Student Conference in Complexity Science

Book of Abstracts

Brighton 19-22 August 2014

Biological Complexity

Wednesday, 20th August 2014

11:20 - 12:40 Ecology

The swarm and the mosquito: emergent group properties arising from local acoustic interactions

Andy Aldersley, University of Bristol, UK (andy.aldersley@bristol.ac.uk)

Mosquitoes form swarms that serve important functions in mating behaviour. Males fly together producing a "coherent" unit, which attracts the attentions of nearby females, who approach individually in the search for a mate. The precise mechanisms that support swarm formation and cohesion are unknown, yet may well rely on acoustic interactions between the individual males and females. Paired mosquitoes are known to modulate their wing beat frequencies in response to the sounds produced by their partner, a phenomenon that plays an important role in the male-female courtship routine. Knowledge of swarm dynamics is central to our understanding of how these insects breed, but also allows us to address pertinent questions with regards to emergent behaviours in animal aggregations. Of primary interest is investigating how group-level properties can emerge and change with varying membership numbers, or, put another way, how many mosquitoes are required to form a swarm? Using a combination of experimental research and data-driven computational approaches, we are able to probe how local interactions in the acoustic field give rise to group-level characteristics of mosquito swarms. This talk will describe the methods we use to study these processes, will present recent findings, and discuss them in the context of the broader literature.

Big fish and wiggly lines: using hidden markov models to describe imperfect time-series

Joe Scutt Phillips, University of Southampton, UK (joe.scuttphillips@soton.ac.uk)

Open ocean predators inhabit a vast three-dimensional world, governed not by physical habitat but rather by complex and dynamic phenomena such as thermally-structured bodies of water and the location and abundance of prey. The temporal and spatial scales that these animals behave on prohibit the undertaking of controlled experiments, and so in describing and examining behaviour we are limited to imperfect data collected from bio-logging devices, alongside simulation experiments. Certain behaviours are exploited by fisherman in commercially important marine animals, although a full understanding of these behaviours and the driving mechanisms behind them are not well understood. Large scale bias and uncertainty in fishing data mean understanding the link between these individual-scale behaviours and exploitation is impossible. Similarly, bio-logging time-series do not allow us to explicitely observe behaviour, but rather give us distinct, but noisy, patterns in movements that are believed to emerge from underlying motivations. Here, we show how hidden Markov modelling for multivariate time-series can be used to overcome the problems of autocorrelation and paucity of information in bio-logging data analysis, and quantitively inform both mechanistic individual-based or phenomenological population dynamics models.

Landscape-scale conservation: the role of space and time in the realisation of biodiversity benefits

Nick Synes, University of Southampton, UK (n.synes@soton.ac.uk)

Using RangeShifter, a novel modelling platform which combines population dynamics with individual-based dispersal behaviour, this study tests a number of landscape-scale conservation actions, and their impact on biodiversity. A number of artificial species have been parameterised within RangeShifter, broadly representing the real dispersal and life-history traits of UK woodland animal species. Species are parameterised with process-based dispersal, rather than a correlative dispersal kernel, meaning that their dispersal ability is dependent on the landscape matrix. Real landscapes are used, and

future landscapes have been created to represent land management actions such as habitat improvement, restoration, creation and landscape matrix modifications. Previous studies on landscape management have often simulated instantaneous impacts on biodiversity when management decisions are made. Here, landscape transitions through time are more realistically represented through the use of empirical data on the time-lag between the initial actions and the realisation of biodiversity impacts. Different spatial allocation routines are being tested to examine the effects of habitat creation both adjacent to and away from existing habitat patches. This study should provide guidance on the impacts that different land management strategies will have on animal populations. This will include tests of whether stepping stone habitats can provide genuine biodiversity benefits. It will also provide guidance on the relative biodiversity benefits of habitat creation versus improvement of existing habitat.

Citizen participation in ecological monitoring: the story of the New Forest cicada

Davide Zilli, University of Southampton (dz2v07@ecs.soton.ac.uk)

The New Forest Cicada (Cicadetta montana s. str.) is the only cicada native to the UK. During May to July it sings with a very characteristic high-pitched song, which is particularly difficult for most adults to hear. Sightings of the cicada within the New Forest date back to 1812, but the last unconfirmed sighting was in 2000. However, it's quite possible that colonies remain undiscovered in less visited parts of the forest. The New Forest Cicada Project (www.newforestcicada.info) is exploring the use of smartphones to enhance human hearing and help them detect and recognise the song of the cicada. We developed an app that can automatically recognise the call of this insect and report a geo-located, time-stamped survey that can analysed further by professional entomologists. After a first year of deployment, the app has collected over 6000 reports from over 1000 users. In this talk, I will describe the importance of smartphone technologies to enable wide participation in scientific research and discuss how the many sensors with which these devices are equipped, together with their ubiquity in every-day life, can enable a new interaction with our surrounding environment.

Thursday, 21th August 2014

11:20 - 12:40 Modelling Human Diseases

How to eliminate solutes from the brain: the role of arterial pulsations

Alexandra Diem, University of Southampton, UK (A.K.Diem@soton.ac.uk)

Alzheimer‘s disease (AD) is the most common form of dementia and although it has been researched for over 100 years to date there is no cure. Its onset and progression is closely related to the accumulation of the neuronal metabolite amyloid beta (Aβ), which raises the question of how metabolites and waste products are eliminated from the brain normally. The brain does not have a true lymphatic system consisting of dedicated lymphatic vessels, which are found in other parts of the body and therefore has to eliminate metabolites differently. In recent years a connection between the pathology of AD and cerebrovascular diseases has been suggested and confirmed in various mice studies, which has lead to the assumption that interstitial fluid in the basement membranes in the walls of cerebral arteries provide the pathways for the perivascular drainage of Aβ with arterial pulsations as the pumping mechanism. However, perivascular drainage occurs in the reverse direction of blood flow, which could not be explained solely by arterial pulsations. In this study we develop a coupled mathematical and computational fluid-structure interaction model to explain the reverse drainage of Aβ in the young. The results of this model will have implications for the development of preventive medication and aims a guiding experimental research in order to eliminate the disease.

A cellular automaton model of atrial fibrillation

Kishan Manani, Imperial College London, UK (kishan.manani08@imperial.ac.uk)

A single beat of the human heart is the result of complex electrical interactions within a network of heart cells which form heart muscle tissue (myocardium). Processes at all scales from molecular to organ level are important in determining proper heart function. Atrial fibrillation (AF), a heart rhythm disturbance, is alarmingly on the increase and occurs due to abnormal electrical wave propagation due to changes in the underlying medium at various scales. We present a cellular automata model of atrial fibrillation in which the essential features of the myocardium are taken into account, namely cellular branching, coupling and conduction. We find that as the underlying medium is altered that the mode of propagation undergoes a spontaneous transition from planar wavefronts to spiral waves and eventually small meandering wavelets. The transition mimics the natural progression of AF in patients from temporary bursts of abnormal wavefronts to a phase of persistent complex wave propagation. The simple model offers potential clinical insight into how the properties of myocardium initiate and maintain AF.

Modeling HIV virulence evolution in the context of immune escape

Christiaan H. van Dorp, Rob J. de Boer, Michiel van Boven, Universiteit Utrecht and National Institute for Public Health and the Environment, The Netherlands (c.h.vandorp@uu.nl)

A pathogen like HIV evolves rapidly under multiple levels of selection, and has to cope with a heterogeneous host population. Although these aspects have been studied before, the true nature of host-heterogeneity has not been addressed to our satisfaction. During (untreated) infection, HIV evades cellular immune responses and because of the massive polymorphism of the Human Leukocyte Antigen, the targets of these responses (epitopes) differ strongly between hosts. Supported by data, it has been suggested that HIV has evolved virulence levels that are optimal for transmission. Some models indeed predict this, but others caution that this mode of adaptation is not self-evident, mostly due to the short-sightedness of evolution during the infection of an individual host. Several theories have been proposed to better explain the evolution of virulence, and we aim to contribute to these attempts. We are developing a model of HIV's evolutionary dynamics that is highly detailed and realistic, and captures the interesting features of host-heterogeneity, immune escape and compensatory mutations, and selection on multiple levels. We hypothesize that these properties might be sufficient to explain HIV's observed virulence distribution.

Variational Bayesian analysis of blood glucose time series

Yan Zhang, University of Warwick, UK (zjwufei@gmail.com)

Diabetes is a lifelong condition in which the body cannot control blood glucose. Patients living with diabetes must learn to control blood glucose levels to avoid life-threatening situations. Researchers have been working on establishing an effective dynamic model to describe and predict blood glucose concentration levels for more than half a century. Many models have been developed to reflect the complex neuro-hormonal control system, but one of the major challenges remains is how to determine large amounts of parameters in these models while only the glucose concentration time series is provided. To simplify the model structure without losing the applicability, we used a top-down data driven approach to establish a stochastic nonlinear model with minimal order and minimal number of parameters tailored for each patient to describe and predict the response of blood glucose concentration to food intake. Various degrees of nonlinearities are considered for three groups of people (the control group, Type I diabetes and Type II diabetes group). Variational Bayesian method is applied to select the best model and infer the needed parameters. The parameters describe the dynamics and characteristics of the underlying physiological processes. Since the mechanisms of the glucose absorption are different for Type I, Type II diabetes and non-diabetic people, different distributions of parameters and noises for these groups are expected. The results from fifteen profiles with 72 hour continuous glucose time series shows that the glucose concentration change during 2 hours after food intake can be modelled by second order linear or nonlinear system for all three groups. The value of the parameters and intensities of the noises vary from peak to peak for a single profile. The analysis of variance for parameters and noise intensities shows significant differences between the control group and both diabetes group.

Darwininan Neurodynamics

Thursday, 21st August 2014

9:00 - 10:40 Darwinian Neurodynamics

Introduction to darwinian neurodynamics

Eörs Szathmáry, Eötvös Loránd University, Hungary

Online extreme evolutionary learning machines

Joshua Auerbach, École polytechnique fédérale de Lausanne, Switzerland (joshua.auerbach@epfl.ch)

Recently, the notion that the brain is fundamentally a prediction machine has gained traction within the cognitive science community. Consequently, the ability to learn accurate predictors from experience is crucial to creating intelligent robots. However, in order to make accurate predictions it is necessary to find appropriate data representations from which to learn. Finding such data representations or features is a fundamental challenge for machine learning. Often domain knowledge is employed to design useful features for specific problems, but learning representations in a domain independent manner is highly desirable. While many approaches for automatic feature extraction exist, they are often either computationally expensive or of marginal utility. On the other hand, methods such as Extreme Learning Machines (ELMs) have recently gained popularity as efficient and accurate model learners by employing large collections of fixed, random features. The computational efficiency of these approaches becomes particularly relevant when learning is done fully online, such as is the case for robots learning via their interactions with the world. Selectionist methods, which replace features offering low utility with random replacements, have been shown to produce efficient feature learning in one class of ELM. In recent work we have demonstrated that a Darwinian neurodynamic approach of feature replication can improve performance beyond selection alone, and may offer a path towards effective learning of predictive models in robotic agents.

Guiding search with neural networks

Siddharth Sigtia, Queen Mary, University of London, UK (s.s.sigtia@qmul.ac.uk)

An algorithm is described that adaptively learns a non-linear mutation distribution. It works by training a denoising autoencoder (DA) online at each generation of a genetic algorithm to reconstruct a slowly decaying memory of the best genotypes so far. A compressed hidden layer forces the autoencoder to learn hidden features in the training set that can be used to accelerate search on novel problems with similar structure. Its output neurons define a probability distribution that we sample from to produce offspring solutions. The algorithm outperforms a canonical genetic algorithm on several combinatorial optimisation problems, e.g. multidimensional 0/1 knapsack problem, MAXSAT, HIFF, and on parameter optimisation problems, e.g. Rastrigin and Rosenbrock functions.

