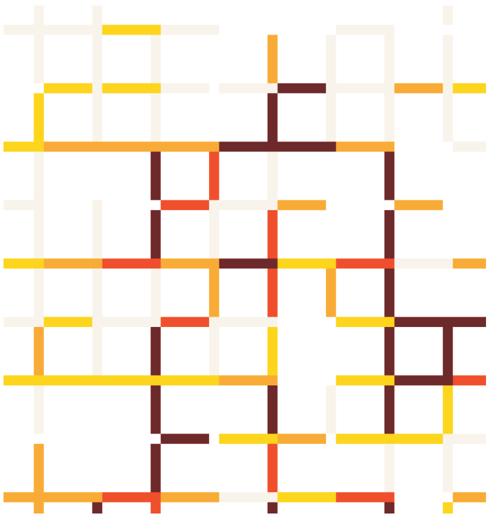
Prof. Dr. Dirk Helbing
Chair of Sociology, in particular of Modeling and Simulation

Phone: +41 44 632 8880 • e-mail: dhelbing@ethz.ch • www.soms.ethz.ch

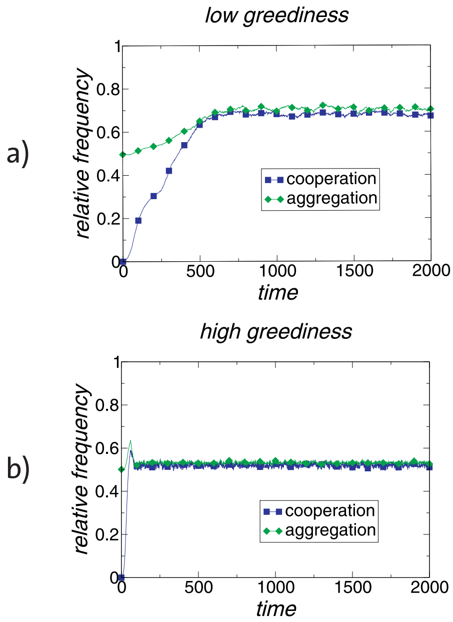
Traffic theory has explained the relationships between fundamental indicators, such as speed, density and traffic flow. The most common relationship is called fundamental diagram, charactering the regimes of traffic flow (free or congested) in a specific road location. Such laws, however, are not sufficient to describe the entire complexity of traffic congestion in an urban road network. To obtain a better understanding of city traffic, we follow a simulation-based approach (see figure below), as data availability from cities is limited. We have developed innovative modeling techniques, which are able to reproduce the variability of urban congestion even for the same traffic volume. Moreover, we have discovered the spatial variability of density as a key variable of urban traffic flow. It reveals surprisingly clear functional relationships rather than producing large data clouds for congested traffic, as previous approaches did.



In our computer simulations, a 6km 6km city-center is repre-sented by a lattice-like road network reminding of traffic flow in Manhattan or Barcelona.

In another project, we investigate the crucial question of social cohesion. While social cohesion in human societies is largely dependent on high levels of cooperation and social ties, both features are steadily challenged by individual self-interest in social dilemma situations. As outbreaks of civil wars and the recent crisis of financial markets illustrate, the stability of social and economic systems can suddenly break down, and the balance between altruism and selfishness is therefore critical for the ultimate survival of societies. Let us consider, for example, the problem of climate change. Will society remain cohesive and make a joint effort to reduce CO_2 emissions? Or on the contrary, will solidarity fall apart, resulting in uncoordinated individual behaviors? To address this issue, we have developed a model which allows us to pose the problem quantitatively. It basically consists of a population where individuals have the option to contribute or not to contribute to public goods. Moreover, they can also migrate, thus deciding how many people and whom they relate with.

The figure below illustrates the kind of results we obtain with this model. Each panel displays different measures showing the degree of cooperation and aggregation in the emerging society. Our main conclusion is that the success of society in staying together and cooperatively working to a common end depends very much on the level of greed, of individuals. Only intermediate levels result in high levels of social cooperation and cohesiveness, which has strong implications in terms of education and public policy. Too high greediness can drive a social system to instability, as it has been observed for the financial system.



