Real-time societies

Maintaining control in the digital world

The rapid growth of digitisation is disrupting society profoundly. To secure a worthwhile future, we need to explore new approaches to govern complex socio-technical systems. Professor Johannes Weyer and his research team at Technische Universität Dortmund in Germany have developed SimCo, a simulation framework to investigate the dynamics of socio-technical systems like transportation or energy supply. This research examines how complex systems can be governed and which mode of governance produces best results.

Contemporary 21st century societies are experiencing the rapid growth of digitisation in virtually all aspects of life. Data concerning our work, travel, health and shopping are collected by smart devices, such as smartphones, smart cars and websites, which enable people and objects, together with their current status and geographical position, to be identified. Where a letter took days or weeks to be delivered, email is delivered and answered immediately.

Smart enterprise resource planning systems ensure suppliers deliver their products just in time to the production lines. Satellite navigation systems offer advice almost in real time, eliminating the need for route planning with paper maps. Smart, networked devices enable databases to be continually updated and relevant information to be communicated to all participants – again very nearly in real time. The processes of planning and acting that were sequential are now concurrent and the digital society has become a real-time society.

This datafication of our society brings with it the need to explore new approaches to govern complex socio-technical systems. These challenges have to be managed while still keeping up with technological development and maintaining control if a worthwhile future for a digital real-time society is to be secured. In order to understand and potentially influence the real-time society, it is necessary to model the mechanisms that guide the dynamics of socio-technical systems such as transportation and energy supply. Professor Johannes Weyer and his research team at Technische Universität Dortmund are investigating the dynamics of these socio-technical systems. The key aims of this research are firstly, to discover how complex systems can be governed and secondly, to determine which mode of governance, i.e. soft or strong control, produces best results.

WHAT HAPPENS WITH OUR DATA?

Professor Weyer explains how they developed a process model to facilitate their understanding of what happens with our data. The model comprises three stages: data acquisition, data analysis and use of data. Data are initially collected by humans, e.g. using smart watches and smartphones, or by machines, e.g. via driver assistance systems, and then transmitted to various data analysts. The data can be processed in order to understand the individual person and their particular preferences, habits and needs. Alternatively, the data can contribute to a wider picture depicting the current state of an entire system, such as road transportation.

While much focus is placed on issues surrounding data protection and data abuse, in contrast, the third step in this model explores the legal use of data analysis to influence people (e.g. giving advice on healthier nutrition) and control machines or even entire systems, such as transportation or energy systems.

TRUST AND SOCIETAL IMPACTS

This newfound governance by algorithms has become part of digital society life. The researchers observe, however, that it only works if all partners are trustworthy, and an institutional, legal framework is in place to protect all participants from fraud or other illegal activities. Furthermore, within digital societies the state has to redefine its role and establish boundary conditions for digital interactions.

This research examines the societal dimension, investigating the dynamics of complex socio-technical systems together with their impacts on politics, the state, different societal subsystems as well as the individual. Professor Weyer remarks that "the main issue will be: Will the digital society be governed by autonomous technological systems and stubborn algorithms and finally get out of control, or will we find measures to cope with the challenges of governing the digital society?"