Information transfer is not enough to preserve systematicity

Emília Garcia Casdemont, Institut de Biologia Evolutiva Barcelona (IBE, UPF-CSIC), Spain (emilia.garcia.casademont@gmail.com)

Language involves a search process at two levels: (1) To process an utterance, a set of constructions needs to be found that is able to reconstruct the meaning of the utterance from the form (in parsing) or construct the form of the utterance from

the meaning (in producing). Because there is often more than one construction that can trigger at any point in time (for example, the same word usually has multiple meanings) we get a search problem. (2) In addition to this, each language user has also the problem of finding which constructions are part of the shared language, based only on interactions with others. The language learner therefore unavoidably has to entertain several hypotheses, gathering enough evidence to decide which construction is part of the communal language. Here we focus on (2), more specifically on the role of information transfer within the framework of evolutionary neurodynamics.

We show in an agent-based experiment that the learning process, if seen as an evolutionary search process, requires information transfer between different hypotheses of communal constructions in order to explain why there is such systematicity in the language, for example, why the sequential pattern used in a noun-phrase with only an article and a noun is similar to one with an article, an adjective and a noun. We also show that it is not enough to achieve this information transfer but that also some form of ‚multi-level alignment' is needed to make the information transfer effective.

Symbol representation in the brain: past and current hypotheses

Yana Knight, Vrije Universiteit Brussel, Belgium (yana@ai.vub.ac.be)

The question of how the brain represents and manipulates symbol structures remains open. Studies have pointed to the existence of neural assemblies encoding a stimulus -- an idea that goes back to Hebb's associative learning and Abeles' synfire chains [1]. The neurons in the assembly are thought to be connected through temporal signals forming a spike train – neural code that may lie at the heart of encoding, decoding and information processing (id). Such assemblies may be permanent or even transient and exist as temporarily formed neural structures [2].

In 1988, Fodor and Pylyshyn [3] put forward a hypothesis that properties of human language and thought such as systematicity, productivity and compositionality suggest that the brain must implement a physical symbol system (PSS), formulated by Newell and Simon [4]. It has been pointed out that the non-symbolic mechanisms such as neural assembly and synfire chains may be used to implement and discover symbol systems. Fernando [5] presented a framework which illustrated how a PSS can be implemented in temporal coding. Within this framework, symbol tokens exist as spatiotemporal spikes on neuronal chains resembling synfire chains. This system is also capable of learning representations – an essential requirement for a realistic implementation of a symbol system.

Several attempts have focused on purely connectionist methods based on Hinton's distributed representations and allowed a network to form representations by statistically inferring constraints [6]. These, however, have succumbed to poor generalisation and training independence. Similarly, representing symbolic structures as semantic networks [7] has shown to suffer from the issue of rapid binding formation [5]. Forming part of a larger project dedicated to the investigation and implementation of linguistic structures in the brain, this paper surveys the existing symbol representation hypotheses and attempts to identify the future steps necessary to make progress with their implementation.

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Earth System Complexity

Wednesday, 20th August 2014

10:00 - 11:00 Earth System Complexity 1

Resilience of the Amazon rainforest under human impact

Bert Wuyts, University of Bristol, UK (bert.wuyts@bristol.ac.uk)

In complex environmental systems such as the Amazon rainforest, it is often not feasible run ecosystem-scale experiments. Additionally, there will be always variables that cannot be fully controlled. Therefore, environmental scientists usually rely on simulation models, data analysis or a combination. Earth system simulation models can be seen as our best attempt to synthesize environmen- tal processes in a computer model under computational constraints but their complexity can make their output often difficult to interpret. Likewise, the idea that complex behaviour can emerge from a limited set of simple rules suggests that at least for some cases we do not need such advanced models to understand system behaviour. In this study, we make an attempt to analyse and model the core complexity of Amazon forest's vegetation dyanmics from a complex systems perspective. We start from recent insights in savanna ecosystem theory, that sees the local environment as in three possible stable tree cover states (forest, savanna or treeless). We estimate the bifurcation diagram from high-resolution remote-sensed tree cover data and merged remote sensed - gauge rainfall and find that human impact considerably affects the derived hysteresis. Finally, we set up a simple model with a fire component derived from the data. Unexpectedly, anthropogenic changes to fire regime tend to stabilise rather than destabilise the dynamics. Hence, it is rather deforestation and impact on vegetation growth that destabilises the rainforest.

Investigating Cenozoic climate change and carbon cycle conundrums using simple numerical models and analysis

David Armstrong-McKay, University of Southampton, UK (D.Armstrong-McKay@noc.soton.ac.uk)

Early warning signals are hypothesised to commonly precede critical transitions in various different complex systems, leading to the suggestion that climate data could in future be monitored to detect such signals before climatic 'tipping points' are reached. However, there are several potential problems with this approach. For example, the discovery of these signals may be strongly dependent on the parameters chosen when performing the statistical analysis, and not all transitions may produce early warning signals. Here we use palaeoclimate data to attempt to detect critical slowing down and other early warning signals prior to significant climate perturbations hypothesised to be the result of critical transitions such as the Eocene-Oligocene Transition, Eocene Hyperthermals and the mid-Miocene Climate Transition. We also use the same approach on 'quiet' data across periods without any known critical transitions occurring and also significantly vary the parameter choices in our analyses in order to investigate the possible prevalence of 'false positives' when using these methods.

Homeostasis in random ecosystems

Iain Weaver, University of Southampton, UK (isw1g10@soton.ac.uk)

The properties of random matrices are of broad interest to a range of fields. Indeed, their study owes its very existence to applications. In this work, we study the behaviour of an abstract ecosystem model, classifying the behaviour of model fixed points by analysing the properties of matrices of independent random variates.

14:00 - 16:00 Earth System Complexity 2

Predicting global ocean circulation from north-south pressure gradients

Edward Butler, University of Southampton, UK (e.d.butler@soton.ac.uk)

The Meridional Overturning Circulation (MOC) is a large-scale global circulation of water (and heat) throughout the World's ocean. It is an integral part of the climate system and is responsible for significant anomalous warming of the North Atlantic region. Despite the complexity of the global ocean system, numerous attempts have been made to scale the strength of the MOC, principally in the North Atlantic, with large-scale, basin-wide physical properties. In particular, it is a long-held idea in physical oceanography that the strength of the MOC scales with the north-south density gradient, notwithstanding the fact that steady-state meridional flow in geostrophic balance is, in fact, linked to east-west pressure gradients. We return to the theoretical principles underlying such a proposal and adopt an alternative relationship, linking overturning to twice depth-integrated density gradients between northern and southern latitudes. We then test the veracity of this proposed scaling on multiannual, decadal, centennial, and millennial timescales within the complex Nucleus for European Modelling of the Ocean (NEMO) model framework. We find that this simple scaling relationship captures the transient response of global ocean overturning remarkably well across multiple timescales, even modeling the highly nonlinear response observed in the deep ocean, and we discuss the implications of these results for our understanding of global ocean circulation and climate change.

Western boundary current dynamics - are they really that simple?

Ed Doddridge, University of Oxford, UK (Edward.Doddridge@magd.ox.ac.uk)

Western boundary currents form an important and extremely energetic part of ocean circulation. Despite their importance for local, regional and global climate very little is known about the fundamental dynamics of western boundary currents. The differences in vertical structure for velocity and temperature remain poorly explained. I will present the results of high-resolution modelling studies of western boundary currents in domains with idealised bathymetry. By analysing the vorticity dynamics we hope to elucidate the physical mechanisms that determine the vertical structure of western boundary currents.

Ekman's Demon: Ocean-atmosphere communication in climate models

Maike Sonnewald, University of Southampton, UK (M.Sonnewald@noc.soton.ac.uk)

Coupled climate models of the ocean and atmosphere rely crucially on the depth of the oceanic mixed layer. This layer facilitates the complex conversation between the two, through exchanges of heat, gas and momentum and varies in depth between tens and hundreds of meters. Its extent sets the exchange of properties between the deep and surface ocean through "Ekman's demon", an emergent system property through which only winter watermasses penetrate to depth, removing factors such as carbon and heat from the surface. However, most ocean models fail to give a fair representation of the mixed layer. In the crucially important oceans around Antarctica the depth of this layer can be off by hundreds of meters. The best model representation of mixed layer depth is found in the NEMO model. Here we examine the mixed layer in observations and use the numerical NEMO model in resolutions from 1 degree to 1/12 degree to determine why. We conclude that the deep structure of the ocean is fundamentally important, a property which even low resolution models can readily simulate.

Shallow-water gaseohydrothermal plume study after massive eruption at Panarea, Aeolian Islands, Italy

Tobia Tudino, University of Exeter, UK (tt282@ex.ac.uk)

Marine water dynamics in the near field of a massive gas eruption near Panarea (Aeolian Islands volcanic arc, SE Tyrrhenian Sea) is described. ADCP current-meters were deployed during the paroxysmal phase in 2002 and 2003 a few meters

from the degassing vent, recording day-long timeseries. Datasets were sorted to remove errors and select good quality ensembles over the entire water column. Standard deviation of error velocity was considered a proxy for inhomogeneous velocity fields over beams. Timeseries intervals had been selected when the basic ADCP assumptions were fulfilled and random errors minimized. Backscatter data were also processed to identify bubbles in the water column with the aim of locating bubble-free ensembles. Reliable timeseries are selected combining these data. Two possible scenarios have been described: firstly, a high dynamic situation with visible surface diverging rings of waves, entrainment on the lower part of the gas column, detrainment in the upper part and a stagnation line (SL) at mid depth where currents were close to zero and most of the gas bubbles spread laterally; secondly, a lower dynamic situation with water entraining into the gas plume at all depths and no surface rings of diverging waves. Reasons for these different dynamics may be ascribed to changes in gas fluxes (one order of magnitude higher in 2002). Description of SL is important to quantify its position in the water column and timing for entrainment-detrainment, and it can be measured by ADCP and calculated from models.

The wavey spin-up of an antarctic subpolar gyre

Craig Rye, University of Southampton, UK (craig.d.rye@gmail.com)

The Antarctic shelf seas are of great climatic importance due to their vigorous interactions with the atmosphere and cryosphere, which influence continental deglaciation, global sea level, and the production of dense bottom waters. However, understanding of these interactions and their impacts is confounded by sea ice, which covers the region for much of the year. In particular, little is known about the local oceanic response to the recent changes in Antarctic freshwater discharge. Here, we use satellite measurements of sea surface height (SSH) during ice-free months and an ocean circulation model to show that over the last two decades (1992-2011) Antarctic coastal sea level has risen at least 2 ± 0.8 mm yr-1 above the regional mean south of 50°S, and that this signal is a steric adjustment to increased glacial melt from Antarctica. Our findings demonstrate the strength of the sea level response to accelerating Antarctic discharge, and expose a significant climatic perturbation to the cryospheric forcing of the Southern Ocean.

Economics and Finance

Wednesday, 20th August 2014

10:00 - 11:00 Economics and Finance 1

A brave new model for a brave new market

Ash Booth, University of Southampton, UK (ash.booth@soton.ac.uk)

Based on recent theoretical, empirical and regulatory developments, this paper proposes an agent-based model for analysing trade execution algorithms. Five types of agents occupy a limit order-book market: liquidity consumers, market makers, mean reverters, trend followers and noise traders. The first group creates large one-directional orders based on portfolio considerations. When they submit an order to the market they split it up into smaller parts to evade price impact costs. The second group of agents act as liquidity providers that forecast order flow and supply liquidity at both sides of the order book. The third a fourth trader types represent typical high frequency trading strategies known to effect market volatility. Noise traders represent all other strategies in the market. The model is able to produce know stylised market facts as well as temporary and permanent market impact and concave market impact functions in order sizes.

An agent-based framework for analysing insolvency resolution mechanisms for banks

Bob De Caux, University of Southampton, UK (rdc1g11@soton.ac.uk)

The issue of bankruptcy and how to handle distressed banks has become an extremely important topic in the wake of the global financial crisis. The decision to allow Lehman Brothers to fail and subsequent bank bail-outs have exposed the fact that the systemic effects of different bank resolution measures are not well understood. Consequently there is a great deal of discussion as to the relative effectiveness of bail-outs, bail-ins and other forms of special resolution.