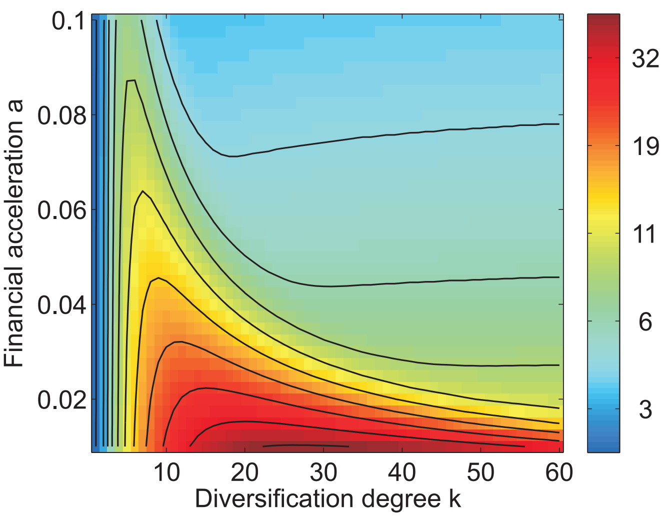
Evolution of a model society for two levels of greed: (a) 0.3 and (b) 0.8. The outcome clearly depends on this parameter. (a) For moderate greediness, society is stable, with high levels of aggregation and cooperation. (b) For high greediness, instability results with random behavior and general dissatisfaction.

Prof. Dr. Dr. Frank Schweitzer
Chair of Systems Design

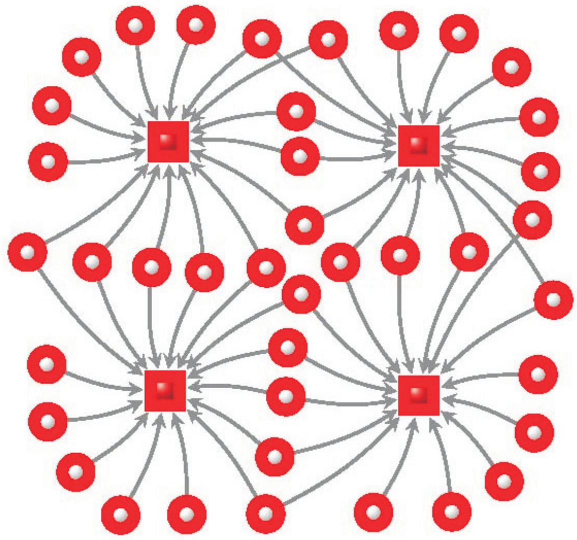
Phone: +41 44 632 83 50 • e-mail: fschweitzer@ethz.ch • www.sg.ethz.ch

Our research focuses on interdependences in financial systems and their impact on systemic risk. To this extent, the financial system is modeled as a network of interdependent units which are connected by financial contracts. We find that a more connected financial system is not necessarily more robust, as it is claimed in the literature (especially before the current crisis). On the contrary, our analytical results show that systemic risk is not a monotonic decreasing function of diversification. Instead, there is an optimal level of diversification beyond which crises become more frequent.

Recently, our efforts have been directed in two directions: One the one hand, we have investigated to what extent our findings for the abstract model remain valid if model parameters are varied. We could show analytically that the results are indeed robust for various parameter modifications, for example the intensity of financial acceleration (see left figure). On the other hand, we have developed micro-founded models of financial systems in order to investigate the non-monotonic behavior of systemic risk. For this, we have proposed a dynamic model of a bond market where financial institutions issue bonds and purchase others' bonds. While basic assumptions about the model are consistent with the finance literature, our network approach leads to



Systemic risk in a financial network. Expected first time for a systemic default to occur, as a function of diversification and financial acceleration.



Systemic risk and geographic integration. As an example of low integration level, firms (circles) borrow from banks (squares) of two different regions.

new and promising results regarding the relation between institutional couplings and systemic risk. This becomes non-trivial because the dynamics of financial fragility displays super-exponential growth with finite time singularities. In this context we plan to strengthen the collaboration with the Chair of Entrepreneurial Risk.

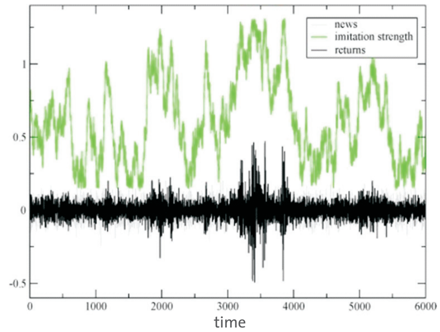
We are working on the relation between systemic risk and economic integration. Building on existing models of business fluctuations with heterogeneous agents, we investigate a system of firms and banks organized in geographical regions. At one extreme of the integration range, firms borrow only from the bank of their region and sell their product only in their region. At the other extreme, firms borrow from and sell in all of the regions. Integration allows for diversification of risk and reduction of profit fluctuations, but it also leads to potential financial contagion. We find that at beyond a certain level of integration, systemic risk increases and gives rise to intermittent cascades of failures (right figure). This result, qualitative similar to what found in our abstract model, confirms the role of financial acceleration in the onset of systemic risk within a more realistic context and in presence of heterogeneous firms.