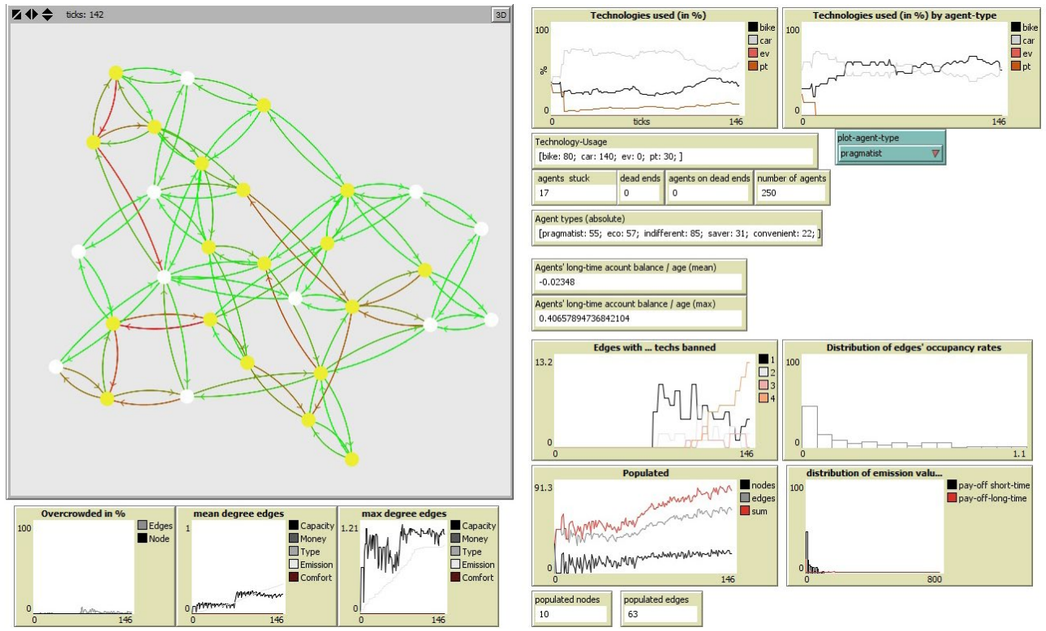

Fig. 1 SimCo simulates various what-if scenarios: this small example network shows 30 nodes and colour-coded edges, relating to the dimensions specified.

A NEW MODE OF GOVERNANCE

Examples of real-time control of complex systems, such as those in urban transportation and energy, demonstrate a central controller collecting vast amounts of data from users, computing an image of the situation and delivering recommendations in real time. Users that can plan independently (e.g. those with local knowledge) can make their own strategic choices and either follow the recommendations or ignore them, whereas others may become increasingly dependent on the system, passively adapting to the situation. The system's state results from the interaction of the different independent decisions made by decentralised decision makers but influenced by the central controller's interventions. Although this amalgamation of central control and decentralised self-control has materialised as a new mode of governance, in practice, a better understanding of these mechanisms is required to develop smart governance options and maintain control.

MULTI-LEVEL MODELLING OF COMPLEX SYSTEMS

A multi-level structure can involve numerous systems and interactions and may appear too complex for sociological analysis. To this end, the researchers have chosen agent-based modelling to model and understand the dynamics of multi-layered structures. Agent-based modelling is a form of computational modelling. It involves simulating complex phenomena via the actions and interactions of a group of autonomous decision-making agents. Each agent individually assesses their situation and makes decisions according to a set of rules. The collective behaviour of multiple agents can then be assessed to provide explanatory insight of their effects on the system being studied. Professor Weyer has developed a conceptual model of a sociotechnical system comprising actor components, rules for action and interaction together with the mechanism of structure formation capable of modelling the systems within systems structure of multi-level governance of complex systems.

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SIMULATION EXPERIMENTS WITH ARTIFICIAL SOCIETIES

This innovative multi-level model of governance facilitates the analysis of complex, non-linear interactions of systems within systems. Deploying agent-based modelling enables the researchers to control parameters and generate artificial societies to experiment with. To aid their understanding of these complex socio-technical systems, the researchers used the simulation framework, SimCo (Simulation of the Governance of

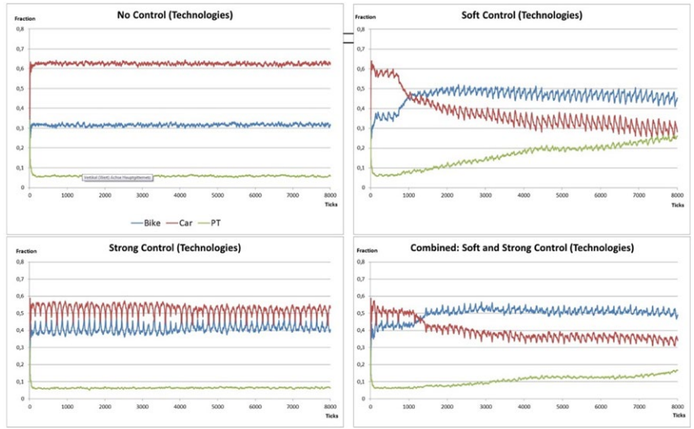

Fig.2 Modes of transport: The researchers simulated three modes of governance with varying degrees of intervention and a reference scenario. Soft control had the greatest effect on agents' behaviour in the long term.

Complex Systems), which was also developed at TU Dortmund.