Most existing network models of bankruptcy are based on simple epidemiological-style contagion and make the unrealistic assumption that banks will passively stand by and do nothing as problems begin to occur. They also begin at the point of the first bankruptcy, so fail to capture the "moral hazard" effect that advance knowledge of a proposed resolution mechanism can cause. By contrast, game theoretical models do examine the incentives of both banks and the financial regulator ex-ante and ex-post to establish the system equilibria that form. However they do not include detailed contagion dynamics, so the true costs of a systemic failure are not fully captured in the payoff matrices that banks use to strategise and the paths that these systems take to reach a given equilibrium state are not captured.

We propose a novel agent-based framework, where a network of asset and liability contagion channels are endogenously formed over time according to individual bank investment strategies. In addition, each bank has the ability to adapt its strategy in a game-theoretic manner. Using this model, we are able to analyse how different resolution mechanisms affect economic stability. We also investigate how timing can impact the effectiveness of any form of resolution, in terms of the point at which a regulator should intervene with a struggling bank and the indicators it should use to do so.

The emergence of money: network formation in monetary search

Timothy Moran, University of Southampton, UK (tam1g09@soton.ac.uk)

Why does money exist, and how does the emergence of money and banking depend on network structures? We use two models to begin to address these questions. An agent-based model considers the evolution of particular commodities as currencies based on intrinsic properties of the commodities themselves. The production and consumption behaviours of

agents combined with an endogenous process of price discovery allow commodity moneys to emerge. Goods that are less intrinsically useful may function well as money because agents are more willing to offer them in trade during the early stages of price discovery, so they are more frequently encountered by the trading agents. They may subsequently become highly valued as exchange goods as a result of a process of reinforcement learning.

This is compared to more standard economic search models that allow intrinsically worthless promisory notes to function as media of exchange. The expected value of these notes in facilitating exchange is sufficiently high that agents may remain willing to accept them even when there is a high probability that their issuers will refuse to redeem them. Adaptability and forgiveness may be essential in monetary economies. In both cases the trading and learning behaviours of agents determine the type, stability and acceptability of the money.

Thursday, 21th August 2014

9:00 - 10:00 Economics and Finance 2

Universality in firm dynamics: insights from big data

Alvis H. T. Tang, Imperial College London, UK (ho.tang11@imperial.ac.uk)

In the UK, a new company is formed every single minute on average, a rate just slightly smaller than the population growth at 1.38 baby per minute. Undoubtedly, companies are the lifeblood of any economy. They generate economic activities to support of our society. However, despite studies of economics have flourished since Adam Smith, our understanding of the dynamics of companies remains very limited.

Unlike a deterministic system, the dynamics of companies are full of uncertainties. Two identical companies founded at the same time doing exactly the same business can archive two very different levels of success. There are infinitely many reasons of such variation at the individual level. Studies are usually done in case-by-case reviews. However, despite the fate of a startup is never certain, at the macroscopic level, a number of empirical observations indicate that the randomness has unique signatures. For instance, the shapes of distributions such as income, wealth and growth are almost identical across different countries and periods of time. It suggests some unknown stochastic laws which governing the dynamics may exist. However, due to the limit of small data size in the past, none of the existing theories can be verified or falsified. In addition, a general theory which does not depend on particular circumstances is lacking.

The aim of the work is to deliver a macroscopic and probabilistic description of companies. To draw a clear global picture, financial information of more than a million companies (1/3 of all companies) in the UK have been traced. The data confirm the existence of universal signatures of company dynamics regardless of time and industry type. Based on this detailed information, some properties have also been identified. In the conference, I will share some insights from the data and ideas in my head.

The regulatory dilemma: an agent-based approach to policy making within innovation systems

Christopher Hughes, University of Southampton, UK (hughsi.ch@googlemail.com)

In any industry where innovation plays a key role, we want to reward entrepreneurs for their investments in cumulative and sequential innovation. But we want to do this without prohibiting follow-on creativity and without raising unreasonable barriers to market entry. Getting this balance right in sectors such as pharmaceuticals, entertainment, and ICT is a significant 21st century policy challenge. Government regulation plays a pivotal role in influencing the innovation activities of companies, industries and whole economies. However, sound regulation must be based on an understanding of how a policy change will affect the behaviour of various actors in the market. This implies that some form of predictive modelling is necessary for intelligent policy formation. However, the modern business landscape is sufficiently complex that predicting responses to policy using traditional methodological approaches such as spreadsheets, regression

analysis, and system dynamics is becoming increasingly difficult (Bonabeau, 2002). The ICT innovation system is a case in point. Previous research illustrates that it is a system with highly inter-connected and dynamic elements with multiple feedback loops, oscillations and side effects. Modelling a system with this degree of complexity requires an appropriate methodological technique. With this in mind, an agent-based approach was chosen. This is an underutilized methodological approach and is the most suitable for testing the effects of a wide range of strategies. Similarly, it allows one to examine the expected behaviour of companies in response to different levels of regulatory aggression. This research begins with an in-depth literature review of research on the ICT Innovation system. The review allows us to identify gaps in our current understanding, and thus to find pertinent research questions for the agent-based approach. A model is subsequently developed where agents adapt using a hill-climbing technique. This is in order to look at the effects of regulatory aggression on the amount of innovation that is produced within the system.

Multiple Agent Fashion Game

Zuzanna Kosowska-Stamirowska, Sciences Po, Paris, France (zuzanna.stamirowska@sciencespo.fr)

The market of luxury exists thanks to the feeling of exclusiveness which it creates. Such specificity creates externalities. On the one hand, luxury firms want to make their product desirable to a big audience in order to maximise profits, but on the other hand they need to take into account the feeling of exclusivity, which is one of the most important features of their products. As a result, such firms face a tradeoff between delivering a large number of products to as many clients as possible, and preservation of exclusivity. In this paper we develop a model of Multiple Agent Fashion Game, which captures both conformist and non-conformist behaviour of agents (consumers) connected by a network, which signifies interactions between them. Non-conformism implies a repulsion of the same, a denial to conform to a rule or standard, whereas conformity implies imitation. In this paper the agents have two alternatives to choose from. We present efficient algorithms for maximisation of social utility in such a setting for special topologies of graphs. In order to solve the problem in general we present approximation algorithms which make use of semidefinite programming. We also provide some auxiliary results on Nash equilibria of the game and the Price of Anarchy.

Engineering and Physical Sciences

Wednesday, 20th August 2014

10:00 - 11:00 Simulation Techniques

Simulation techniques: the finite element method

Rebecca Carey, University of Southampton, UK (r.carey@soton.ac.uk)

The Finite Element Method (FEM) is a numerical analysis technique that approximates the solution of boundary value problems (differential equations, which have certain boundary conditions which must be satisfied). It is commonly used in heat transfer and fluid mechanics and it allows for the solution to problems which are too complex for mathematical analysis alone. In this presentation the FEM technique is introduced and explained, with attention paid to problem types that it is well-suited to solving. An example of such a problem is provided to demonstrate the general principles of the technique. Lastly comparisons are made with the finite difference method described earlier in this conference.

Simulation techniques: markov-chain monte carlo methods

Matthew Spraggs, University of Southampton, UK (matthew.spraggs@gmail.com)

I discuss the general principles behind Monte Carlo method as a method for efficiently computing multidimensional integrals, before going on to study Markov chain methods in more detail. I illustrate the generalised form of a Markov chain process, before going on to outline some specific examples in physics, biology and the social sciences.

Simulation techniques: from atoms to planets: "molecular" dynamics as a simulation tool

Chris Cave-Ayland, University of Southampton, UK (C.Cave-Ayland@soton.ac.uk)

Phenomena within complex systems frequently occur not simply in terms of spatial properties but through a temporal dimension e.g. chemical clocks, protein interactions, neuronal signalling. "Molecular" Dynamics provides a robust tool suitable for studying the time evolution of complex systems over a range of length and time scales. This talk will consider what goes into and what can be reasonably expected from a Dynamics simulation, as well as some of the technical considerations.

Thursday, 21th August 2014

9:00 - 10:00 Engineering and the Environment

Stability of power networks under higher penetration of renewable energy sources

Lewis Roberts, University of Bristol, UK (lewis.roberts@bristol.ac.uk)

Increased penetration of renewable energy sources for the generation of electrical power negatively affects the overall stability of the power grid. Using models of synchronisation on the grid we exhaustively study the stability of the smallest non-trivial network, the case of two coupled generators connected to the rest of the grid, under conditions of decreased

inertia. We use a simple coupled oscillator model, the Swing Equation, to study the power grid stability so that we can aggregate generation from similar sources on one node. We develop our stability analysis in the context of Potential Energy Boundary Surfaces and we compare our method to the Critical Clearing Time, a method that is currently used by power engineers. We vary the power output from each machines and the amount of power flowing between the generators in order to investigate conditions for maximising stability.

Exact coherent states in purely elastic parallel shear flows

Toby Searle, University of Edinburgh, UK (T.W.searle@sms.ed.ac.uk)

Parallel shear flows provide a model system for the understanding of the transition to and structure of Newtonian fluid turbulence in incompressible fluids. The turbulent attractor is often thought of as structured by a series of exact solutions to the Navier-Stokes equations. A turbulent flow `pinballs' between these solutions in phase space, spending most of its time very near one or other of these organising structures. So far these structures have been identified in Taylor-Couette, plane shear and pipe flows. One of the first and most important of these exact solutions is the self-sustaining process in plane Couette flow.

Viscoelastic fluid mechanics is complicated by additional nonlinear terms introduced in the constituitive equation for the polymeric fluid stress tensor. As the Reynold's number is reduced and the elasticity of the fluid is increased the nonlinear character of the equations shifts from the Navier-Stokes equation to the constituitive equation. A novel form of turbulence has been discovered in polymeric fluids where the Reynold's number is very low, $Re \leq 1$, and the Weissenberg number (characterising the fluid elasticity) is large.

Using an analogy with the Newtonian self-sustaining process in parallel shear flows, we attempt to construct the purely elastic counterpart for plane Couette flow of polymer solutions. By introducing a forcing term to the coupled Navier-Stokes and Oldroyd-B equations, we observe the formation of purely elastic streaks and consider their linear stability. We find that there exists a previously unrecognised purely elastic analogue of the Kelvin-Helmholtz instability that gives rise to the streamwise waviness of Newtonian coherent structures. I will discuss how this instability might close the cycle and lead to a sustained purely elastic coherent structure.

Optimal strategies for electricity storage

Ellen Webborn, University of Warwick, UK (e.webborn@warwick.ac.uk)

With an increase in the amount of renewable power generation in the UK and a reduction in the proportion of traditional synchronous generators, the task of balancing the electricity grid is becoming increasingly challenging. An energy storage facility could potentially provide multiple types of service to the grid, thus increasing its value beyond what would be possible from price arbitrage alone. In this talk I shall describe my research done in collaboration with National Grid, which models energy storage facilities in order to assess their potential value from price arbitrage, alternatives to infrastructure reinforcement investment, and as providers of grid balancing services.

10:00 - 11:00 Micromagnetics

Micromagnetism and skyrmions: the complex simulation approach

Mark Vousden, University of Southampton, UK (mark.vousden@soton.ac.uk)

This presentation describes the problem that students of micromagnetism face, what a skyrmion is, and how simulations can be used to improve understanding of this complex challenge. The micromagnetics problem is outlined, along with potential applications for its solution. A broken-down description of this problem is provided, showing that the problem can be defined in terms of competing interactions of different types. When these interactions are combined with varying strengths different magnetisation patterns, such as the skyrmion and the helix, are found to emerge. A variety

of simulation approaches to the micromagnetics problem are described, with particular attention to a finite-element method. To conclude the author briefly describes a number of unanswered questions pertaining to the application of this technology, including how the existence of skyrmions depends on the strength of the aforementioned interactions, and the stability of skyrmions in response to perturbation by a magnetic field.

