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Satellite Meeting

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http://www.eccs14.eu

Time	Speaker	Title	email
08:45-09:00	**Organizers**	**Welcome**	
09:00-10:00	K. Nagel	*Transport simulation as a complex adaptive system*	*nagel@vsp.tu-berlin.de*
10:00-10:20	F. Caravelli	*From production to export via transport: An agent-based model for agricultural logistics chain in Uganda*	*francesco.caravelli@gmail.com*
10:20-10:40	J. Barthélemy	*A dynamic traffic assignment model with strategic agents*	*johan@uow.edu.au>*
10:40-11:00	F. Lamanna	*Temporal analysis of perturbed railway networks: centralities, periodicity and delay correlations*	*fabio@timenetwork.org>*
11:00-11:30	coffee-break		
11:30-12:30	A. Vespignani	*Transportation networks and the global spread of emerging infectious diseases*	*alex@indiana.edu*
12:30-12:50	G. De Luca	*Holydays in age structured spatial models for influenza spread: a realistic model for Belgium*	*giancarlo.de-luca@inserm.fr*
12:50-13:10	B. Monechi	*Universal Behaviour in Urban Mobility Emerging from Geo-referenced Floating Car Data: Analysis and Modeling*	*bernardo.monechi@uniroma1.it*
13:10-13:30	A. Bazzani	*Congestion Transition in traffic stochastic models on networks*	*armando.bazzani@unibo.it*
13:30-13:40	**Organizers**	**Final Remarks**	

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Transport simulation as a complex adaptive system

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Abstract

Transport systems of large cities or regions consist of the order of 10^7 to 10^8 elements (persons, vehicles, signals, …). Given today's computational capabilities, it is possible to build microscopic computational models of all these elements for such a city or region, including all cars, buses, trains, bicycles, etc.

For many questions, however, it is also necessary to have a model of the demand, since the system reacts to policy measures mostly not by changes in the driving behavior, but by changes in route choice, mode choice, departure time choice, location choice, etc.

There are two major approaches to address this problem:

- build a model of travelers who solve the problem in real time, i.e. while being en route, or
- assume that the synthetic travelers learn good or optimal behavior from day-to-day iterations.

In our work, we have concentrated on the second option. It can be modeled with methods from Complex Adaptive Systems, where each synthetic traveler optimizes for her-/himself while everybody around does the same. This results in an approach that is a similar to, e.g., Brian Arthur's "bar problem" approach, and can be considered a (co-)evolutionary game.

The resulting simulation system also has similarity to random utility modeling, which is arguably the most important modeling approach in travel behavior research. An advantage of the approach includes that there are well-established methods and software packages to estimate random utility models from (revealed or stated preference) data.

Yet, the contexts under which random utility models are typically estimated are not exactly the same as those under which they are used in the simulations. Therefore, a re-calibration of the models within the simulation system is necessary. This is a bit similar to calibrating the behavioral rules of a complex systems model based on its emergent properties.

This presentation will demonstrate what we have achieved in terms of large-scale microscopic simulation of traffic systems, in terms of calibration, and in terms of economic interpretation in particular with a view to cost-benefit analysis.

From production to export via transport:

An agent-based model for agricultural logistics chain in Uganda

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Abstract

Transport costs in Uganda at all levels are very high in relation to its neighbouring African countries. However, the simple investment of transport, particularly on road transport, through significant investment policies may not reach the expected results in terms of increase in trade flows. In order to gauge the importance of transport, in this work we consider an agent based model (ABM) for the agricultural logistics chain in Uganda. The aim of the model is to determine the factors which could improve the trade market dynamics of Ugandan farmers. In this context we design the AB to model the flow of goods from farmers to markets, and the flow of information from markets to farmers. The AB system is decentralized with no designated command and control, although a further assumption on the topology of social network among farmers and traders is made. Each agent follows a decision tree in order to maximize their utility, and minimize the amount of money paid upfront (risk aversion). We introduced several agents, such as producers, traders, itinerant traders, exporters, alongside various on road transport means (and whether with fridge or not, realistic capacity and speed), a banking system and government taxation, together with seasonal weather factors such a temperature for the spoilage of the product. Using the bankruptcy rate as an order parameter, we checked the effects of policies such as: Raising/reducing transport costs, improvement of logistics infrastructures and coordination policies for logistic consolidation centres. We compared the effect of these policies with the equilibrium values of the bankruptcy rate in the basic simulation. We focussed on 7 districts located in the Central and Eastern regions of Uganda: Luwero, Mpigi, Masaka, Iganga, Mitiyana, Kamuli, and Mukono, using available GIS data to define the spatial, geographical and demographic environment of the agent based system. Other behavioural data has been collected from different sources and from a supervised survey among farmers in Uganda. The survey also helped us define the costs of transport, production and the current situation of the Ugandan market. We iscovered that most of the trade among farmers is performed through itinerant traders. The data from the survey was used also to understand the overall behaviour of the agents in the model. The outcome of the simulation showed the impact of transport costs on the bankruptcy rate of the agents. At equilibrium, the bankruptcy rate decrease/increase is proportionally to the decrease/increase in transport cost. Also, we observe that the improvement of logistics infrastructures and in particular the road system, as turning gravel roads into paved ones, has little impact on the bankruptcy rate, while the introduction of logistic consolidation centres among farmers reduces it drastically.

