

Dirk Helbing (ETH Zurich)

What the Digital Revolution Means for Us

Never before were politicians, business leaders, and scientists more urgently needed to master the challenges ahead of us. We are in the middle of a third industrial revolution. While we see the symptoms, such as the financial and economic crisis, we haven't understood the implications well. But at the end of this socio-economic transformation, we will live in a digital society. This comes with breath-taking opportunities and challenges, as they occur only every 100 years.

Let me start with Big Data. When the social messaging portal WhatsApp with its 450 million users was recently sold, 19 billion dollars were made -- almost half a billion dollars per staff member. Big Data is fundamentally changing our world. It is becoming the new oil of the 21st century, and we need to learn how to drill and refine it, i.e. how to produce data and turn them into information, knowledge and wisdom.

The potential of Big Data spans across all areas of society. It reaches from natural language processing over financial asset management, to smartly managing our cities and better balancing energy consumption and production, thereby saving energy. It allows for better protection of our environment, risk detection and reduction, and the discovery of opportunities, which would otherwise be missed. It will be possible to tailor medicine to patients, thereby increasing drug effectiveness while reducing side effects. Preventing diseases may become even more important than curing them.

Big Data applications spread quickly. They enable personalized offers, services and products. Big Data open up entirely new possibilities for process optimization and allow one to identify unexpected interdependencies. They also imply great potentials of evidence-based decision-making. Scientific institutions will be important to drive socially oriented ICT innovations and to avoid the pitfalls of Big Data applications. Independent scientists will be crucial to ensure transparency, quality, and public trust. Therefore, science should become a fifth pillar of democracies, besides legislation, executive, jurisdiction, and the public media.

However, we definitely need to think beyond Big Data and realize that we are just at the beginning of a transformation process, which is about to change human history. The invention of the steam engine turned agricultural society ("economy 1.0") into industrial society ("economy 2.0"), and wide-spread education turned it into service society ("economy 3.0"). Now, the invention of computers, the Internet, the World Wide Web, and Social Media are transforming service societies into digital societies ("economy 4.0").

With computers reaching the level of human brainpower in about 10 years, with intelligent service robots, and the Big Data tsunami, 50 percent of jobs in the industrial and service sectors will be lost within the next 20 years. And most of our current ways of doing things will fundamentally change: the way we educate (MOOCs – Massively Open On-line Courses – and personalized education), the way we do research (Big Data analytics), the way we move (self-driving Google cars) or transport goods (drones), the way we go shopping (take Amazon and eBay), the way we produce (3D printers), but also our health system (personalized medicine), and most likely politics

(participation of citizens) and the entire economy as well (with the makers community, the emerging sharing economy, and prosumers, i.e. co-producing consumers). Financial business, which used to be the domain of banks, is increasingly replaced by algorithmic trading, Paypal, Bitcoin, and Google Wallet, etc. Moreover, the biggest share of the insurance business is now in financial products such as credit default swaps. Even wars seem to change from conventional battlefield wars to cyberwars.

Thus, how will the digital revolution transform our societies? While the processing power doubles every 1.8 years, the amount of data doubles even every 1.2 years. However, the complexity of networked systems grows even faster. This implies the impossibility of real-time optimization, and the gradual loss of top-down control. But there exists an interesting alternative: distributed (self-)control, i.e. bottom-up management. In fact, cybernetics (i.e. control theory) and complexity theory tell us that it is feasible to create resilient social and economic order by means of self-organization, self-regulation, and self-governance. The work of Nobel prize winner Elinor Ostrom and others has demonstrated this. By "guided self-organization" we can let things happen in a way that produces desirable outcomes in a flexible and efficient way.

How can it be done? In a rapidly changing world, which is hard to predict and plan, we must create feedback loops that enable systems to flexibly adapt in real time to local conditions and needs. For example, my research team has shown that self-regulating traffic lights, controlled by the traffic flows, can outperform classical top-down control by a traffic center. Can we transfer and extend this principle to socio-economic systems? Indeed, we are now developing mechanisms to overcome coordination and cooperation failures, conflicts, and other age-old problems. This can be done with suitably designed social media and sensor networks for real-time measurements, which will eventually weave a Planetary Nervous System. Hence, after 300 years, we can realize the dream of self-regulating systems, fueled by real-time data, and participatory societies are on their way.

A new kind of economy is born

While one might think that a largely self-regulating society is utopia, a new kind of economy is already on its way. Social media are networking people and, thereby, enable "collective intelligence." This paradigm is superior to the self-regarding optimization by the "homo economicus", the egoistic decision-maker assumed in mainstream economics ("economics 1.0"). While the bottom-up self-organization of the "homo economicus" can outperform top-down decision making in complex environments, highly competitive conditions can lead to coordination failures and poor outcomes (for example, "tragedies of the commons" such as environmental degradation). It has been theoretically and empirically shown, however, that a considerable fraction of people have other-regarding preferences -- I will call these "homo socialis." Hence, a new economic thinking ("economics 2.0") is needed. Considering the impact of their own decisions on others enables self-regulation, which can overcome the above mentioned coordination failures and "tragedies of the commons." Interestingly, suitable institutions such as certain social media -- combined with suitable reputation systems -- can promote other-regarding decision-making. The quick spreading of social media and reputation systems, in fact, indicates the

emergence of a superior organizational principle, which creates collective intelligence by harvesting the value of diversity. Properly designed social media allow diverse knowledge and skills to come together, thereby unleashing creativity, social capital and productive value.