Finite size effects and stability of skyrmionic textures in nanostructures

Marijan Beg, University of Southampton, UK (mb4e10@soton.ac.uk)

Recent research demonstrated that topologically stable skyrmions have the potential to provide new solutions for efficient low power data processing and retrieval. For instance, skyrmions can be as small as a few atoms in diameter, and can be easily manipulated using spin currents five orders of magnitude smaller than those required in conventional magneto-electronics. The geometries of thin film systems in most experimental and theoretical studies are large in comparison to their thickness and close to the limit of thin films that extend to infinity in two dimensions. Of particular importance to the technological application of skyrmionic systems is to understand under what circumstances the skyrmion phase occurs in thin film samples of finite size, which is the main focus of this work. In this work, by using finite element based micromagnetic simulator we show that nanoscale patterned FeGe samples support a new class of incomplete and complete skyrmions without need of external fields or anisotropy (http://arxiv.org/abs/1312.7665). Thin film disk shaped samples with thickness 5 nm were studied for different diameters d and applied external magnetic fields H. We also demonstrate hysteretic behaviour of a single skyrmion in nanostructures, proving that in principle skyrmions in patterned media have unique properties important for data storage and manipulation.

Good vibrations: how to play the magnetic nano-flute

Maximilian Albert, University of Southampton, UK (maximilian.albert@gmail.com)

Magnetic nanostructures are a fascinating example of "real-world" physical systems which exhibit very rich and complex behaviour, due to the interaction of various competing forces at the nano- and micro-level.

One such example is the so-called "spin-torque nano-oscillator" (STNO) which can be thought of as a "magnetic nano-flute". Similar to how a stream of air produces sound waves in a flute when it hits the right resonance, it is possible to excite resonances and standing waves in STNOs by replacing the air with an electric current, creating electromagnetic waves.

In this work we describe the computational aspects of how this property can be used for a novel nano-sensing method where the STNO acts as a kind of "sonar" to detect nearby magnetic nano-particles. By using "functionalised" nano-particles which are coated with antibodies that only attach to a specific substance, this opens up experimental applications for very small, sensitive and versatile detection techniques in "lab-on-a-chip" devices, e.g. to detect tumor markers in a blood sample or environmental polluting agents in water.

11:20 - 12:20 Computational Chemistry

Time correlation function formalism: the case of computational spectroscopy

Valerio Vitale, University of Southampton, UK (vv1c12@soton.ac.uk)

Thanks to the development of new theories and numerical methods, the field of electronic structure theory has undergone a radical change in recent years [1][2]. Contextually, the rapid spread of massively parallel platforms both in the industry and in academia, has precipitated this change. Nowadays, many of the properties of materials can be predicted directly from the fundamental equations of quantum mechanics (QM), or for very large system, a combination of quantum mechanics and classical molecular mechanics QM/MM (for which M. Karplus, M. Levitt, and A. Wershel won the Nobel prize in chemistry in 2013).

This opened the doors to the simulation of a whole range of complex phenomena that were inaccessible before, shedding a new light on critical problems in physics, chemistry, and material sciences, such as superconductivity, drug optimization and biological processes, catalysis etc.

In this work, I will focus on the time correlation function formalism (TCF) applied to ab initio (from first principles) molecular dynamics, which allows to generate accurate and reliable spectra (Infra-red and vibrational) for molecules both in gas and acqueous phase[3][4]. This method naturally takes into account all the anharmonicity arising from a finite temperature, which is not possible with other static methods, providing a better understanding of the structure and conformational transitions that molecules undergo in their native environment. All the calculations have been carried out within the Onetep program, a linear scaling code based on density functional theory. The method has been tested on both small systems in gas phase and very large systems in aqueous phase, such as neutral alanine dipeptide with 500 water molecules, i.e. 1522 atoms, currently the state of art for ab intio molecular dynamics in Onetep. For the latter, about 2000 cores have been used to achieve a trajectory of few picoseconds.

[1] Richard M. Martin. Electronic Structure: Basic theory and Practical methods. Cambridge University Press, 5th edition, 2011. [2] Sidney Redner. Citation statistics from 110 years of physical review. Physics Today, 58(6):49–54, 2005. [3] Mark E. Tuckerman. Statistical Mechanics: Theory and Molecular Simulation. Oxford University Press Inc., 2010. [4] Marie-Pierre Gaigeot. Theoretical spectroscopy of floppy peptides at room temperature. a dftmd perspective: gas and aqueous phase. Phys. Chem. Chem. Phys., 12:3336–3359, 2010.

Lipids - gel to liquid and back again, using meta dynamics to get a leg up in the free energy landscape

Sophia Wheeler, University of Southampton, UK (sophia.wheeler@soton.ac.uk)

Membranes make a cell an autopoetic system. From relatively simple molecules, such as phospholipids, with easily described interactions, membranes self assemble into supra molecular assemblies with rich phase behaviour. Our work focuses on reproducing phase behaviour in silico using a coarse grained forcefield to enable larger systems to be simulated for longer timescales. Phase transitions from "liquid" phases to "gel" type phases have been reproduced for a particular phospholipid. Metadynamics is now being used to drive the simulations over free energy barriers towards "freezing" type events to explore whether such events have not bee seen in previous simulations because the "gel" phase is only meta stable or because the free energy landscape is insufficiently sampled.

Recasting a model atomistic glassformer as an effective system of icosahedra

Rhiannon Pinney, University of Bristol, UK (rp7865@bristol.ac.uk)

The glass transition is one of the greatest open problems in statistical mechanics. One of the mysteries is that at a molecular level, glasses and liquids are seemingly indistinguishable. The exact mechanisms which drive this transition are frequently debated. Sir Charles Frank postulated that five-fold symmetric icosahedra could lead to a change in local structure which might underpin the glass transition. These structures have been shown to play a particularly important role in the glass transition in some binary glass former models. A recently developed topological cluster classification (TCC) algorithm decomposes data into a zoo of clusters – in this case, we seek the icosahedral clusters as described by Frank and ignore all other identified structures for our analysis. By decomposing the full system into an effective system of icosahedra and using techniques from statistical mechanics, we hope to ultimately shed some light on the mysterious nature of the glass transition.

Evolution and the Origin of Life

Wednesday, 20th August 2014

14:00 - 16:00 Evolution and the Origin of Life

Learning general models from past environments: how stochasticity and the cost of ontogenetic interactions can facilitate evolvability

Konstantinos Kouvaris, University of Southampton, UK (kk6g11@soton.ac.uk)

One of the most intriguing questions in evolution is how organisms exhibit novelty to adapt in a plethora of selective environments. Recent work has shown that developmental biases are structured such that random (undirected) genetic variation is channelled into potentially beneficial (directed) phenotypic variation, thus facilitating evolvability. In particular, when selective environments vary in a systematic manner (i.e., encompass structural information), development can constrain the phenotype space in regions that are evolutionarily more advantageous. Nonetheless, the underlying mechanism that enables the spontaneous emergence of such adaptive developmental constraints is poorly understood. We hypothesise that when organisms evolve to remember past environments and generate appropriate novel responses to unseen environments, this is functionally equivalent to the task a neural network faces when learning over a training set and then generalising to previously-unseen data (i.e., test set). We specifically argue that the failure of natural selection to enhance evolvability is directly analogous to the problem of over-fitting and failure to generalise in the area of machine learning. Here we show that conditions that are known to alleviate over-fitting in machine learning can provide insight into the conditions that enhance the evolution of evolvability under natural selection. More precisely, we describe how well-known techniques, such as Jittering (i.e., learning with noise) and L1 (or L2) regularisation (i.e., penalising model complexity), that improve the generalisation ability of neural networks can help us understand how noisy selective environments and the reproduction cost of the ontogenetic interactions can enhance evolvability in gene networks. This provides the first formal theory to characterise the conditions that enhance evolvability in natural systems.

The evolution of short-term and long-term evolvability in gene-regulation networks

Loizos Kounios, University of Southampton, UK (lk9g12@soton.ac.uk)

How do evolving populations exhibit variation that enables adaptation in such a wide variety of challenging environments? One possibility is dumb luck – random variation. Another possibility is that via the slow adaptation of developmental biases and constraints, accumulated over a broad distribution of selective environments experienced in the past, evolution can tune the distribution of phenotypes explored to amplify promising variations and avoid less-useful avenues [1-3]. The problem for such evolution of evolvability [4-6], however, is that natural selection is myopic, and short-term benefits, e.g., from increased robustness, seem more likely to oppose than facilitate long-term evolvability [7]. As a result, no theory has been successful in characterising the general conditions for the evolution of evolvability. Here we simulate the evolution of a gene-regulation network and investigate how ontogenetic interactions affect evolvability. Specifically, we describe conditions under which the selective pressures on ontogenetic interactions systematically increase the speed of adaptation in the short term and the probability of finding high-fitness phenotypes in the long term. We show that there is a trade-off between mutational robustness and speed of adaptation when natural selection optimises ontogenetic interactions in varying selective environments characterised by smooth fitness landscapes. More importantly, we find that natural selection optimises ontogenetic interactions for long-term adaptation on rugged fitness landscapes, thus enabling evolution to find fitter phenotypes with higher probability.

[1] Pavlicev, M., Cheverud, J. M., and Wagner, G. P. (2011). "Evolution of Adaptive Phenotypic Variation Patterns by Direct Selection for Evolvability". Proc. R. Soc. B, Biol. Sci. 278.1713, pp. 1903–1912. [2] Clune, J., Mouret, J.-B., and Lipson, H. (2013). "The Evolutionary Origins of Modularity". Proc. R. Soc. B, Biol. Sci. 280.1755, 20122863.

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The relationship between the adaptation of individual species and whole ecosystem behaviour

Daniel Power, University of Southampton, UK (dap1e12@soton.ac.uk)

It is a priority to understand how ecosystems respond to, and recover from, environmental stresses, yet the inherent complexity of these natural systems makes analysing their underlying organisational principles a challenge. We are interested in how the behaviour of ecosystems are affected by the numerous coevolved interactions of their component species, and how the form of these interactions shapes the dynamical properties of ecosystems as a whole.

Here we present a study of species coevolving in an ecosystem whose dynamics are governed by Lotka-Volterra dynamics. By subjecting this model to specific patterns of environmental forcing that differentially affect the species within it, and simulating the effects of evolutionary pressures under these conditions, we find that the system develops attractors for these patterns. The development of these attractors creates an ecosystem that will consistently return to configurations of species densities corresponding to these previously experienced states, even in the absence of any simulated forcing. These 'memory-like' ecological dynamics are emergent from evolutionary changes at the species level. We recognise that the emergence of this adaptive system-level behaviour can be understood via a mechanical isomorphism with well-understood models from neural networks. Specifically, we illustrate how our system evolves in accordance with the principle of Hebbian learning: we find that species that co-occur 'wire together'.

Recognition of this isomorphism provides insight into how ecosystems may differentially respond to changes in environmental conditions: they may resist certain patterns of environmental forcing, but exhibit catastrophe in response to others, particularly if changes correlate with a historically experienced attractor. Similarly we observe how this conditioning affects the stability of species compositions, and recognise that the disturbance of particular sets of species is most likely to cause a regime shift between ecological attractors.

Division of labour games in relation to the major transitions in evolution

Simon Tudge, University of Southampton, UK (sjt4g11@soton.ac.uk)

Throughout the history of life there are a number of examples of so called "major-transitions". These occur when previously independent entities coalesce to form higher level individuals. One such example is the emergence of multicellular organisms from single celled individuals. A salient feature of all such transitions is high levels of cooperation. The overwhelming majority of studies that formally study the evolution of cooperation use the prisoner's dilemma as their definition of cooperation. I argue that this game does not properly represent the biological reality of cooperation as it does not model gains from specialisation. I extend the notion of a cooperative dilemma (such as the prisoner's dilemma) to include the potential for the division of labour, and parameterise the conditions under which this may emerge.

Changing the game

Adam Jackson, University of Southampton, UK (aj3e10@soton.ac.uk)

Why do social creatures play particular social games? The fitness consequences of social behaviours are initially set by the physical and ecological nature of the social interaction, such as competition for limited resources. But all social

behaviours occur against a social context. The same physical action, such as altruistic self-sacrifice, can have very different fitness outcomes depending on the context. Many different factors contribute to this social context, such as the population structure and relatedness of individuals. Individual-level adaptions can alter the social context, for example by changing the level of behavioural assortment - the likelihood that individuals interact with others with the same social strategies. Assortment on social behaviours is argued to be the ultimate cause for the successful spread of cooperative behaviours. A complete account of social evolution must consider how altruism and assortment-promoting traits evolve - that is, consider the coevolution of social behaviours and social context.