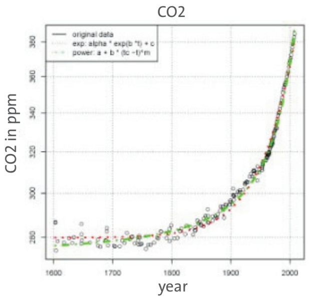
Prof. Dr. Didier Sornette
Chair of Entrepreneurial Risks

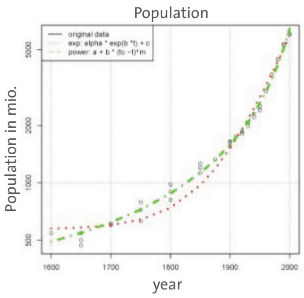
Phone: +41 44 632 89 17 • e-mail: dsornette@ethz.ch • www.er.ethz.ch

A solution of the excess volatility puzzle based on stochastic resonance (G. Harras)

Excess volatility is one of the major unsolved problems in finance. It refers to the observation that the volatility in financial markets is by far larger than the volatility of the fundamentals, the data which are used to estimate the fair value of an asset. We approach this problem by modeling traders in an artificial stock market, who base their trading decisions not only on the latest news of the fundamentals but also on their own private information and the trading activity of their colleagues. We can show that by increasing the imitating behavior of the traders, the impact from the news onto price dynamics is amplified, resulting into a much higher volatility in the returns as in the news. By allowing the imitation strength, which can be seen as a proxy for the uncertainty in the market, to change in time, our model is also able to explain clustered volatility and crashes as they are seen in real markets.







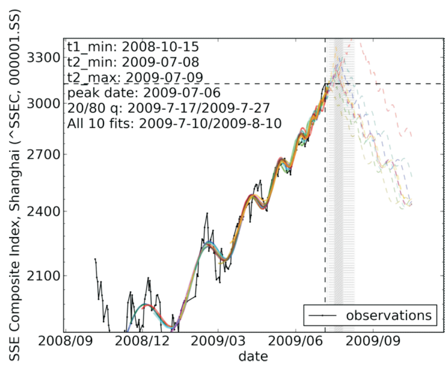
Economic model with endogeneous growth and evidence from global population and CO2 emmission trends (Andreas D. Hüssler)

Population has been growing increasingly fast over the last two centuries and was the most important driver of economic production measured as GDP. GDP itself can be directly related to CO_2 emission which is believed to be the most important human emitted greenhouse gas and harmful contributor to global warming. In the Kyoto protocol, nations agreed not only to stabilize current emissions, but to bring back CO_2 share in the atmosphere to the 1990's level.

This goal seems very ambitious to us. Considering population growth and economic development of emerging markets, such as China and India, which have just started to catch up with "western consumer" lifestyle. China and India together represent 35% of world's population, but account only for 14% of gross world product and already emit a quarter of the current CO_2 emissions. Analyzing this problem requires careful consideration of the interplay between population growth, industrial production and technology.

Prediction of the 2005-2007 and 2008-2009 Chinese stock market bubbles (Financial Crisis Observatory)

We use the LPPL model in one of its incarnations to analyze two bubbles and subsequent market crashes in two important indexes in the Chinese stock markets between May 2005 and July 2009. Both the Shanghai Stock Exchange Composite and Shenzhen Stock Exchange Component indexes exhibited such behavior in two distinct time periods: 1) from mid. 2005, bursting in Oct. 2007 and 2) from Nov. 2008, bursting in the beginning of Aug. 2009. We successfully predicted time windows for both crashes in advance with the same methods used to successfully predict the peak in mid. 2006 of the US housing bubble and the peak in July 2008 of the global oil bubble. The more recent bubble in the Chinese indexes was detected and its end or change of regime was predicted independently by two groups with similar results, showing that the model has been well-documented and can be replicated by industrial practitioners.



