***COMPLEXITY SCIENCE WORKSHOP 18, 19 June 2015***

**Systems & Control Research Centre**

**School of Mathematics, Computer Science and Engineering**

**CITY UNIVERSITY LONDON**

**PROGRAM OF THE WORKSHOP**

**Thursday, 18 June (Room AG07)**

**9.00-9.15 : Welcome, Coffee, Registration**

**9.15-9.30 : Introduction: Nicos Karcanias,** Systems & Control Centre, CUL

“Complex Systems and Challenges for Emerging fields of Applications”

**Chairman** (Morning Session)**:** Martin Newby

**10.00-10.30: Presentation (1): Michael Zervos,** Dept of Mathematics, LSE

*“Optimal execution with multiplicative price impact”*

**10.30-11.00 : Presentation (2): Charles Baden-Fuller** CASS Business School, CUL

*“Business Models: the challenge of modelling business and technology simultaneously”*

**11.00-11.15: Coffee Break**

**11.15-11.45:  Presentation (3): Eduardo Alonso,** Systems & Control Centre, CUL

“*C-agents: a notion that allows extension of Multi-Agent Systems (MAS) to SoS*”

**11.45-12.15:  Presentation (4): Nicos Karcanias** Systems & Control Centre, CUL

"*Systems Complexity: The paradigm of System of Systems*"

**12.15-13.00:  Discussion**

**13.00-14.00:  Lunch Break**

**Chairman** (Afternoon Session)**:** Veselin Rakocevic

**14.00-14.30: Presentation (5): Martin Newby ,** Systems and Control Centre , CUL

*“Resource Allocation for System Robustness”*

**14.30-15.00: Presentation (6): Stelios Kotsios** *Dept of Econ, Univ of Athens, Greece*

*“Controlling National Debt Dynamics. A First Approach”*

**15.00-15.15 : Coffee, Tea Break**

**15.15-15.45: Presentation (7): Mark Broom,** Dept of Mathematics, CUL

*“Modelling evolution in structured populations involving multi-player interactions”*

**15.45-16.15: Presentation (8):**  **Anne Kandler** Maths Dept, CUL

*“Inferring cultural transmission processes from frequency data”*

**16.15-16.45: Presentation (9):**  **John Leventides,** Systems & Control Centre, CUL

*"Low rank tensor approximation, approximate decomposability and the determinantal assignment problem"*

**16.45-17.30: Discussion on possible research initiatives**

**17.30-17.45: Conclusions**

**Friday, 19 June (Room AG08** (AG02 Catering)**)**

**9.00-9.15: Coffee, Registration**

**Chairman** (Morning Session)**:** David Stupples

**9.15-9.45 : Presentation (10): George Halikias**, Systems and Control Centre, CUL

*“The structured singular value problem arising in Robust Control: Complexity and Convex relaxation algorithms”*

**9.45-10.15: Presentation (11): John Leventides & Nicos Karcanias,**  Syst & Contr, CUL

*“Decision Theory and Design in Multi-level hierarchical management structures”*

**10.15-10.45: Presentation (12): Giulia Iori,** Dept of Economics, CUL

*"A network approach to Financial Stability"*

**10.45-11.15 : Presentation (13): Antonis Alexandridis,** Univ. of Patras, Electr. **,** Greece

*“Modeling and control of distributed generation power systems as complex nonlinear Hamiltonian systems”*

**11.15-11.30: Coffee Break**

**11.30-12.00: Presentation (14): Nicos Karcanias** Systems & Control Centre, CUL

"*Systems Complexity: the paradigm of Structure Evolving Systems* "

**12.00-12.30: Presentation (15): Alexandra Brintrup**, Cranfield University

*" Analysing Complexity and Resilience in Emergent Manufacturing Networks"*

**12.30-13.00: Discussion**

**13.00-14.00: Lunch Break**

**Chairman** (Afternoon Session)**:** George Halikias

**14.00-14.30: Presentation (16): David W. Stupples**

Systems and Control Centre, CUL

*“Future Surveillance System Technology - for a safer society”*

**14.30-15.00: Presentation (17): Stathis Kasteridis** Novocaptis, Greece

*“Smart Systems as Complex Systems: Research and Design Challenges – An overview”*