We can then ask, if a population can evolve to change the social game it is playing, how does it do so? Will the game become more of a selfish Prisoner's Dilemma scenario, because of the inherent benefits to selfish individuals of receiving the benefits of cooperation without paying the costs? Or it might change to a more harmonious game, because of the advantages to groups of increased cooperation? By considering metagames, 'games of games' in which the game played is also subject to evolutionary control, we investigate the coevolution of individual's social strategies with traits that affect the social conditions. In simple metagames we find that both these possibilities and others for the game change can happen, with the equilibria of the social game the strongest influence on the path the population takes through game-space.

Pre-template metabolic replicators: genotype-phenotype decoupling as a route to evolvability

William Hurndall, University of Southampton, UK (w.hurndall@soton.ac.uk)

The RNA World is generally heralded as the leading candidate for a template first vision of the origin of life, yet doubts as to the plausibility of the natural formation of RNA with catalytic function have led to revived interest in the metabolism first paradigm. Recent studies of the evolvability of reflexively autocatalytic sets of polymers have also revealed the nature of limited heredity in Farmer & Kaufmann's compartmentalised reaction networks. In the algorithmic sense, the lack of a meaningful distinction between data storage and functional expression results in a heritability-fitness dichotomy which gives an intrinsic selective advantage to those compartments with limited heredity. An idealised model is used explore a minimal set of dynamical requirements necessary to weaken the dichotomy. This is achieved by explicitly modelling an outer compartment 'phenotype', heritable only indirectly, in which competitive exponential growth may occur without compromising heredity of previously discounted non-competitive growth in an inner

sub-compartment, 'genotype'. Results show that heritable variation can be achieved under simulations of natural selection in populations of such metabolic replicators." The RNA World is generally heralded as the leading candidate for a template first vision of the origin of life, yet doubts as to the plausibility of the natural formation of RNA with catalytic function have led to revived interest in the metabolism first paradigm. Recent studies of the evolvability of reflexively autocatalytic sets of polymers have also revealed the nature of limited heredity in Farmer & Kaufmann's compartmentalised reaction networks. In the algorithmic sense, the lack of a meaningful distinction between data storage and functional expression results in a heritability-fitness dichotomy which gives an intrinsic selective advantage to those compartments with limited heredity. An idealised model is used explore a minimal set of dynamical requirements necessary to weaken the dichotomy. This is achieved by explicitly modelling an outer compartment 'phenotype', heritable only indirectly, in which competitive exponential growth may occur without compromising heredity of previously discounted non-competitive growth in an inner sub-compartment, 'genotype'. Results show that heritable variation can be achieved under simulations of natural selection in populations of such metabolic replicators.

Network Science

Wednesday, 20th August 2014

11:20 - 13:00 Spatial Networks

Planar growth of spatial networks

Garvin Haslett, University of Southampton, UK (G.A.Haslett@soton.ac.uk)

Spatial scale free networks have been demonstrated to emerge from the mechanisms of space-filling, vertex fitness and link length penalisation. We add to the first class of these with a growth model that forbids new connections from crossing existing ones, i.e. planarity is conserved at each stage of network formation. Numerical results demonstrate that a power law degree distribution, the small world property, disassortativity and high clustering all obtain in the ensuing networks. The results hold for any degree of attachment, $m < 3$.

We investigate the extent to which planarity accounts for this outcome with a series of experiments which allow varying proportions of edge crossing. In doing so, it is observed that a small ratio maintains the properties discussed but at high values of this ratio they no longer hold.

The impact of constrained rewiring on network structure and node dynamics

Prapanporn Rattana, University of Sussex (pr87@sussex.ac.uk)

In this paper, we study an adaptive planar/geometric network. We consider a SIS (susceptible-infected-susceptible) epidemic on the network, with a link/contact rewiring process constrained by spatial proximity. In particular, we assume that susceptible nodes break links with infected nodes independently to distance, and reconnect at random to susceptible nodes available within a given radius distance. We investigate the impact of the rewiring by changing the radius of the area and consider how this impacts on the structure of the network and characteristics of the epidemic. We present a step-by-step approach to first understand the impact of the rewiring scheme on the network structure, in the absence of an epidemic, then with nodes assigned a disease status but still with no disease dynamics, before finally running the network and epidemic dynamics simultaneously. For the case of no labelling and no epidemic dynamics, we provide an analytic and semi-analytic formulas for the value of clustering achieved in the network. Our results also show that the radius of the neighborhood area and the network‘s initial structure have a pronounced effect of the final size of the epidemic; increasingly large rewiring radiuses corresponding to smaller final epidemic sizes.

The effects of social fallout on friendship circles

Elisabeth zu Erbach-Schoenberg, University of Southampton, UK (ezes1m13@soton.ac.uk)

The choices of individuals aggregate in non-linear ways to create social systems and this interaction structure can be represented as a network. These social networks are not static but vary over time as connections are made and broken or change in intensity. Generally these changes are gradual, but in some cases individuals disagree and as a result “fall out“ with each other, meaning they actively end their relationship by ceasing all contact. These “fallouts“ have been shown to be capable of fragmenting the social network into disconnected parts. Fragmentation can impair the functioning of social networks and it is thus important to better understand the social processes that have such consequences.

To answer questions about the mechanisms underlying these fragmentation processes and to understand the necessary conditions for fragmentation we need a model of social network dynamics that is stable enough such that fragmentation does not occur spontaneously, but is simultaneously dynamic enough to allow the system to react to perturbations

(i.e.\ disagreements). We present such a model and show that it is able to grow and maintain networks exhibiting the characteristic properties of social networks, and does so using local behavioural rules inspired by sociological theory.

We provide an investigation of fragmentation and identify the connections that are most important for the cohesion of the network. We are able to confirm basic intuitions of the importance of bridges for network cohesion. Furthermore, we show that this topological feature alone does not explain which points of the network are most vulnerable to fragmentation. Rather, we find that dependencies between edges are crucial for understanding subtle differences between stable and vulnerable bridges. This understanding of the vulnerability of different network components is likely to be valuable for being able to prevent fragmentation and limit the impact of social fallout.

Soft random geometric graphs: obstructions and no-convexity

Alexander Giles, Bristol University, UK (eeapkg@bristol.ac.uk)

Soft random geometric graphs are mathematical structures consisting of a set of nodes placed uniformly in some V (a subset of R^d) mutually coupled with a probability dependent on their Euclidean separation and, inter alia, are being used to model large-scale wireless networks. When considering these mathematical structures, a commonplace assumption is that V is a convex set, such that each pair of nodes is mutually visible; in the real-world, this is rarely the case, and so it is of particular interest to understand how the behaviour of these graphs changes after the convexity restriction is relaxed (such as when an obstacle is placed inside the domain, or when the graphs have to cope with an internal obstructing wall). Particularly, we focus on estimating the proportion of random graphs that connect inside an annulus.

Null models for community detection in spatially-embedded, temporal networks

Marta Sarzynska, University of Oxford (marta.sarzynska@sjc.ox.ac.uk)

I use community detection on time-dependent correlation networks to study the geographical spread of disease. Using proprietary data on country-wide dengue fever, rubella, and H1N1 influenza occurrences for several years, I create networks with the provinces of a country as nodes and the correlation between the number of disease cases in each pair of provinces giving weights to the edges. To study these temporally evolving networks, I use the framework of "multilayer networks", which allows modelling the temporal aspect of the data with less data aggregation than with collections of ordinary (static) networks. I perform community detection, looking for groups of provinces in which disease patterns change in similar ways, and I analyse the properties of the communities (such as their relationship to climate, population, geographical location etc.) and their changes over time.

I develop a novel null model for community detection that takes into account spatial information, allowing uncovering additional structure that might be obscured by spatial proximity. The null model is based on a radiation model proposed recently for modelling human mobility, with the hope it would be better at capturing disease spread than the previous spatial null model based on gravity models for interaction between nodes. I test the behaviour of the two spatial null models against the standard Newman-Girvan null model on benchmark spatial networks with known community structures and the disease correlation networks.

I also study the performance of a temporal null model developed for correlation networks created from time series on the disease correlation networks, and observe the differences in predicted community structures and their relationship to space between the four null models. The Newman-Girvan null model finds spatial and temporal partitions of the multilayer network depending on parameters used, and the spatial null models remove majority of the network structure.

14:00 - 16:00 Network Science Applications

Analysing the structure of human language via phonological networks

Massimo Stella, University of Southampton, UK (massimo.stella@inbox.com)

This work aims to investigate the phonetic structure of English words. By using data from Wolfram Research, we build a complex network of phonological similarities, where nodes are the phonetic pronunciations of words and edges connect words differing by the addition, deletion or substitution of exactly one phoneme. The resulting network reveals interesting properties, quite uncommon in other real-world social or technological networks, such as a very high assortativity and a clustering coefficient independent of node degree. We explore whether these peculiar features are artifacts of the network construction methodology or whether they represent genuine structural patterns in the organisation of human language. We consider various null models based on repertoires of synthetic words, successively including more constraints (e.g. phoneme frequency, word length, consonant-vowel correlations). We find that some properties, such as clustering or assortativity, can partly be attributed to the underlying construction method, but others (e.g. link densities, component sizes) reveal significant additional patterns in the phonetic structure of language. Importantly, by comparing to percolation models, we argue that our findings about link densities and giant component size support the hypothesis that large parts of the (phonetic) word repertoire might have formed by gradually applying modifications to existing words in order to invent new ones. Finally, we propose a simple model that mimics such gradual process and demonstrate that it can accurately reproduce a number of important characteristics of phonetic networks. Applying tools from Statistical Physics, our results constitute a quantitative assessment of human language properties and explain how they are structurally reflected in phonetic networks.

Multiple time scales and hub structure observed in spontaneously evolved neurons on high-density CMOS electrode array

Eiko Matsuda, The University of Tokyo, Japan (eikomatsuda@gmail.com)

Spontaneous development of cultivated neural cells were recorded in vitro (DIV) with the high-density CMOS micro-electrode array, which enables the detailed study of spatio-temporal neural activity (Frey et al., 2010). We used the same system to characterize the developmental changes of neural dynamics over a few weeks. Based on the time series obtained from the neural cells, we computed transfer entropy between neuronal states, to reveal the network structure of those neurons. As the results, we found 1) those networks changed their topologies through the course of development, and 2) different network structures were distinguished by the transfer entropy measured on the different time scales. We identified the revealed network structures as "functionally connected sub-networks". In other words, the networks worked in the multiple time scales. To evaluate the network structure further, we applied the methods of network analyses (Honey et al., 2007). Especially, we focused on identifying hub nodes, i.e., nodes with very high incoming and outgoing connections, by calculating centrality of individual neurons. In general, hub nodes allow higher levels of information flow because they can connect spatially remote nodes. We therefore took the hub for an indicator of information flow in the network. As a result, at the earlier stage of the development, higher amount of hub nodes was observed, while, at the later stage, the amount of hubs was dropped. However, when we estimate the hubs with longer time scales, the amount of hubs remained high throughout the whole recoding period. The result therefore indicates that information flow at faster time scales, i.e., micro-level interaction, decreased through development, while information flow at longer ones, i.e., global interaction, maintained. As a conclusion, the result suggests the possibility that the neurons can spontaneously develop efficient structure to maintain global interaction while saving costs for micro-level interaction.

Brain signal complexity correlates with conscious level

Michael Schartner, University of Sussex, UK (m.schartner@sussex.ac.uk)

What is the key feature of brain activity that determines that we are conscious when we are awake and that we are unconscious when we are in deep sleep? Tononi's integrated information theory (IIT) of consciousness suggests that for the awake brain, causal interactions between brain regions are both integrated, i.e. all regions are to a certain extent

connected, and differentiated, i.e. there is inhomogeneity and variety in the interactions. IIT has inspired the development of several measures of dynamical complexity, each designed to capture in different ways the co-existence of these two features of network dynamics. Casali et al recently successfully applied a measure based on Lempel-Ziv complexity to robustly predict presence or absence of consciousness from EEG responses to pulses of magnetic stimulation applied transcranially (TMS), recorded during deep sleep, anaesthesia and wakeful rest. We explored several different complexity measures on spontaneous EEG from subjects undergoing propofol induced anaesthesia, and through them could reliably distinguish wakeful rest from anaesthesia.