Prof. Dr. Kay Axhausen
Chair of Transport Planning and Systems

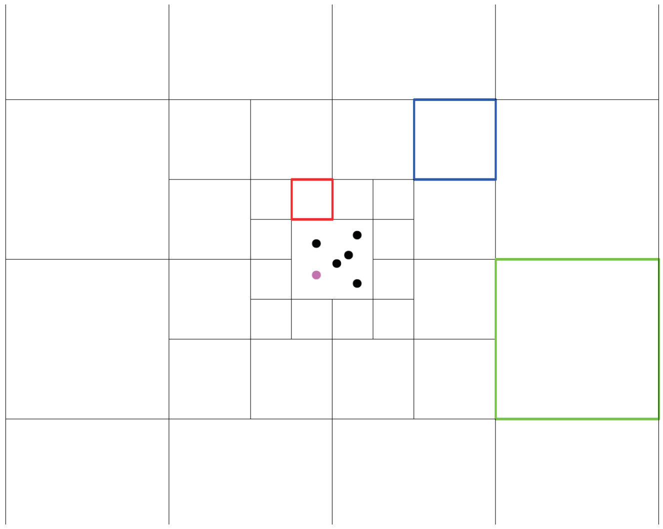
Phone: +41 44 633 39 43 • e-mail: axhausen@ivt.baug.ethz.ch • www.ivt.ethz.ch

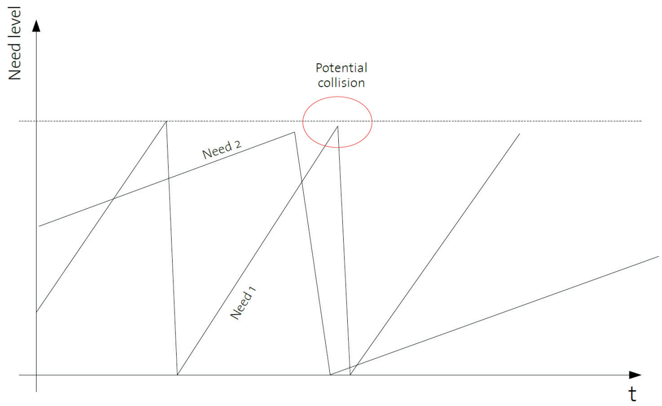
Need-based Short Term Travel Behavior

Current integrated agent-based transport planning models use individual activity plans as a representation of the transport demand. Each agent (representing a virtual person in a microscopic simulation) has such a plan describing precisely his/her intended actions during the analysis period under investigation. The plan is called complete if it contains all information including activity types, times, locations, and routes.

Currently, daily activity plans are often generated by using an optimization approach: Various possible activity plans are created and examined using a utility function. Finally, the assumed best plan is selected for execution.

While suitable for modeling the average work day, this approach poses troubles when we want to describe travel behavior in situations relatively far away from every day situations, or when the state of the infrastructure shows strong fluctuations every day.





The problem with such scenarios is the impossibility of reliably predicting what is going to happen and hence – from the point of view of the agent – to plan in advance how to perform. In real life, we deal with that problem by simply reacting to whatever situation we might encounter. This is usually done relatively quickly.

We investigate how the described behavior can be reproduced by modeling for each agent a set of endogenous needs (e.g. sleep, food, work, shop, leisure). These needs build up constantly and can be satisfied by performing a corresponding activity at a suitable location.

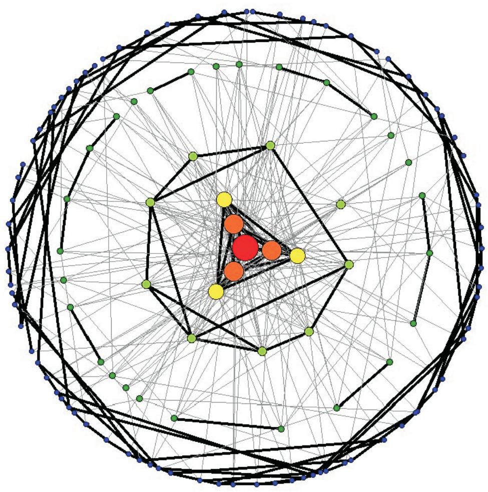
The behavioral rule is now to monitor all of these needs and make sure that none of them "starves". This is achieved by executing the corresponding activities early enough to avoid overly high need levels (right figure: two conflicting needs).