SIMCO

SimCo is a general-purpose framework for agent-based modelling of networked systems where the agents have to consider the physical infrastructure when making their individual choices. SimCo can simulate various what-if scenarios and is underpinned with analytical sociology. This enables the researchers to predict which scenario leads to politically desirable and societally acceptable results, thus suggesting ways to influence and govern the real-time society.

To perform scenario-specific simulations, SimCo requires an initial setup of the networked system being modelled *(see figure 1)*. This takes the form of the underlying network, such as a transport system in terms of its nodes (e.g. home or work), edges (e.g. roads or bicycle tracks) and controls (e.g. charges or emission limits). The various technologies available to the user are specified, e.g. cars, bicycles and public transport. Different types of agents are initially located at various nodes. The agents represent road users with different preferences (e.g. cheap or eco-friendly) and are equipped with different technologies and individual task lists. The tasks involve choosing modes of transport in order to travel to various destinations. Agents are influenced by both incentives and traffic situations and the results of their decisions can be observed in terms of traffic jams, lower emissions etc.

EMPIRICAL RESULTS

The research team performed a number of simulation experiments to test the efficiency of various governance measures on road transportation scenarios. They were also able to note any unintended side effects. Experiments were conducted comparing the traditional mode of governance and its sequential planning and action with real-time governance, where decisions are influenced by real-time information. The researchers analysed the effects of real-time governance at the system level by measuring the efficiency of the system. They were also able to measure the satisfaction of actors, i.e. the efficiency at the actor level.

Experiments focusing on reducing the use of cars with internal combustion engines in order to reduce their negative impact on the environment, such as CO_2 emissions, involved comparing three different governance scenarios with a base scenario involving no intervention. The three scenarios involved simulating varying degrees of intervention *(see figure 2)*. The soft control scenario used road pricing with increased costs for agents using the cars when capacity or pollution exceeded pre-set limits. Strong control was implemented with spatial and temporal bans of cars, where agents are forced to change technology or take another route when a particular threshold is reached. The third scenario was a blend of soft and strong control.

Understanding the challenges of the digital society requires understanding the mechanisms that are guiding the dynamics of socio-technical systems.

All three modes of governance succeeded in reducing the use of cars and increasing the use of more sustainable modes of transport, such as bicycles and public transport, therefore having positive impact on the environment. Soft control was observed to have the greatest effect on agents' long-term behaviour, followed by the combined soft and strong control. A significant result was observed in relation to political interventions, such as minimising risk or improving a system's sustainability. The simulations demonstrated that scenarios that employed a soft control mode of governance using incentives worked better than those using strong control measures such as bans.

CONCLUDING REMARKS

Professor Weyer comments that "understanding the challenges of the digital society requires understanding the mechanisms that are guiding the dynamics of socio-technical systems in general and of the digital society in particular". This research delivers a multi-level model of governance supported by a basic model of a sociotechnical system. This model enables researchers to analyse complex, nonlinear interactions of multi-layer systems and inform good governance within digital societies. In order to forestall the risk of losing control, political regulation will also have to become 'smart', as they will not be able rely on the traditional measures of the past if they are to form a human future for the digital society.

Behind the Research

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Research Objectives

Through the simulation framework SimCo developed at TU Dortmund, Dr Weyer investigates the dynamics of socio-technical systems like transportation or energy supply.

Detail

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Bio

Johannes Weyer has been appointed Professor of Sociology of Technology at TU Dortmund University in 2002, after having worked at the University of Bielefeld from 1984 to 1999. His areas of research are human-machine interaction, governance of complex systems, agent-based modelling and digital as well as sustainable transformations.

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Collaborators

- Michael Roos (Univ. Bochum)
- Christian Rehtanz (TU Dortmund)
- all members of the Technology Studies Group at TU Dortmund

Technology Studies Group

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Personal Response

What inspired you to combine agent-based modelling with multi-level modelling of complex systems?

"As a sociologist, my starting point has been governance research, above all the question if complex social systems can be steered into certain directions. In the 1980s, we debated about nuclear technology and asked ourselves if alternatives might be possible. Nowadays, we debate about sustainable energy or mobility, which still has the same question at its core: how can we direct a complex system into a desirable future? In the past, my methodology had mostly been case study based, which, however, means looking into the past. In the early 2000s, I became aware of agent-based modelling as a method of forecasting by means of computer simulation."