A dynamic traffic assignment model with strategic agents

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Abstract

The aim of this work is to present a novel and promising approach for an original behavioural Dynamic Traffic Assignment model, particularly suitable to be used and implemented in micro-simulations relying on individual agents modelling. Indeed a behaviour can be seen as one of the agent characteristics. The proposal relies on the assumption that travellers take routing policies rather than paths, leading us to introduce the possibility for each simulated agent to apply, in real time, a strategy allowing him to possibly re-route his path depending on the perceived local traffic conditions, jam and/or time spent.

The re-routing process allows the agents to directly react to any change in the road network, which removes the need of restarting the whole simulation process and consequently decreases the computational cost with respect to more classical equilibrium approaches. For the sake of simplicity, the agents strategy is modelled with a simple neural network whose parameters are determined during a preliminary training stage. The inputs of such neural network read the local informations about the route network and the output gives the action to undertake: stay on the same path or modify it. As the agents use only local information, the overall network topology does not really matter, thus the strategy is able to cope with large networks, i.e. the model is highly scalable.

The goal of each agent is to be able to choose the best links, i.e. the less congested ones on his path taking into
account the dynamically varying traffic conditions. Because we are interested in modelling adaptive agents able to
well perform in many different scenarios, we introduced a learning phase based relying on a genetic algorithm approach instead of fine tuning by hand
each agent's behaviour, in this way the emerging strategies would be able to have good performances across
different (dynamic) environments.

Numerical experiments are performed on different scenarios containing different proportions of trained strategic agents, agents with random strategies and not strategic agents, to test the robustness and adaptability to new environments. The new methodology is also compared against a conventional equilibrium approach. The results suggest that as the proportion of strategic agents increases, the average fitness, the ratio of used streets and the agents average speed slightly improve. Moreover the differences between the solution computed by the proposed model and the one generated by the conventional algorithm decrease.

Temporal analysis of perturbed railway networks: centralities, periodicity and delay correlations

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July 11, 2014

abstract

In this work we analyse the dynamics and the correlations among the traffic at stations of a whole rail service network, making use of the temporal variations of a timetable structure due to delays, taking into account both the topology and the services running throughout the system. We considered a data set of timetables of the Deutsche Bahn national German railway network, which includes complete information, with the precision of the minute, about the exact time of arrival and departure of each train at each station along its route during year 2012. We considered both high-speed and long-distance train services (IC and ICE) running within Germany, and we constructed 245 daily service graphs, based on the concept of "Space of Stops". In this framework, nodes represent stations and two nodes are connected if they are the consecutive stops of a route of at least one scheduled train service. Moreover, each edge is associated to a weight proportional to the total delay observed in that day on the corresponding route segment. Each daily network consists of up to 656 stations, and on average around 650 trains run throughout the system on a typical working day. We performed a temporal analysis of the daily service networks, which shows that the system is characterised both by periodicities and burstiness. We found several properties about the centrality of nodes: in particular the structural properties of each node, such as betweenness centrality, are broadly distributed and can substantially fluctuate over time and there are both local and long-range spatial correlations among delays. In order to analyse the scheduling dynamics over the network, we defined a weighted betweenness centrality measure called *timetable centrality*, evaluated over the delays associated to edges. Analysing the yearly distribution of centralities measures, we found strong correlations

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between weighted and non-weighted betweenness centrality over the days of the year. This may reveal that there are groups of services which are both non-stop and scheduled among nodes which deserve the role of shortening the distances in the network, both in terms of service availability and in terms of scheduling. Finally, some correlations among *betweenness impact* (which measures the relative variation of the graph average *timetable centrality* due to the removal of a vertex), betweenness and timetable centrality can be found as well, showing that the nodes crossed by the most scheduled paths play a role in the whole network dynamics. These results suggest that a complex-network approach can reveal some interesting properties about a national transportation system, and in particular that centrality measures can be effectively employed to spot potential vulnerabilities.

Transportation networks and the global spread of emerging infectious diseases

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Abstract

Human mobility and transportation networks are the underlying substrate over which global pandemics spread.

Mathematical and computational models that integrates transportation networks have gained importance in the public-health domain, especially in infectious disease epidemiology, by providing quantitative analysis in support of the policy-making processes. In this lecture I will focus on discussing the recent successes as well as the methodological challenges in integrating transportation networks in the modeling of global epidemics. I will discuss the phenomenology emerging from the integration of multi-scale networks, the accuracy provided by different levels of data-integration, the problem of real-time estimation of parameters, and the validation through high quality data sets of the computational models. Finally I will discuss the applications of these modeling approaches to real world situations such as the West African Ebola outbreak.