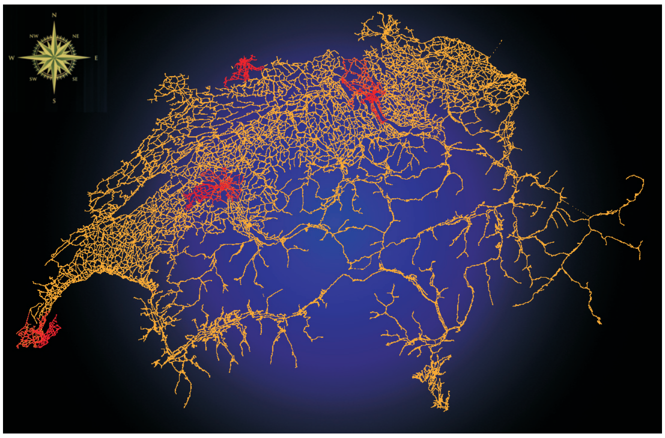
The new modeling framework contains several new data structures and algorithms to provide online information about the state of the infrastructure, locations, and the best routes to travel between any two locations (left figure: hierarchical routing table).

Prof. Dr. Hans J. Herrmann
Chair of Building Materials

Phone: +41 44 633 27 01 • hans@ifb.baug.ethz.ch • www.ifb.ethz.ch/comphys

The security of real networks, like power supply, communication, computer or spy networks, is an important issue. Networks are considered to be secure if their function is not affected by the removal of nodes, which can be either random or targeted. Many networks are remarkably resistant against random failure, but a malicious, targeted attack can disrupt them removing only a small fraction of nodes. We develop a method to generate robust networks against malicious attacks, as well as to substantially improve the robustness of a given network by swapping edges and keeping the degree distribution fixed. A novel measure for network robustness based on persistence of the size of the largest cluster during attacks is introduced. The method was applied to several types of model networks and to the AS Internet. We find that the method improves robustness significantly. Our results show that robust networks have a novel "onion-like" topology consisting of a core of highly connected nodes hierarchically surrounded by rings of nodes with decreasing degree. Networks of compromised computers, botnets, are nowadays the main source of malicious internet traffic. Since botnets are used for sending unsolicited commercial emails, spams, characteristics of temporal patterns in receiving such emails can be used for revealing botnet properties. We model sending of the botmaster orders inside a botnet with a complex ordering hierarchy, or sending of the spam emails through internet, as a dynamical process on directed complex networks. Our goal is to understand the source of correlations in interarrival times of spam massages. In the first approximation we model messages by random walkers,





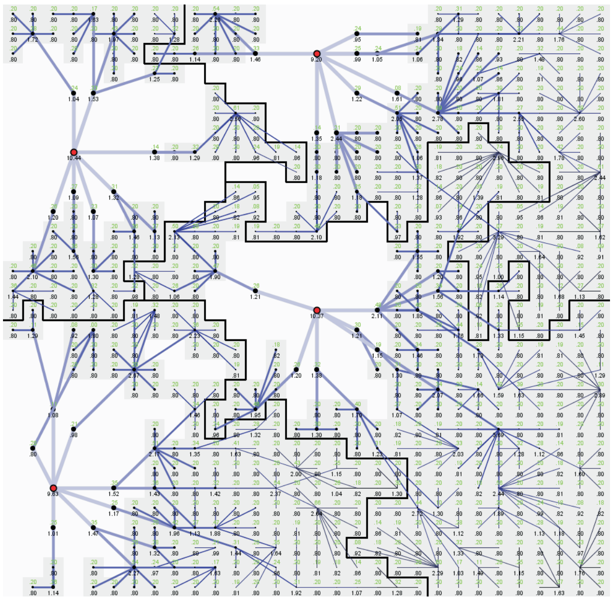
sent using different dynamical rules from the chosen source nodes. We use the first arrival times of random walkers to the chosen receiver node to calculate the interarrival time distribution of messages. We find that even in this simple model, for specific network topologies the distribution of interarrival times deviates from exponential distribution, meaning that the dynamical processes studied are not random. The obtained distributions allow for bursts in receiving spam, which is a property of spamming process observed in the analysis of the real spam data. Traffic networks are essential elements of infrastructure and an important example of networks in which the interplay between the network's topology and the dynamics taking place on it has a crucial role in network's functionality. In order to understand influence of network's topology on its functioning, we introduce a traffic model on at first different model networks, and then finally on the road network of Switzerland. In modeling traffic we use the "coarse-grained" fluid-dynamical description in which the traffic is viewed as a fluid formed by the vehicles. For given maximal velocity and maximal density of cars in each street, we study traffic flow on different network topologies. Our aim is to gain the understanding of mechanisms responsible for emergence of traffic jams. Of our special interest is the study of the phenomenon of traffic gridlock, which is a special traffic jam affecting a whole network of intersecting streets. The traffic gridlock is an important case of infrastructure failure. Understanding interaction between traffic dynamics and the topology of traffic networks, which is giving rise to this phenomenon, is an important step in increasing security and robustness of infrastructure.