Hence, in accordance with the paradigm of distributed control and self-regulation, a **participatory market society** is on the rise. While the 20th century was an era of democratization of consumption, the 21st century can become an era of democratization of production. Next to today's companies, we see the emergence of flexible, participatory forms of production, which I term "projects". Here, creative minds come together to realize joint project ideas. After completing a project, everyone looks for another one, and so on. Social media platforms such as *Amazon Mechanical Turk* make it possible to bring ideas and skilled workers together. As a consequence, this leads to a more direct participation of people in production processes ("prosumers"). Over time, there will be a much greater diversity of products, tailored to individual needs. Thus, while computers will increasingly replace our current types of routine and executive work, we will have an opportunity to replace these jobs by more creative activities. Production by large corporations will then be complemented by an innovation ecosystem made up of millions of projects. The huge range of smartphone apps that low-cost downloads from *App stores* have enabled, gives just a first idea of the unlimited possibilities for new projects. Open access data and the Web2.0, Web3.0, etc. will further accelerate this development.

The new algebra of prosperity and leadership

The 21st century will be governed by fundamentally different principles than the 20th century, and that's why we need to change our way of thinking about the world. To understand this, it is important to recognize the following facts and trends: information is ubiquitous and everywhere instantly available, such that borders dissolve. The "second machine age" comes with extreme speed. Most of our knowledge is outdated, and we can't learn quickly enough to fully understand the changing world by ourselves. Many systems become more variable, less predictable, and less controllable. Their increased connectivity implies a higher complexity. The increase in data volumes means we are overloaded by data that ultimately needs to be converted into information and then into actionable knowledge. Furthermore, the more data we produce, the less likely can we keep secrets and, in fact, the cheaper will data become. This means that we will make less profits on data alone, but more on algorithms turning data sets into useful information and knowledge. In such an environment ideas will become more powerful, and ethics more important. Digitally literate people will be better informed than experts used to be, therefore, classical hierarchies will dissolve. Moreover, data can be replicated as often as we like. It's a virtually unlimited resource, which indeed may help overcome conflicts that scarce resources used to imply. However, services and products will be more individualized, personalized, and user-centric. Finally, what used to be science fiction, may become reality. The countries first recognizing these new principles and turning them into their advantage will be leading. Those failing to adapt to these trends in a timely manner will be in trouble. We may just have 20 years for this -- a very short time considering that planning and building a road often takes 30 years or more.

What does it take to master our future?

So far, no country in the world seems to be well prepared for the digital era. Therefore, we urgently need an Apollo-like program, and the equivalent of a Space Agency for ICT: an **Innovation Alliance** with the mission to develop the institutions and information infrastructures for the emerging digital society. This is crucial to master the challenges of the 21st century in a smart way and to unleash the full potential of information for our society. For illustration, it is helpful to recall the factors that enabled the success of the automobile age: the invention of cars and of systems of mass production; the construction of public roads, gas stations, and parking lots; the creation of driving schools and driver licenses; and last but not least, the establishment of traffic rules, traffic signs, speed controls, and traffic police. All of this required many billions each year. We invest a lot into the agricultural sector, the industrial sector, and also the service sector. But are we investing enough into the emerging digital sector?

What are the technological infrastructures and the legal, economic and societal institutions needed to make the digital age a big success? This question would set the agenda of the Innovation Alliance. A partial answer is already clear: we need **trustworthy, transparent, open, and participatory ICT systems**, which are compatible with our values. For example, it would make sense to establish the emergent "**Internet of Things**" as a **Citizen Web**. This would enable self-regulating systems through real-time measurements of the state of world, which would be possible with a public information platform called the "**Planetary Nervous System**." It would also facilitate a real-time measurement and search engine: an open and participatory "**Google 2.0**."

To protect privacy, all data collected about individuals should be stored in a **Personal Data Purse** and, given informed consent, processed in a decentralized way by third-party **Trustable Information Brokers**, allowing everyone to control the use of their sensitive data. A **Micro-Payment System** would allow data providers, intellectual property right holders, and innovators to get rewards for their services. It would also encourage the exploration of new and timely intellectual property right paradigms ("**Innovation Accelerator**"). A pluralistic, **User-centric Reputation System** would promote responsible behavior in the virtual (and real) world. It would even enable the establishment of **Qualified Money**, which would overcome weaknesses of the current financial system by providing additional adaptability.

A **Global Participatory Platform** would empower everyone to contribute data, computer algorithms and related ratings, and to benefit from the contributions of others (either free of charge or for a fee). It would also enable the generation of **Social Capital** such as trust and cooperativeness, using next-generation **User-controlled Social Media**. A **Job and Project Platform** would support crowdsourcing, collaboration, and socio-economic co-creation. Altogether, this would build a quickly growing **Information and Innovation Ecosystem**, unleashing the potential of data for everyone: business, politics, science, and citizens alike.

We could also create a **Digital Mirror World** to explore the likely risks and opportunities of prospective decisions. Finally, **Interactive Virtual Worlds** would

realize the full creative potential within different socio-economic settings and intellectual property right approaches. **Social Information Technologies** would help us to cope with the diversity resulting from this and to benefit from it. **Digital literacy** and good education will be more important than ever. But with the emerging "Internet of Things" and participatory information platforms, we can unleash the power of information and make the digital society a great opportunity for everyone. It just takes our will to establish the institutions required to make the digital age a great success. Are we ready for this?