HOLIDAYS IN AGE STRUCTURED SPATIAL MODELS FOR INFLUENZA SPREAD: A REALISTIC MODEL FOR BELGIUM

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Abstract

Holidays and week-ends affect both the social contact patterns and mobility of persons. In this work we investigate the effects of holiday and week-end induced variation of social and mobility patterns on the spread of communicable airborne disease (such as influenza) and compare the relative effect of each of such factors on the output of such models in an age-structured SEIR meta-population.

The heterogeneity of social contacts is included in the model using POLYMOD contact matrices for week and week-end of both regular an holiday periods. The variation of mobility patterns is harder to estimate: we inferred it from several studies on transportation and used as the census data to infer the mobility fluxes between municipalities.

Another, intrinsic, layer of heterogeneity is due to the differences in the demographic distribution of population in the patches: this, even assuming that infectious rate is constant for a given strain in a given year, owing to the age structure in the patches, induces a large variability of the basic reproduction and thus the in-patch dynamics of the meta-population model.

To investigate the behaviour of this system, we compare four different scenarios: a baseline scenario in which all these effects are considered together, a scenario in which only variation in social contact patterns is included, a scenario in which only variation of mobility patterns are included and, finally, a situation in which neither social nor mobility patterns vary. Such analysis suggests that variation in social patterns has a significant impact on the evolution of system, whereas variation in mobility patterns seem to have only marginal effects. Moreover, during a typical influenza season, the main contribution seems to come from the week vs. weekend variations: during week-ends, in fact, the reduction in social contacts induces a significant drop of the basic reproduction number of the in-patch age-structured SEIR and thus slows down the spread of the disease.

Phase Transition in an Air Traffic Control Model

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The importance of air transport has considerably grown in time, being nowadays an essential fast mean to connect national and international locations. Despite the competition with other new transportation systems, above all high-speed railways, and the recent economical crisis that reduced the load of traffic, an increase of air traffic demand over Europe has been forecast in the coming years. This growth of the traffic load could bring the actual Air Traffic Management system (ATM) over its capacity limits so that safety standards and performances might not be guaranteed anymore. Hence, it is important to understand the limits and the features of the current system, seeking for new solutions aimed at improving its capacity. Complex Systems Physics has already proven to be useful to study and understand the criticality of many transportation systems.

In the current ATM system each aircraft is supposed to fly over predefined "airways" between some geographical references called navigation points. Safety standards are guaranteed by air traffic controllers, whose duty is to prevent aircraft from getting too close each other. In order to guarantee such separation, controllers can perform easily the required redirections without the need of following the established preexistent airways.

In this paper we present a simplified model of Air Traffic Control (ATC), where air traffic is regulated by controllers who provide the necessary safety separation between aircrafts while trying to minimize flight delays. As the traffic load increases, the model shows a phase transition from a phase in which all conflicts are resolved irrespective to the traffic pattern injected in the system, to a phase in which many conflicts cannot be resolved anymore. The model is first tested onto an idealized regular airspace with periodic boundary conditions and then applied to the actual airspaces recovered by means of real historical data. The presented study is innovative in considering the "geographical" structure of the routes and in analysing the efforts of the ATC to provide separation between aircraft, preventing or minimising delays at the same time.

Congestion transition in traffic stochastic models on networks

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Abstract

The fluctuation effects are especially relevant for statistical systems near critical points. We study the transition to congested states for a stochastic dynamical model of traffic on a road network. The model simulates a finite population that moves from one road to another according to random transition probabilities. In such a way we mimic the traffic fluctuations due to
the heterogeneity of the individual behaviour and the dynamics at the crossing points (e.g. the effect of traffic lights), and the amplitude of traffic flow fluctuations is proportional to the average flow as suggested by empirical observations.
Assuming a parabolic shaped flow-density relation there exists an unstable critical point for the road dynamics and the system can perform a phase transition to a congested state, where some roads reach their maximal capacity.
By using a statistical physics approach and the Kramer transition rate theory, we study the stochastic dynamics when the vehicle number tends to the critical value. In particular we compute the correlation among the traffic flows of connected roads and the fluctuation of the transition probabilities
and we estimate the probability of congestion appearance. We also analyze the network evolution during hysteresis cycles in the fundamental diagram average flow-average density when one modulates the load of the road network over the critical value and the formation of congestion traffic waves that back propagates on the road network.
The basic assumptions of the model are validated using the traffic data recorded by the MTS system composed by $\simeq 270$ inductive-loop traffic detectors on the main roads of Emilia Romagna region in Italy. These data allow a detailed study of the traffic dynamics in different load conditions that can be qualitatively compared with the results of the model.
Our analysis points out as the statistical properties of the traffic fluctuations not only allow define a congestion probability even when the system state is subcritical, but also influence the traffic dynamics during the congestion spreading in the orad network. We also suggest the possibility of forecasting the congestion formation in real situations by studying the properties of traffic flow fluctuations.