**15.00-15.15 : Coffee, Tea Break**

**15.15-15.45: Presentation (18): Veselin Rakocevic,** Systems & Control Centre, CUL

*“Connecting Moving Objects: Managing the Complexity of Movement in Modern Communication Networks”*

**15.45-16.15: Presentation (19):**  **Ali G. Hessami ,** Vega Systems, Syst & Control, CUL

*“Smart Safety Assessment for Complex Systems-Abstract”*

**16.15-16.45: Presentation (20):**  **George P. Papavassilopoulos** Contr & Dec. Lab, NTUA, Greece

*“Energy Policy Using Graph and Game Models”*

**16.45-17.30: Discussion on possible research initiatives**

**17.30-17.45: Conclusions**

**Abstracts**

**Thursday 18th June**

**9.00-9.15 : Welcome, Coffee, Registration**

**9.15-9.30 : Introduction: Nicos Karcanias**

Systems & Control Centre, CUL

***“Complex Systems and Challenges for Emerging fields of Applications”***

**Workshop Description:** Complex Systems emerge in many disciplines and domains and have many interpretations and problems associated with them. The specific domain provides dominant features and characterise the nature of problems to be considered. A major classification of such systems are to those linked with *physical processes* (physics, biology, genetics etc) and those which are *man-made* (engineering, technology, economics, management, social etc) and deal with decision making and working out solutions to complex problems. Expectations feedback and adaptive behaviour through learning are key ingredients distinguishing socio-economic systems from complex systems in engineering and the natural sciences. In economics the “system components can think”, they learn from experience and adapt their behaviour accordingly. The individual elements of a system are influenced directly by the behavior of the system as a whole, and at the same time their interactions lead to the emergent behaviour at the aggregate level of the system. Such systems emerge in engineering, economics, finance and management which define a range of high complexity problems, requiring fundamentally new thinking and address complexity with an interdisciplinary approach going beyond the current approaches.

The workshop aims to address the challenges and explore the possibilities of developing fundamental research by bringing together expertise from many and diverse areas for such systems and stimulate the formulation of ideas leading to new research. The presentations address current activities and present some ideas that can stimulate collaborative research. The topics listed below are indicative and include:

■ Complex Systems and Emergence

■ Modelling of Complex Systems: Conceptual Modelling, Data, Signals, Information

■ Simplification of Complexity: Modelling and Computations

■ System of Systems and Applications

■ Systems Structure Evolution

■ Financial and Social Networks

■ Systems Biology

■ Systems Organisation: Hierarchics, Autonomy and Holonics

■ Decision Theory

■ Control of Complex Systems, Cooperative Control

■ Network Theory: Communication and Supply Chains.

■ Management of and Control of Business Processes

**10.00-10.30: Presentation (1): Michael Zervos**

Dept of Mathematics, LSE, [M.Zervos@lse.ac.uk](mailto:M.Zervos@lse.ac.uk)

***“Optimal execution with multiplicative price impact”***

**Abstract:** We consider the so-called ``optimal execution problem'' inalgorithmic trading, which is the problem faced by an investorwho has a large number of stock shares to sell over a giventime horizon and whose actions have impact on the stock price.In particular, we develop and study a price model thatpresents the stochastic dynamics of a geometric Brownianmotion and incorporates a log-linear effect of the investor'stransactions. We then formulate the optimal execution problemas a two-dimensional degenerate singular stochasticcontrol problem. Using both analytic and probabilistictechniques, we establish simple conditions for the market toallow for no price manipulation and we develop a detailedcharacterisation of the value function and the optimal strategy.In particular, we derive an explicit solution to the problem ifthe time horizon is infinite.