Prof. Dr. Lars-Erik Cederman
Chair of International Conflict Research

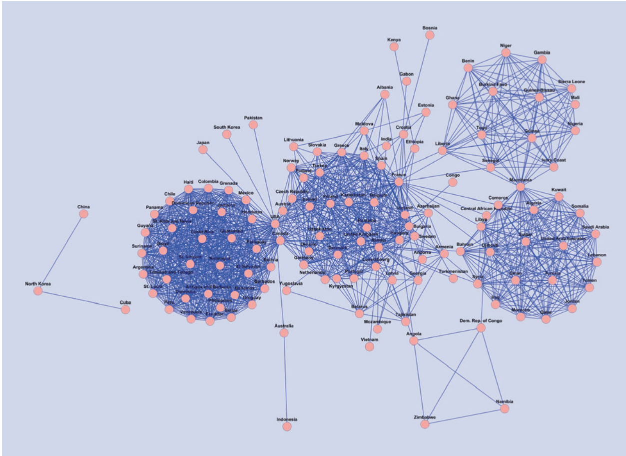
Phone: +41 44 632 67 59 • e-mail: lcederman@ethz.ch • www.icr.ethz.ch

The ICR group studies crises generated by human conflict, such as civil wars and ethnic conflict, focusing particularly on the consequences of macro-historical processes such as state formation and nationalism. While much of our recent research has centered on data collection, including geographic information systems, the group also has a long-standing interest in computational modeling. Under the auspices of CCSS, our computational framework "Geosim" was recently extended to a study of emergent state hiearchies. Lars-Erik Cederman & Luc Girardin's (forthcoming in International Studies Quarterly) agent-based model focuses on the shift from indirect to direct rule, by explicitly representing the causal mechanisms of conquest and internal state building as organizational bypass processes. The computational findings confirm our hypothesis that technological change is sufficient to trigger the emergence of modern, direct state hierarchies.

In order to study another historical phase shift, Lars-Erik Cederman also initiated a project on war-size distributions in collaboration with CCSS colleague Didier Sornette. By applying distributional analysis to conflict data from the last five centuries, we show that the the size of interstate wars, measured as the number of combat fatalities, is power law distributed

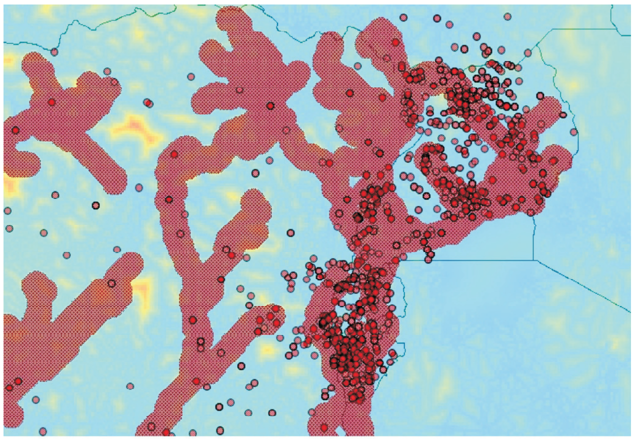


Medieval states with deep hierarchies before the onset of direct rule.



The network of interstate alliance commitments in 1999.

and has increased significantly after the emergence of nationalism following the French Revolution.In the study "Regions at Risk", Sebastian Schutte estimates high-intensity conflict zones in civil wars. The project identifies guerrilla warfare and proposes a stylized model to analyze its spatial dynamics. Data on infrastructure, terrain, population, and locations of the primary political actors allow for the identification of high risk zones along time-cost optimal centerperiphery routes. These zones are good statistical predictors for conflict locations in civil wars. The combination of spatial statistics, political theory, and Geographic Information Systems enables this project to go beyond the traditional questions of conflict research.



Estimated risk zones for Central Africa. The red dots are conflict events from the ACLED dataset.