Community structure of a phone calls network

Federico Botta, University of Warwick (f.botta@warwick.ac.uk)

Real-world networks often present a community structure which has important consequences on the topology and the properties of the network itself. There are several methods to try and detect such structures, the most prominent one given by the modularity function introduced by Newman. Recently, other methods have been shown to give good results by using non-backtracking operators on the networks. In the talk, I will present my work to try and extend this method to directed and/or weighted networks.

Exploring the vulnerability of spatially complex infrastructure networks

Craig Robson, Newcastle University, UK (c.a.robson1@ncl.ac.uk)

The resilience of critical infrastructure networks, such as such as transport, energy and telecommunications, to perturbations is of significant interest given their increasing importance to our quality of living and economic prosperity. Such systems have been shown in several notable cases to be vulnerable to unforeseen events leading to their catastrophic failure for significant time periods. However, different types of infrastructure system seem to respond in different ways to a range of failure types, due to their particular individual characteristics such as their spatial and topological configuration. Thus, in order to understand how infrastructure systems can be adapted and their resilience improved, one needs to understand their initial vulnerability to different types of perturbations.

In our work, we have compiled a comprehensive suite of critical spatial infrastructure networks for the UK covering energy, water, transport and telecommunication sectors. Using a range of graph metrics that characterise their basic and higher-order topology, along with a suite of failure models these networks have been statistically analysed and compared to synthetic graph models that range from random through to hierarchical and include scale-free and small-world examples. In total, 25 infrastructure networks were investigated. Most networks (16) were found to exhibit statistically a scale-free or small world structure. However, a notable number (5) were found to exhibit a hierarchical or hierarchical communities structure. Critically, such hierarchical networks when subjected to failure modelling were found to be much more vulnerable than scale-free models. This suggests that real infrastructure systems that exhibit a hierarchical structure will require in the future greater adaptive capacity via increased redundancy in terms of their topological structure. Authors: Craig Robson, Stuart Barr, Phil James and Alistair Ford.

Modelling the formation and hierarchical network structures of covert illegal organisations assembled within law abiding social populations.

Dominic Kerr, University of Warwick, UK (d.g.kerr@warwick.ac.uk)

My talk will present research obtained from the simultaneous agent-based modelling of civilian and illegal human interaction networks, whose motives for social interactions and communication of personally held ideologies are fundamentally different. I will also introduce results from a social experiments I have conducted in order to investigate the handshaking mechanisms used in the formation of illegal organisations within student populations, and the accuracy with which individuals perceive the personal opinions held my the members of their social neighbourhoods.

Thursday, 21th August 2014

9:00 - 10:20 Dynamics on Complex Networks

Robustness and self-organization in complex networks

Xueke Lu, Queen Mary University of London, UK (xueke.lu@qmul.ac.uk)

Networked ecosystems originated from complex interactions are highly dynamic and often subject to a wide range of perturbations that may lead to rippling effects in networks. For instance, telecommunications networks are susceptible to random failures and malicious attacks which affect reachability of nodes; and ecological networks (e.g. food webs, mutualistic networks) are exposed to numerous environmental (e.g. climate change, acidification, pollution) and biotic (e.g. invasive species) stressors, whose impacts on biodiversity have been the subject of considerable research activity. Robustness refers to a system's ability to sustain its behaviour when it is disturbed and it is often used to assess the effect of perturbations. Here, we examine the evaluation of robustness and methodologies in identifying vulnerabilities in various disciplines of complex networks, with a particular emphasis on ecological networks. Self-organization property in food webs is said to be one of the underlying reasons why food webs are stable. For example, link rewiring forces predators to switch diet when their original prey goes extinct, preventing them from dying out. Top-down/bottom-up control directly and indirectly enables population of each species to flow within range when disturbance takes place. Weak interactions between species can effectively disperse the dependence of one predator fed on a certain prey, which strengthens the robustness. This provides means to better understand how robust network is organized and pertained in natural systems, and enable us to gain an insight into designing better and more stable networks.

Dynamical systems coupled in heterogeneous networks, reduction and synchronisation

Matteo Tanzi, Imperial College London, UK (m.tanzi13@imperial.ac.uk)

It is nowadays widely agreed that graphs are an invaluable tool for modelling a large class of real world systems in all kinds of scientifical and societal investigation fields. In these network models, each fundamental element (neurons, servers, power plant,…) occupies a node of the network, and interacts with the elements to which it is connected by an edge. The state of the elements can be described by internal variables that undergo time-evolution prescribed by some law plus the effect of the coupling with other elements. It then seems necessary to develop a mathematical theory able to describe the time evolution of these variables in the light of their internal laws, the type of coupling, and the structure of the network.

In my work I have considered the case of piecewise C^1 expansive maps coupled in a highly heterogeneous network, i.e., a network characterised by highly connected nodes (hubs) and poorly connected nodes. For certain types of couplings, it is possible to describe the influence of nodes on the hubs with a mean field approach. To do this I have used ergodic properties of the dynamics of the poorly connected nodes treating the coupling as a perturbation and analysing the spectrum of the perturbed transfer operator. The analysis leads to the conclusion that one can substitute the non-autonomous coupling with its averaged value with respect to the unique invariant density of the internal dynamics. This introduces a time-dependent error term whose norm is controlled by the size of the network.

TITLE TBC

Ed Barter, University of Bristol, UK (edmund.barter@gmail.com)

A major challenge in networks research is to understand how information spreads through society. Given a message that enters a social network at a certain point, and is then retransmitted along social contacts with given probability, we want to know the extent to which the message spreads. This question is closely related to invasion percolation on networks. Here we revisit this problem and derive an expression for the number of people who receive a message with a particular

probability of transmission. Further we present derivations for the number of people who receive a message from any number of distinct paths. We compare the analytical solutions to simulations on networks representing real communities in rural India. We also consider data giving the variation of participation rates in a Microfinance scheme between these communities. The analytical solutions are shown to give a good correlation with simulations for the reach of the message. The variation in Mircofinance participation is shown to potentially be explained by the existence of a critical point in the relationship between the probability of message transmission and its final reach. Many of the derivations are such that more complicated models of message transmission may be easily considered within the same framework.

Exploring altruism in social networks

Abeer El-Bahrawy, Cairo University, Egypt (a.yehia@fci-cu.edu.eg)

The objective of this presentation is to show the effect of social pressure and social networks properties on the diffusion of altruistic behaviour. The analysis is conducted by simulating the ultimatum game on different network topologies. While many studies focused on the evolution of the number of altruistic agents given different game rules such as the nature of agents and the strategic update rules, our work focuses on the relationship between network structure and the community pressure on the diffusion. The model starts with a selfish population with a limited number of altruistic agents to show how altruistic behaviour spread around the network forming a clique given different social pressure. Agents in the model are empathic and memoryless and the strategic update rule is natural selection.

11:20 - 12:40 Structural Properties of Complex Networks

The useage of nestedness for the analysis of bipartite networks

Stephen Beckett, University of Exeter, UK (S.J.Beckett@exeter.ac.uk)

Many different metrics have been devised to assess the structure and behaviour of bipartite (two part) networks. Nestedness is a network structural concept that has gathered much attention, particularly within the field of ecology where they can be used to describe and explain abundance patterns in species-site data and the patterns of interactions between members of mutualist (e.g. plant-pollinator) or antagonistic (e.g. phage-bacteria) networks. These methods are increasingly being applied to other types of bipartite networks (which need not be ecological!).

Many measures of nestedness have been proposed, but which of the many tools should be chosen for a particular network is still an open question. I will discuss the implications of having such a wide selection of tools at our disposal and show results from a recent effort to compare nestedness indicators in bipartite networks - and explore some of the networks I have been investigating (phage-bacteria, genes-genomes, users-hashtags).

Random weighted networks with fixed strengths

Francesc Font-Clos, Centre de Recerca Matemàtica, Spain (fontclos@crm.cat)

Complex networks grow subject to structural constraints which affect their measurable properties. Assessing the effect that such constraints impose on their observables is thus a crucial aspect to be taken into account in their analysis. To this end, we examine the effect of fixing the strength sequence in multi-edge networks on several network observables such as degrees, disparity, average neighbor properties and weight distribution using an ensemble approach. We provide a general method to calculate any desired weighted network metric and we show that several features detected in real data could be explained solely by structural constraints. We thus justify the need of analytical null models to be used as basis to assess the relevance of features found in real data represented in weighted network form.

TITLE TBC

Martin Ritchie, Univeristy of Sussex, UK (mr284@sussex.ac.uk)

Motifs, connected subgraphs that appear with greater frequency than one would expect in random networks, destroy a network's tree-like property by introducing loops. Conceptually this has been addressed by viewing the network at a higher level and considering motifs as meta-nodes to recover the tree-like structure. As yet this approach has only been applied in specific cases or to specific classes of motifs. We introduce the notion of hyperstubs - a structured grouping of classic stubs - and use it to generalise the configuration model to account for networks composed of an arbitrary set of motifs. Given a set of motifs, we first identify the set of hyperstubs and then impose a hyperstub degree distribution (HDD) on nodes, a multivariate distribution describing the probability of a node having a certain combination of hyperstubs. Following a configuration model approach we use the HDD to generate sequences of hyperstubs that are combined to form motifs. Using the HDD's probability generating function, and taking the SIR epidemic model as an example, we derive the set of ODEs giving the average system behaviour. A highly modular approach is taken where each motif has a corresponding system of ODEs akin to the exact Kolomogorov equations, which are embedded in a framework that describes the interaction between motifs. Finally we provide a computational framework to automate this process for arbitrary sets of motifs. This framework has the potential to facilitate the next generation of models on highly structured networks.

The entropy of conditional markov trajectories. application to mobility predictability

Mohamed Kafsi, EPFL, Switzerland (mohamed.kafsi@epfl.ch)

Quantifying the randomness of Markov trajectories has applications in graph theory and in statistical physics, as well as in the study of random walks on graphs. The need to quantify the randomness of Markov trajectories first arose when Lloyd and Pagels defined a measure of complexity for the macroscopic states of physical systems. They examine some intuitive properties that a measure of complexity should have and propose a universal measure called depth. They suggest that the depth of a state should depend on the complexity of the process by which that state arose, and prove that it must be proportional to the Shannon entropy of the set of trajectories leading to that state. Subsequently, Ekroot and Cover studied the computational aspect of the depth measure. In order to quantify the number of bits of randomness in a Markov trajectory, they propose a closed-form expression for the entropy of trajectories of an irreducible finite state Markov chain. Their expression does not allow, however, for computing the entropy of Markov trajectories conditional on the realisation of a set of intermediate states. Computing the conditional entropy of Markov trajectories turns out to be very challenging yet useful in numerous domains, including the study of mobility predictability and its dependence on location side information. In our work, we propose a method to compute the entropy of conditional Markov trajectories through a transformation of the original Markov chain into a Markov chain that exhibits the desired conditional distribution of trajectories. Moreover, we express the entropy of Markov trajectories—a global quantity—as a linear combination of local entropies associated with the Markov chain states.

Planning and Industry

Thursday, 21st August 2014

11:20 - 13:00

Steering "real world" complex adaptive systems: developing bio-based economy in the Humber region

Alexandra Penn, University of Surrey, UK (a.penn@surrey.ac.uk)

Many important problems for society involve the management of interlinked complex adaptive systems. Such systems have well known properties which make understanding and controlling them challenging. These include non-linear responses to change in variables, "emergent" effects which may feedback to those lower-level processes, the importance of network structure and crucially, the ability to adapt and evolve to changes in their environment. All of these properties present new challenges for policy intervention or engineering as they may give rise to behaviours which run counter to our intuition and experience and may change their responses as we intervene. Additionally many of the complex systems which we would most like to influence have significant social components and may require the integration of participatory or political processes with tools from complexity science.