**10.30-11.00: Presentation (2): Charles Baden-Fuller**, Stefan Haefliger and Paolo Aversa

CASS Business School, City University, [c.baden-fuller@city.ac.uk](mailto:c.baden-fuller@city.ac.uk)

***“Business Models: the challenge of modelling business and technology simultaneously”***

**Abstract:** Business Models are representations of business, typically used by managers or observers to understand how firms identify their customers, create value for those customers, deliver that value and monetize the result. Understanding what possibilities exist require managers to engage in model manipulation, that requires them to make assumptions; these assumptions are typically that the model can be simplified, made nearly decomposable and be nearly modular – all in line with the proscriptions of Herbert Simon, and recognized widely by modelers in social sciences. Significant work has been done unravelling the specific challenge by the EPSRC team at Cass “Building Better Business Models”; – we have identified 4 core types of business model (see [www.businessmodelzoo.com](http://www.businessmodelzoo.com)), methods of manipulation, and methods of generating new sub-types. But we have also identified an important challenge: when managers enact their models, they have to utilize technology that is frequently digital and also complex. To make the technology effective and optimize the business model, it is often made modular. And here-in lies the challenge, the boundaries of modularity in the technological world are frequently different from those of the business model world. So in this presentation, we want to explore the link between modularity and manipulation in the technological work with that of the world of business models, and to solicit suggestions from others on how to make progress on this challenge – that crosses boundaries between traditional science and social science.

**11.00-11.15: Coffee Break**

**11.15-11.45: Presentation (3): Eduardo Alonso**

Systems & Control Centre, City University, E.Alonso@city.ac.uk

**“*C-agents: a notion that allows extension of Multi-Agent Systems (MAS) to SoS*”**

**Abstract:** We present a new approach to Systems of Systems (SoS), based on a classification of different types of systems and the way they interact and get co-ordinated. In particular, we identify C-agents as a notion that allows us to move from Multi-Agent Systems (MAS) to SoS. The agents playing such role can intervene and enforce new solutions to a MAS problem, and are thus instrumental in providing space for emergent properties. We believe that this analysis constitutes the starting point for the development of a methodology that may lead to systematic design of SoS. Examining the rules of composition of the subsystems and their coordination as agents in a larger system defines a challenging new area for research and requires links across many disciplines. We will also present an attempt at formalizing the notion of hierarchical emergence in both MAS and SoS using abstract algebra.

**11.45-12.15: Presentation (4): Nicos Karcanias**

Systems & Control Centre, City University, [N.Karcanias@city.ac.uk](mailto:N.Karcanias@city.ac.uk)

"***Systems Complexity: the paradigms of Structure Evolving Systems & System of Systems***"

**Abstract:** Complex Systems is a term that emerges in many disciplines and domains and has many interpretations, implications and problems associated with it. A major classification of such systems are to those linked with *physical processes* (physics, biology, genetics, ecosystems, social etc) and those which are *man made* (engineering, technology, energy, transport, software, management and finance etc) and deal with the *“macro level”* issues and technology. A new major emerging paradigm expressing new forms of engineering complexity are the:

**●** *Structure Evolving Systems (SES)*

The SES class of systems emerges in natural processes (such as Biology, Genetics, Crystallography etc) and it is central to Integrated Design,and Re-design of Engineering Systems (Process Systems, Flexible Space Structures etc), Systems Instrumentation, Design over the Life-Cycle of processes, Control of Communication Networks,Supply Chain Management, etc. This family departs considerably from the traditional assumption that the system is fixed and its dominant features relate to *variability of interconnection topology,* *System evolution from Early to Late stages of the design process, variability due to lifecycle issues*, *variability in the information and control* in response to changes in goals and operational requirements. We examine a number of new Control Theory and Mathematical nature problems which are essential building blocks in the development of new methodologies for *Integrated Systems Design, Reengineering* and *Systems Instrumentation.*

**12.15-13.00:  Discussion**

**13.00-14.00:  Lunch Break**

**Chairman** (Afternoon Session)**:** Veselin Rakocevic

**14.00-14.30: Presentation (5): Martin Newby**

Systems and Control Centre, City University, [martinnewby.1@gmail.com](mailto:martinnewby.1@gmail.com)

***“Resource Allocation for System Robustness”***

**Abstract:** Concepts from reliability and uncertainty engineering are exploited to develop ways of improving therobustness of systems. The algorithmic approach allows the identification of the importance or criticalityof subsystems and their contribution to overall system performance. The ranking of subsystems is thebasis for resource allocation to improve robustness. A Taguchi approach determines the optimal allocation of resources to minimize the variation in system output. The importance measures are calculated at the nominal values of system parameters. Because actual system parameters are subject to variation the improvements are based on the most economic choice of actions to reduce variation. The modelling uses Birnbaum importance combined with a Taguchi approach to reducing variationto define an optimum strategy for improvement. By reducing the variation in behaviour the system becomes more robust and more easily controlled.

