- The observation of self-organized 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.[33] The practical performance of this approach has been successfully tested in the city of Dresden.

**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:[34] the social force model. (Different kinds of models – from agent-based, over cellular automata, to gas-kinetic, fluid-dynamic and stochastic – have been developed for various other kinds of problems.[35]) The social force model can explain all of the above-mentioned observations (lane formation, oscillations at bottlenecks, stripe formation, and the clogging phenomenon of escaping crowds at bottlenecks). The model that has been inspired by physics, but adapted to social behavior. It is based on an

[30] D. Helbing, I. Farkas, and T. Vicsek (2000) Freezing by heating in a driven mesoscopic system. Physical Review Letters 84, 1240-1243.

[31] D. Brockmann and D. Helbing (2013) The hidden geometry of complex, network-driven contagion phenomena. *Science* 342(6164), 1337–1342; M. Schich et al. (2014) A network framework of cultural history. *Science*345(6196), 558-562; for further references see http://www.coss.ethz.ch/publications.html

[32] D. Helbing, T. Seidel, S. Lämmer, and K. Peters (2006) Self-organization principles in supply networks and production systems. In: B.K. Chakrabarti *et al.* (eds.) *Econophysics and Sociophysics* (Wiley-VCH, Weinheim), pp. 535-559.

[33] S. Lämmer and D. Helbing (2008) Self-control of traffic lights and vehicle flows in urban road networks. *JSTAT* P04019; Method for coordination of competing processes or for control of the transport of mobile units within a network. Patent PCT/DE2006/000837.

[34] D. Helbing et al. (2015) Saving human lives: What complexity science and information systems can contribute. J Stat Phys (2015) 158: 735.

[35] See www.coss.ethz.ch for background information.

equation of motion and an acceleration equation. The latter contains a number of 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 does not only reproduce the observed self-organization phenomena in a qualitative way. It also passes empirical and experimental tests. For example, we have compared the model with empirical pedestrian trajectories[36] and performed a series of lab experiments.[37] 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.[38] During the Hajj, an estimated 1.5-3 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 caused extremely crowded situations on the Jamarat Bridge in the past, such that crowd disasters happened on average every 2-3 years. In 2006, a crowd disaster occurred on the open plaza in front of the entrance to the Jamarat 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 advance warning signal of potential trouble to come.[39]

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 a large number of soldiers. Later, we found out that the same mechanism was also the cause of the Love Parade disaster.[40] 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 built a new Jamarat Bridge in the past years.[41] A five-level-structure with more

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[36] A. Johansson, D. Helbing, and P. S. Shukla (2007) Specification of the social force pedestrian model by evolutionary adjustment to video tracking data. Advances in Complex Systems 10, 271-288.

[37] M. Moussaïd, D. Helbing, and G. Theraulaz (2011) How simple rules determine pedestrian behavior and crowd disasters. PNAS 108 (17) 6884-6888; M. Moussaïd, D. Helbing, S. Garnier, A. Johansson, M. Combe, and G. Theraulaz (2009) Experimental study of the behavioural mechanisms underlying self-organization in human crowds. Proceedings of the Royal Society B 276, 2755-2762.

[38] K. Haase, H. Z. Al Abideen, S. Al-Bosta, M. Kasper, M. Koch, S. Müller, and D. Helbing (2016) Improving Pilgrim Safety During the Hajj: An Analytical and Operational Research Approach. Interfaces 46 (1), 74-90.

[39] A. Johansson, D. Helbing, H. Z. A-Abideen, and S. Al-Bosta (2008) From crowd dynamics to crowd safety: A video-based analysis. Advances in Complex Systems 11(4), 497-527.

[40] D. Helbing and P. Mukerji (2012) Crowd disasters as systemic failures: Analysis of the Love Parade Disaster. EPJ Data Science 2012, 1:7

[41] Supplementary information can be found here: http://web.archive.org/web/20140816222258/http://www.trafficforum.org/crowdturbulence

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 a number of them for realization. One of the suggestions made was to avoid crossing and counter-flows, that means to implement a unidirectional flow organization. This has worked savely for many years. The government was very happy with the results, and the work received high international recognition. In the following years, I have not been involved in expert workshops or otherwise anymore. Then, in 2015, a crowd disaster happened, most likely due to the occurrence of crossing flows.[42]

**Optimization does not prevent turbulent flow in crowds**

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

One of the neglected problems of optimization is the right choice of the goal function. In the above case, it seems that travel times were chosen rather than safety (which was optimized in previous years). In the case of our economy, gross domestic product was maximized rather than sustainability. Unfortunately, in many cases one only finds out when it is 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-organization phenomena. For example, we can predict various kinds of traffic congestion and the travel times associated with them.[43] However, we cannot predict the moment when congestion sets in, because this may depend on a random event such as the overtaking maneuver 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.