In order to manage complex adaptive systems, we suggest a "steering" approach; applying a series of actions to a complex system and/or its environment to achieve a specific purpose. Steering is a continuous process which involves interacting with, monitoring and learning from the system in question. The techniques required for effective steering fall into two categories. Firstly we wish to understand, and indeed exploit, the systems' structure and dynamics in order to intervene effectively with them. Hence we need techniques to uncover this structure and to choose points of intervention. Secondly we frame those techniques within a participatory "adaptive management" structure which explicitly takes into account the adaptive nature of these systems and our limited capacity to fully model real world complex systems, by building in monitoring and feedback processes with which to modify our interventions as systems respond.

Using work on development of a bio-based economy in The Humber region of the UK, I will discuss the various modelling approaches which allow us to uncover system structure and a mathematical "control nodes" technique which allows us to choose a set of points of intervention within a given network. I will then describe how these can be used in a real world participatory context in which policy makers and industrial stakeholders must make decisions.

Exploring the coevolution of urban form and road networks with cellular automata

Oliver Laslett, University of Southampton, UK (ol1g13@soton.ac.uk)

The process of urbanisation is happening at an alarming rate, especially in many developing economies where internal migration is at its highest. In order to sustain a reasonable quality of life, these urban areas must be efficient; of which the transport network topology is a key driver. Urban form is determined by the transportation topology but the reverse is also true; recently developed models have attempted to capture this land use - transport (LUT) interaction. These models, however, are limited to considering the feedback loop between accessibility/congestion measures and land use. This study attempts to extend an early and influential land use model, based on cellular automata ideas, with a co-evolving transport network topology. Although the resulting model fails to capture the urban form dynamics as successfully or elegantly as the original model, it raises questions of how network topologies evolve from the decentralised process of rapid urban growth and how these dynamics may be understood and used for more effective transport policy.

ODD protocol application to review simulation model literature on complex social-technical systems within the metal recovery

Sandra Regina Mueller, University of Southampton, UK and Swiss Federal Laboratories for Materials Science and Technology, Switzerland (sm11g11@soton.ac.uk)

Electrical and electronic equipment (EEE) production is booming (UNEP, 2011). Such a product can contain more than 40 different metals and are mostly applied in very small quantities (UNEP, 2013). With the current material-centric recycling system, the recycling rate of speciality metals is below 1%. These metals include: indium and rare earth elements. They are used in high strength magnets and computer chips. These speciality metals are applied to enhance the performance of such products and thus play a vital role for modern society (Reck & Graedel, 2012). In order to recover these metals the present recycling system of a material-centric approach needs to shift to a product-centric approach. Thereby it is crucial to consider the complexity of modern products in relation to the complex interactions within the recycling system and the society (UNEP, 2013). To demonstrate the potential to increase the recovery rate of metals from EEEs during the recycling process, a clear structured model will be developed, taking into account socio-technological factors. Therefore, this research draws on the structured framework provided by the ODD (overview, design concept, details) protocol (Railsback & Grimm, 2011; Müller et al., 2013). The categories and questions of the protocol will be critically analysed and adapted if necessary (Grimm et al., 2010). Application of the ODD protocol allows a systematic and comprehensive review of the scientific literature (Müller et al., 2014) to develop the conceptual framework of the model. The focus of my presentation will be to discuss the strength and weaknesses of applying the ODD protocol, in order that other researchers will be able to reap the maximum benefits of this structured approach.

Large scale queuing network based pedestrian evacuation modelling using volunteered geographical information

Bharat Kunwar, University of Bristol, UK (b.kunwar@bristol.ac.uk)

In recent years, we have seen a surge in the number of natural disasters. Rapid urbanisation and population growth are contributing factors. Emergency planning tools available are usually specific to a region and incompatible in new areas. Therefore, we utilise a growing wealth of crowd-sourced open spatial databases like OpenStreetMap alongside computational mobility and behavioural models to achieve rapid simulation of large-scale evacuation effort in response to major crises. This is based on a new pedestrian model where agents move along a road-network, and the model is designed to take congestion effects into account while still being computationally efficient enough to be able to run numerous evacuation scenarios.

We envision 'Evacuation-Friendliness Index' for major cities worldwide at the end of this project. Focusing on suitability of road networks for emergency evacuation and non-linear effects using agent based models, the outcome is expected to have implications on emergency planning in the short term by testing multiple strategies in the run up to a disaster and influence policy makers in the long term by identifying weakest links and bottlenecks in a city system.

Integrated infrastructure modelling - managing interdependencies within a generic approach

Beate Dirks, Alexander Otto, Jim Hall, University of Oxford, UK (Beate.Dirks@linacre.ox.ac.uk)

Infrastructure provision is a highly challenging task, especially when accounting for climate change mitigation and adaptation needs [1]. Efforts of making infrastructure more efficient and flexible result in an increasing number of sensitive infrastructure interdependencies [2]. This enforces an integrated infrastructure assessment for planning purposes, in contrast to the traditional independent infrastructure-sector modelling [3]. For the unification of the existing infrastructure-sector models, we propose the implementation of a generic communication interface, which allows the separate sector-models to communicate at the necessarily disaggregate level in order to account for interdependencies appropriately. This approach allows for infrastructure provision modelling under one unified umbrella in a minimally invasive way, while conserving crucial individualities of the separate models. This is achieved through a generic network description, in which we solve the resource allocation through a pragmatic network-flow algorithm that resembles real market and consumer behaviour, while not overstretching computational resources. The developed framework

establishes the basis for fully integrated infrastructure evaluation and hence cross-sectorial infrastructure investment decision making – a crucial tool in times of tight governmental budgets.

[1] HMGovernment, Climate Resilient Infrastructure: Preparing for a Changing Climate, 2011. [2] Miriam Heller, Interdependencies in Civil Infrastructure Systems, Frontiers of Engineering 31(4), 2001. [3] Steven M. Rinaldi, Modelling and Simulating Critical Infrastructures and their Interdependencies, Proceedings of the 37th Hawaii International Conference on System Sciences, 2004.

Social Systems

Wednesday, 20th August 2014

10:00 - 11:00 Language and Social Dynamics

Why not to learn from each other - A new approach to investigate the evolution of social learning

Marco Smolla, University of Manchester, UK (marco.smolla@postgrad.manchester.ac.uk)

Organisms strive to reduce uncertainty in their environment by gaining as much information about it as possible. Theory predicts that learning from others (social learning) is an adaptive strategy that avoids the high costs of private (asocial) learning. Animal studies, however, show that relying on asocial learning is far more common than theory predicts. Here, we present an agent-based model that simulates a producer-scrounger game where individuals have to compete over resources, i.e. rewards have to be shared by individuals that perform the same action. Although competition is an omnipresent property in nature it is missing in other learning strategy models. We show that the fitness of pure social learners decreases with its frequency and even falls below the fitness of pure asocial learners. We also show that the pay-off distribution affects the fitness of social learners. Thus, asocial learners benefit from normally distributed pay-offs, while social learners benefit from exponential pay-offs. We suggest incorporating competition and testing the effect of pay-off distributions in future learning strategy models to increase their biological relevance.

Measuring success in communication

Patrick McGovern, University of Bristol, UK (patrick.mcgovern@bristol.ac.uk)

Conceptual spaces are a representation framework in which concepts are defined in terms of a set of attributes and an associated distance metric. Concepts are thus represented as convex regions within a conceptual space, which itself is made up of several feature dimensions. In this paper we describe a possible tactile conceptual space for an artificial fingertip. We then show how this space can be used in a language game, in which a population of autonomous agents co-evolves a set of shared tactile concepts. In particular, we have analysed a variety of textures and chosen two features to represent them. Given these features, we run simulations where agents use this conceptual space with a language model to communicate about the textures. Using a learning process to update their concepts based on the assertions of others, these agents can coordinate the way they describe the textures they observe.

Vocabulary growth curves: from random to real books

Francesc Font-Clos, Centre de Recerca Matemàtica, Spain (fontclos@crm.cat)

The study of language from a quantitative perspective has its roots in the late 19th century and has since never ceased, being embraced in recent years by the complexity community. In this work we cast doubt in the compatibility of two of its most basic laws: Zipf's law and Heap's law. The former, undoubtedly the most well-known and studied fact in the field, states that the number of different words with a given frequency follows a power-law distribution with an exponent γ close to 2; the latter, also known as Herdan's law, states that the number of different words V(l) in the first l words of a corpus also follows a power law, $V(l) \propto l^{\alpha}$ with $\alpha < 1$. Using very simple mathematics, we will show that both laws cannot hold simultaneously for random texts, at least in a strict sense. By constraining the distribution of frequencies to be a pure power-law, we will derive the expected growth of the vocabulary V(l), showing that the resulting function is not a power-law. Our results consistently hold not only for simulated random texts, but also for the case of real texts. In both cases, the observed curves V(l) show a clear bending or concavity in log-log space, which our solution accurately captures, and which is at odds with the classic power-law formulation of Heap's law.

11:20 - 12:20 Society and Technology

In search of a model of human dynamics analysis applied to social sciences

Dalton Martins, Universidade Federal de Goiás, Brazil (dmartins@gmail.com)

The study of Social Systems, particularly what we call human dynamics, is essentially a multidisciplinary field and requires the establishment of research approaches that take account of their complexity. The objective of this research is to present a field of analysis that consider 3 dimensions for analytical research and development of new knowledge about social systems focusing on human dynamics. These dimensions are referred to in this proposal as a philosophical mathematical and technological dimensions. The philosophical dimension seeks to connect explanatory models of human behavior, focusing specifically on the biopolitics of Michel Foucault and further developed and updated by Toni Negri and Michael Hardt, and the historical materialism of Karl Marx updated by current discussions of David Harvey. The mathematical dimension seeks to articulate principles of statistics, especially multivariate analysis, in addition to social networks analysis and complex systems as a way to operationalize the abstract concepts used by the philosophical dimension. The technological dimension proposes ways to use technology, such as programming language, spreadsheet and graphic design tools as a way of creating images, representations and ways of showing what the mathematical dimension allows operationalize.

We used these 3 dimensions in the production of researches in the area of public policy, particularly in the areas of social welfare and health. There is substantial evidence that the articulation of these dimensions has allowed us to create new concepts and mathematical operators, such as transversallity index hierarchical coefficient, among others . We believe that only by expanding the dimensions of analysis you can perform innovative research and new concepts and ways to operationalize these concepts that produce new ways of understanding the social systems.

Anatomy of scientifc evolution

Jinhyuk Yun, Korea Advanced Institute of Science and Technology (bluekura@kaist.ac.kr)

The quest for historically impactful science and technology provides invaluable insight into the innovation dynamics of human society, yet many studies are limited to qualitative and small-scale approaches. Here, we investigate scientific evolution through systematic analysis of a massive corpus of digitized English texts between 1800 and 2008. Our analysis reveals remarkable predictability for long-prevailing scientific concepts based on the levels of their prior usage. Interestingly, once a threshold of early adoption rates is passed even slightly, scientific concepts can exhibit sudden leaps in their eventual lifetimes. We developed a mechanistic model to account for such results, indicating that slowly-but-commonly adopted science and technology surprisingly tend to have higher innate strength than fast-and-commonly adopted ones. The model prediction for disciplines other than science was also well verified. Our approach sheds light on unbiased and quantitative analysis of scientific evolution in society, and may provide a useful basis for policy-making.

Understanding infrastructure, shared resources at all biological levels

Richard Thanki, University of Southampton, UK (richardthanki@gmail.com)

As human societies and economies have grown in scale, scope and complexity they have come to be ever more reliant on infrastructures. If defined simply as “shared means to many ends” (sensu Brett Frischmann) then the notion of “infrastructure” can include many of the things we traditionally regard as infrastructure, such as transport systems, utilities and communications networks. In addition we can easily conceive of more abstract infrastructures, such as the internet, legal systems and common-pool resources. Existing approaches in economics and the social sciences have not systematically the topic of infrastructure, especially in its broader sense. However, simulation models and other dynamic systems approaches can help to illuminate the important and subtle role that infrastructures play in the development and stability of complex adaptive socio-technological systems.