**14.30-15.00: Presentation (6): Stelios Kotsios** and Ilias Kostarakos,

*Dept of Economics, Division of Mathematics, University of Athens, Greece,* [*skotsios@econ.uoa.gr*](mailto:skotsios@econ.uoa.gr)

***“Controlling National Debt Dynamics. A First Approach”***

**Abstract:** In this paper we explore an alternative framework for the design of fiscal policy based on the algorithmic linear feedback methodology. In particular, we construct linear feedback policy rules for government expenditures so that (fixed) policy targets for National Income and public debt are exactly met. The main tool this contribution is based on, are the feedback rules. That is functions which relate the policy instrument (control variable) to (lagged) values of the policy targets (state variables) and the policy instrument itself. Once these rules are calculated and applied to the model at hand, they are able to modify its dynamics i.e. its future behavior, in a pre-specified manner.Specifically, we propose a control-theoretic approach based on the algorithmic linear feedback methodology. Actually, as the (fixed) targets for the national income and public debt have been set, we use the model matching technique in order to calculate linear feedback rules for the policy instrument, so that the policy objectives are met. The general model we chose to work with is a linear, deterministic variant of the multiplier-accelerator model that was introduced in Samuelson’s (1939) seminal paper, coupled with a difference equation describing the time path of the economy’s public debt. That is:



This is an input-output system with two equations, where G plays the role of the input, while Y and B are the outputs. Using this description, the said problem can expressed in two sub problems: That of finding a feedback-law which matches the national income to a predefined sequence and brings  as close as possible to a sequence and that of finding a feedback-law which matches the debt with a predefined sequence and asking to be close to. A variant of this approach will be also studied. It is based on models of the form:



This is an input-output form, with two inputs: the government expenditure G(t) and the extra taxation E(t). It is used for studying current debt-recovery techniques, where the citizens are asked to pay extra taxes additional to the traditional ones. Moreover, adaptive control schemes are also used in order the influence of a dynamic policy to the parameters of the original system to be into account. Finally, we try to comprehend nonlinear extensions of the original problem, where the above linear models have been replaced with various nonlinear ones. All the aforementioned problems are faced by means of the model matching methodology. Following this methodology, we first construct a desired linear system with an “ideal” dynamic behaviour and then, using algebraic techniques, we find the appropriate feedback-laws, by solving certain polynomial equations.

The method has certain economic advantages, both theoretical and quantitative. Regarding the theory, it can be used as a tool of studying specific theories or approaches to how the debt may face. If, for instance, a government intervention is needed or not. Quantitatively, it can be used to estimate, quite satisfactory, the levels of government spending or of special taxation. Additionally, our approach develops proper computational algorithms. Using these algorithms, all the procedure can be totally computerized and applied “on-line”. Finally, these algorithms can provide us with a whole class of feedback policy among of which, we can select some laws appropriate for meeting some extra conditions. Simulations indicate that for an economy suffering from a severe economic downturn along with very large debt-to-income ratios, like the Greek economy, fiscal policy should be designed on the basis of increases in government expenditures that will ensure positive growth rates and will stabilize –if not, decease- the debt-to-income ratio.

**15.00-15.15 : Coffee, Tea Break**

**15.15-15.45: Presentation (7): Mark Broom**

Department of Mathematics, City University, [Mark.Broom.1@city.ac.uk](mailto:Mark.Broom.1@city.ac.uk)

***“Modelling evolution in structured populations involving multi-player interactions”***

**Abstract:** Within the last ten years, models of evolution have begun to incorporate structured populations, including spatial structure, through the modelling of evolutionary processes on graphs (evolutionary graph theory). One limitation of this otherwise quite general framework is that interactions are restricted to pairwise ones, through the edges connecting pairs of individuals. Yet many animal interactions can involve many individuals, and theoretical models also describe such multi-player interactions. We shall discuss a more general modelling framework of interactions of structured populations, including the example of competition between territorial animals. Depending upon the behaviour concerned, we can embed the results of different evolutionary games within our structure, as occurs for pairwise games such as the Prisoner's Dilemma or the Hawk-Dove game on graphs. For a population to evolve we also need an evolutionary dynamics, and we demonstrate a birth-death dynamics for our framework. Finally we discuss some examples together with some important differences between this approach and evolutionary graph theory.