The right approach for this is “mechanism design”, in this case an adaptive cruise control (ACC) system that is changing the interactions between successive cars.[44] 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-organization in complex systems does not necessarily produce desirable outcomes, but we can generate favorable outcomes by changing the interactions. This approach can also be applied to urban traffic. In our self-organized traffic light control,

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[42] K. Haase et al. (2017) OR Practice: A pilgrim scheduling approach to increase public safety during the Hajj. Submitted.

[43] D. Helbing, M. Treiber, A. Kesting, and M. Schönhof (2009) Theoretical vs. empirical classification and prediction of congested traffic states. European Physical Journal B 69(4), 583-598.

[44] A. Kesting, M. Treiber, M. Schönhof, and D. Helbing (2008) Adaptive cruise control design for active congestion avoidance. Transportation Research C 16(6), 668-683.

traffic flows control the traffic lights in a bottom-up way rather than the other way 'round, as it is common today. This approach makes traffic flow much more efficiently than the state-of-the-art control systems, attempting to optimize the flow by a traffic control center.[45]

We propose to apply a similar approach to social and economic systems. Mechanism design[46] can improve the outcome of social and economic interactions, for example, in markets (whose performance depends on the respectively applied auctioning mechanism).[47] 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 by empirical observations that self-governance can be efficient, if the institutional design is well chosen.[48] Therefore, I propose to use personal digital assistants to help us take better decisions.[49] 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 behavior, cooperation and quality.[50]

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, which allows the knowledge and ideas of many minds to come together and create "collective intelligence".[51] Massive open online deliberation platforms (MOODs) can support this.[52]

It turns out that diversity is highly important to come up with good solutions, which work for many people.[53] 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

[45] A collection of related documents can be found here: http://www.stefanlaemmer.de , http://www.stefanlaemmer.de/#Literatur

[46] E.S. Maskin (2008) Mechanism Design: How to Implement Social Goals. The American Economic Review 98 (3), 567-576.

[47] A. Ferscha et al. (2012) Socio-inspired ICT: Towards a socially grounded society-ICT symbiosis. EPJ Special Topics 214, 401-434.

[48] E. Ostrom (2015) Governing the Commons (Cambridge University Press).

[49] D. Helbing, Interaction Support Processor. Patent PCT/IB2015/050830.

[50] A. Diekmann, B. Jann, W. Przepiorka, and S. Wehrli (2014) Reputation formation and the evolution of cooperation in anonymous online markets. American Sociological Review 79 (1), 65-85.

[51] D. Helbing and E. Pournaras (2015). Build Digital Democracy. Nature 527: 33-34.

[52] D. Helbing and S. Klauser (Aug 2016) How to make democracy work in the digital age. Retrieved from http://www.huffingtonpost.com/entry/how-to-make-democracy-work-in-the-digital-age_us_57a2f488e4b0456cb7e17e0f

[53] S.E. Page (2008) The Difference: How the Power of Diversity Creates Better Groups, Firms, Schools, & Societies: How the Power of Diversity Creates Better Groups, Firms, Schools, and Societies (Princeton University); A.W. Woolley et al. (2010) Evidence for a collective intelligence factor in the performance of human groups. Science 330, 686-688; C.A. Hidalgo et al. (2007) The product space conditions the development of nations. Science 317 (5837), 482-487.

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 has recently started to work on a digital platform, called Nervousnet.[54] 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 trash 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.

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-organizing or self-regulating systems.[55] 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", 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.[56] 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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[54] See the webpage nervounet.info for details.

[55] D.Helbing (2016) A digital world to thrive in. Pan European Networks. Retrieved from http://www.nervousnet.ethz.ch/wp-content/uploads/2014/09/A-digital-world-to-thrive-in_GOV18_Professorship_20756_pro_AMEND2_final.pdf

[56] D. Helbing, Qualified Money – A Better Financial System for the Future. Retrieved from https://papers.ssrn.com/sol3/papers2.cfm?abstract_id=2526022;
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