14:00 - 15:00 ABM: Human-natural Systems

ABM in digital humanities: the case study of the Movius line

Iza Romanowska, University of Southampton, UK (i.romanowska@soton.ac.uk)

The Movius Line controversy is one of the most persistent research themes in Early Palaeolithic Archaeology. A number of hypotheses have been put forward to explain the pattern of the spatial distribution of Mode 1 and Mode 2 industries. It has been suggested (Lycett & Von Cramon-Taubadel 2008; Lycett & Norton 2010) that in areas further away from the origins of the first 'Out of Africa' dispersal the population density was lower than in the zones closer to Eastern Africa. As a result, smaller and less well connected human groups could not sustain the sophisticated technological knowledge necessary to produce Mode 2 implements and reverted to simpler knapping strategies i.e. Mode 1.

An Agent-based model was developed to test the above hypothesis. It consists of an paleoenvironmental reconstruction of the Old World coupled with a dynamic simulation of the sea level fluctuations in which large areas of dry land would occasionally (on a geological time scale) become submerged and reappear due to climatic changes, acting as an 'environmental pump' driving human movement. The goal of this study is to compare population density in the Acheulean and Oldowan regions throughout the simulation to evaluate if the proposed demographic disparity between the two regions is plausible. If, under a wide sweep of parameters informed on contemporary hunter-gatherer but also mammalian data, the model will show no differences between the Mode 1 and Mode 2 areas in terms of population density then the aforementioned hypothesis can be rejected.

References: Lycett, S. J., and C. J. Norton. 2010. "A Demographic Model for Palaeolithic Technological Evolution : The Case of East Asia and the Movius Line." Quaternary International 211 (1-2) (January): 55–65; Lycett, S. J, and N. Von Cramon-Taubadel. 2008. "Acheulean Variability and Hominin Dispersals : a Model-bound Approach." Journal of Archaeological Science 35: 553–562.

Insights to past migration behaviour in the Maldives

Laurens Speelman, University of Southampton, UK (lhs1e11@soton.ac.uk)

Impacts of climate change for low-lying islands will almost certainly include accelerated coastal erosion and increased flooding from the sea. Resettlement has often been mentioned as a potential adaptation option to sea-level rise on these islands. Previous studies focused on calculating the potential number of environmental refugees by directly projecting physical impacts on coastal societies. However, there are many social, economic and environmental factors involved in migration decision-making and to date there has been limited effort to investigate migration behaviour in low-lying islands. Based on demographic, socio-economic, and environmental datasets this paper explores historic migration behaviour in the Republic of Maldives. Careful analysis of this new dataset shows that addition to classic migration determinants such as level of education, age, employment and health; factors such as vulnerability to storm surges and impacts of the 2004 Boxing Day tsunami are also important in predicting migration behaviour in the Maldives.

The use of participatory approaches and agent-based modelling to explore the complexity of food security within rural Malawi.

Samantha Dobbie, University of Southampton, UK (s.dobbie@soton.ac.uk)

Food security remains a deep seated issue throughout Sub-Saharan Africa. Within Malawi, the vast majority of the rural population are engaged in subsistence farming. Continued reliance upon rain-fed agriculture renders smallholders vulnerable to climatic shocks, whilst high population densities, small plot size and poor soil quality further compound food insecurity. In order to elicit greater understanding of the complex behavioural decisions and coping strategies undertaken by subsistence farmers, simulation techniques have been proposed as a potential tool. Agent-based modelling (ABM) is one possible technique, which comprises a computerised simulation of agents located within an environment. ABM can be categorised as abstract, experimental, historical or empirical depending on the type of rules they abide

by. The aim here was to determine whether results from participatory exercises could be utilised in the construction of an empirical ABM. A participatory rural appraisal (PRA) exercise was designed to elicit greater understanding of smallholder responses to drought; as well as the perceived impact of government interventions in the form of input subsidies. Results from participatory field work were successfully incorporated into an agent-based model of Malawian smallholders. However, scarce availability of data was identified as a key factor undermining model integrity. Initial implementation of the model found inferences could be made concerning the impact of policy upon household decision making and food security. Overall the project provides fertile ground for future work. It is hoped that by integrating PRA exercises and ABM it will be possible to create a collaborative framework which promotes interaction between scientists, policy makers and stakeholders, alike.

15:00 - 16:00 ABM: Epistemology and Methods

"But all my friends do it!" - evidence for a threshold model of social contagion

Daniel Sprague, University of Warwick, UK (D.A.Sprague@warwick.ac.uk)

In human society, some trends and behaviours die out quickly, while others explode in popularity: some bands gain fans and become huge hits, while others stay obscure. Much of collective social behaviour shows these highly variable, unpredictable outcomes. There have been attempts to model this and similar phenomena, using ideas such as preferential attachment, but they are generally agent-based or Monte-Carlo models, which are therefore difficult to fit to data, or they are empirical generalisations of data without a firm underlying model. Instead, we use a simple model for social influence based on ‚complex contagion', in which individuals canvas a small number of friends; if more than some threshold number of these friends are taking part in the behaviour or trend then the individual is much more likely to also take part. We combine these ideas with the SIR model of an epidemic to obtain a simple, low-dimensional model of the spread of a trend, which we then fit to internet search data to show that ‚complex contagion' is a better model for social trends than a simpler, linear model of contagion.

Deciding to disclose: pregnancy and alcohol misuse

Jonathan Gray, University of Southampton, UK (j.gray@soton.ac.uk)

In this paper we examine the feasibility of Bayesian games played by populations of decision theoretic agents as an approach to Agent Based Modelling (ABM). The use of explicit and theoretically grounded models of decision making is intended to address concerns about the perceived ad hoc character of ABM. Taking alcohol consumption during pregnancy as an exemplar, we apply a combination of agent based modelling and decision theory to explore a scenario where a population of pregnant women choose how far to disclose their drinking patterns to their midwives.

This is explored through an agent based model of a set of stylised scenarios, where populations corresponding to pregnant women and midwives play a series of games. In each game, the woman chooses to claim a level of alcohol consumption, and their midwife chooses whether to refer them to a specialist. Both players employ a simple decision rule using information from previous rounds to choose their actions. Midwives attempt to refer only women who need treatment, and women endeavour to avoid being stigmatised for their drinking behaviour while still receiving appropriate treatment.

There are two key questions addressed in this work: firstly how far a relatively abstract decision theoretic agent based model is able to capture the dynamics at play in a complicated, and opaque real world situation; secondly, to investigate how information sharing within the two populations affects overall behaviour. The simulation model is able to produce a number of qualitative trends described in the literature, in particular an increased tendency to disclose as women have more encounters, and greater underreporting of consumption by heavy drinkers. The results also demonstrate that how the decision making is operationalised in such models, is an important decision in itself.

Gaussian process emulators for bayesian uncertainty and sensitivity analysis and calibration of agent based models

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The analysis of Agent Based Models (ABMs) is often complicated. Large parameter spaces; non-linearities and feedback; stochasticity; long run-times; and uncertainty in input variables are just some of the obstacles faced by those attempting to makes sense of their models. Gaussian Process Emulators offer a way avoid some of these difficulties by creating a flexible statistical model of the simulation based on a relatively small sample of training runs. Simulator outputs can then by inexpensively estimated by the emulator. A Bayesian framework allows uncertainty around input parameters to be reflected in the distribution in the model output. A sensitivity analysis can also be conducted by examining reduction in output variance achieved by observing a parameter or collection of parameters.

This work examines the utility of Gaussian Process Emulators as a tool for the analysing and calibrating agent-based social models, using a simple example. The advantages and the limitations of such an approach are assessed, and the paper concludes with a discussion of how ABMs might be used in combination with Gaussian Process Emulators to make policy choices in situations of uncertainty within a decision-analysis framework.

Swarm Robotics

Wednesday, 20th August 2014

11:20 - 12:40 Swarm Robotics

Understanding the role of recruitment in collectiverobot foraging

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The ability of a swarm of simulated robots to forage collectively for environmentally distributed resources is assessed relative to the performance of a population of independent, individualist foragers. The conditions under which recruitment (where one robot alerts another to the location of a resource) is profitable are characterised, and explained in terms of the impact of three types of interference between robots (physical, environmental, and informational). Key factors determining swarm performance include resource abundance, the reliability of shared information, time limits on foraging, and the ability of robots to cope with congestion around discovered resources and around the base location. Additional experiments introducing odometry noise indicate that collective foragers are more susceptible to odometry error.

Communication in a Swarm of Robots

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In swarm robotics, the many robots composing the swarm have very local informations and can't rely on an external infrastructure. Hence, a collaboration among robots is needed for the swarm to tackle an issue on a scale bigger than the individual robots. Part of swarm robotics is studying & design how robots interact and how this sum of local interactions can give the swarm a coherent behaviour.

The type of communication between robots has a strong impact on the ability of the task they can handle. On one side you have hard coded expert-designed protocols that fits particular situations, while on the other extreme you find natural languages which evolving process allow for new usages over time, self-organised by the robots themselves.

My work is focused on the study of such interactions, its dynamics, and the effect it has on the swarm's behaviour. I will present the experiments I've done on protocol communication in swarm robotics applied to foraging, as well as as future endeavours linked with self-organised emergence of language in swarms of robots.

Enhance the exogenous fault detection approach by analysing transferable data in swarm robotics

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A robotic swarm needs to ensure continuous operation even in the event of failure of one or more individual robots. In case one robot breaks down, another robot can take steps to repair the failed robot or take over the failed robot's task. Even with less number of faulty robots, the expected time of achieving the task will be affected.

Observing failure detection techniques require an investigation of similar techniques in the insects. Fireflies synchronisation approach as a exogenous failure detection technique was proposed by Christensen et al. (2009). This approach require all robots in the swarm to be initially synchronised together in order to announce a healthy status to each individual robot. Another exogenous failure detection inspirational approach were discussed by Alan G. Millard (2013) is Robot Internal Simulator. The concept of this approach is having robots to be capable of detecting partial failures by possess a copy of

every other robot's controller, which, then, they instantiate within an internal simulator on-board. After a robot get the data from another robot in the swarm, the internal simulation runs for a short period of time to predict the future state of the other robots based on their data. A failure will be indicated whenever there is a significant discrepancy between the predicted and observed behaviour of a particular robot.

This research is taking inspiration from both approaches, Fireflies and Robot Internal Simulator, where they still have several issues when they are implemented in swarm robotics. Some modification to the developed ap- proaches will provides a reliable exogenous failure detection mechanism that could deal with multiple hardware and software failures in swarm robotics during the research experiments. The enhanced technique in this research will count on the live input and output values in the robot's controller to diagnosis other robots within the swarm during the entire swarm operation.

During the experiment, each robot broadcast their own id and values to be received by the nearest robot within the communication range. When another robot receive these values, they broadcast their id and values in addition to the computed diagnosis results back to the first robot to be computed and compared. In case of any suspicious in the received values they broadcast an acknowledgement with the failure to their neighbours in the swarm robotic. Then a recovery action take place to recover or mitigate the cause of the failure.

References: Alan G. Millard, Jon Timmis, A. F. W. (2013). Towards exogenous fault detection in swarm robotic systems; Christensen, A. L., O'Grady, R., and Dorigo, M. (2009). From fireflies to fault-tolerant swarms of robots. Evolutionary Computation, IEEE Trans- actions on, 13(4):754–766.

Hardware variation in mobile swarm robots

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One assumption that is made by the majority of swarm robotic researchers, particularly in software simulation, is that a robotic swarm is a large number of identical robots with no difference found between any two of them. However, differences among hardware robots are unavoidable, which exist in robotic sensors, actuators, etc. These hardware difference, albeit small, affect the robots response to its environment. In this work, robots with hardware variation have been modelled and simulated in a line following scenarios. It is found out that even small hardware variation can result in behavioural heterogeneity. Although the variations can be compensated by the controllers in training, the hardware variation and resulting differences in controller settings are amplified in the non-linear interaction between robot and environment. Accordingly, the behaviour of the identically trained robots in the same environment are subject to divergence.

It is further found out that the level of robotic behavioural divergence is strongly influenced by the magnitude of hardware variation and different robotic parameters change robotic behaviours in different perspectives and with different strength. In addition, environment is another key factor when differentiating the behaviours of robots with different types of hardware variation."It is further found out that the level of robotic behavioural divergence is strongly influenced by the magnitude of hardware variation and different robotic parameters change robotic behaviours in different perspectives and with different strength. In addition, environment is another key factor when differentiating the behaviours of robots with different types of hardware variation.