**15.45-16.15: Presentation (8):**  **Anne Kandler**

City University London,

***“Inferring cultural transmission processes from frequency data”***

Cultural change can be quantified by temporal frequency changes of different cultural artefacts. Based on those (observable) frequency patterns researchers often aim to infer the nature of the underlying cultural transmission processes and therefore to identify the (unobservable) causes of cultural change. Especially in archaeological and anthropological applications this inverse problem gains particular importance as occurrence or usage frequencies are commonly the only available information about past cultural traits or traditions and the forces affecting them. Matters are further complicated by the fact that observed changes often describe the dynamics in samples of the population of artefacts whereas transmission processes act on the whole population. In this talk we start analyzing the described inference problem. We develop a generative inference framework which firstly establishes a causal relationship between underlying transmission processes and temporal changes in frequency of cultural artefacts and secondly infers which cultural transmission processes are consistent with observed frequency changes. In this way we aim to deduce underlying transmission modes directly from available data without any optimality or equilibrium assumption. Importantly this framework allows us to explore the theoretical limitations of inference procedures based on population-level data and to start answering the question of how much information about the underlying transmission processes can be inferred from frequency patterns. Our approach might help narrow down the range of possible processes that could have produced observed frequency patterns, and thus still be instructive in the face of uncertainty. Rather than identifying a single transmission process that explains the data, we focus on excluding processes that cannot have produced the observed changes in frequencies. We apply the developed framework to a dataset describing the LBK culture.

**16.15-16.45: Presentation (9):**  **John Leventides**

Marie Curie Fellow Systems & Control Centre City University, Dept of Economics University of Athens, [Ioannis.Leventidis.1@city.ac.uk](mailto:Ioannis.Leventidis.1@city.ac.uk)

***"Low rank tensor approximation, approximate decomposability and the determinantal assignment problem"***

**Abstract:** Complex data in many applications may have tensorial form ie may be indexed by more than two indices making SVD matrix approximation unusable. Low rank approximation in that case may require a type of SVD theory appropriate for tensors. This type of approximation also applies in problems in Control where we require to approximate a skew symmetric tensor by a decomposable tensor. This approximation may be viewed as a distance problem of a linear variety to the Grassmann variety and may be tackled via Exterior Algebra methods.We present cases that the problem may be solved and how it may be applied to Control problems.

**16.45-17.30: Discussion on possible research initiatives**

**17.30-17.45: Conclusions**

**Friday 19th June**

**9.00-9.15: Coffee**

**Chairman** (Morning Session)**:** David Stupples

**9.15-9.45 : Presentation (10): George Halikias**,

Systems and Control Centre, City University, [G.Halikias@city.ac.uk](mailto:G.Halikias@city.ac.uk)

***“The structured singular value problem arising in Robust Control: Complexity and Convex relaxation algorithms”***

**Abstract:** The talk introduces the "structured singular value" ( problem in the context of robust control synthesis of dynamic systems subject to structured model uncertainty. This is essentially a distance-to-singularity matrix problem under structured perturbations. The complexity of the problem is analysed and convex relaxation methods obtaining easily computable upper bounds are presented, along with necessary and sufficient conditions that guarantee zero duality gap. In the case when the gap is not zero (i.e. the upper bound is strictly larger than ), tighter bounds of  can be obtained by considering artificial perturbation structures defined via simultaneous spectral-radius and norm constraints. It is shown that, provided the solution (or a "good" bound) of an auxiliary reduced-rank -problem can be obtained, the proposed method produces a bound which breaches the convex relaxation bound for the original problem. Similarities with a parallel method applied to the Quadratic Integer Programming (QIP) problem are identified, suggesting general applicability of the technique in the area of convex relaxations.

**9.45-10.15: Presentation (11): John Leventides and Nicos Karcanias**

Systems & Control Centre, City University,

[Ioannis.Leventidis.1@city.ac.uk](mailto:Ioannis.Leventidis.1@city.ac.uk), [N.Karcanias@city.ac.uk](mailto:N.Karcanias@city.ac.uk)

***“Decision Theory and Design in Multi-level hierarchical management structures”***

**Abstract:** Decision and control problems on multi-level hierarchical structures emerge in areas such as integrated operations in manufacturing, business management, banking and finance. The common characteristic of such systems is the multi-layer hierarchical structure of the system. Each layer is characterized by a model and the nature and complexity of models at the different stages varies (continuous, discrete time, discrete event etc). The different layer sub-systems are interconnected and the solution of control problems provides inputs for the decision and control problems at the lower levels. Strategy at the top level cannot be implemented unless they can be realized as feasible solutions at each level in the hierarchy. Knowledge of behavior at each layer is critical for informed decision making at the top. The control problems on multi-model, variable complexity and nested systems introduce new challenges for hybrid systems and global controllability and observability studies.

**10.15-10.45: Presentation (12): Giulia Iori**

Department of Economics, City University, [G.Iori@city.ac.uk](mailto:G.Iori@city.ac.uk)

***"A network approach to Financial Stability"***

**Abstract:** The global financial crisis of 2008 has highlighted the importance of market interconnectedness on financial stability and the need to develop an appropriate framework to understand systemic risk. Financial markets are a system of individually complex institutions that are connected to one another in a complex network of counterparty exposures.  In this talk I will focus on a particular market, the e-MID interbank lending market. In the first part of the talk I will focus on the analysis on the temporal evolution of the e-MID network of interbank transactions, in an attempt to identify early warning signals of the crisis. In the second part I will explore if  bank's specific network metrics can explain the variation in funding rates across banks, and trading volumes.

**10.45-11.15 : Presentation (13): Antonios Alexandridis,**

University of Patras, Greece **,** Power Systems **,** [**a.t.alexandridis@ece.upatras.gr**](mailto:a.t.alexandridis@ece.upatras.gr)

***“Modeling and control of distributed generation power systems as complex nonlinear Hamiltonian systems”***

**Abstact-**The deployment of modern power systems is mainly based on the high penetration of renewable energy sources (RES) in a decentralized structure known as distributed generation (DG). Distributed generation has dramatically changed the structure of modern power systems. The power electronic interfaces used to connect the different parts of a DG, play an important role that exploits the local capabilities of the system on managing energy in a simple cooperated and self-controlled manner at the common scheme of a microgrid. The microgrid is defined as an integrated energy system consisting of distributed energy sources and multiple electrical loads operating as a single, local grid either in *grid connected-mode* or in *islanded-mode* with respect to the existing utility power system. Hence, in DG, the effective and reliable control and utilization of RES can be designed and analyzed at a microgrid level. In this structure, power electronic devices are extensively used providing the possibility of new control strategies in the distribution network. To implement these strategies, a complete dynamic analysis of the distributed generation system is needed. To this end, exploiting a common feature of almost all the distributed generation components, which is their individual modeling in Hamiltonian form, a systematic methodology of obtaining the complete distributed generation system model is proposed. Furthermore, it is shown that this model is also in Hamiltonian form with certain damping properties that can be effectively used for stable control designs. As a result, based on the Hamiltonian modeling, the entire system is described as a large nonlinear system with external inputs, wherein a particular sequence of stages for the analysis and design are needed.

**11.15-11.30: Coffee Break**

**11.30-12.00: Presentation (14): Nicos Karcanias**

Systems & Control Centre, City University, [N.Karcanias@city.ac.uk](mailto:N.Karcanias@city.ac.uk)

"***Systems Complexity: the paradigm of System of Systems***"

**Abstract:** Amajor new familyof Complex Systems expressing a new form of complexity of complexity are those referred to:

**●** *Systems of Systems (SoS)*

The notion of *“System of Systems”* (*SoS*)has emerged in many fields of applications from air traffic control to constellations of satellites, integrated operations of industrial systems in an extended enterprise. Such systems introduce a new systems paradigm with the main characteristic **the interaction of many independent, autonomous systems, frequently of large dimensions, which are brought together in order to satisfy a global goal and under certain rules of engagement.** They represent a synthesis of systems which themselves have a degree of autonomy, but this composition is subject to a central task and related rules frequently defined as “system play” expressing the subjection of subsystems to a central task. A major challenge in the development of the theory of *SoS* is the formal characterization of the notion of *systems play* that emerges as the counterpart of the *interconnection topology* that is central in the characterization of Composite Systems (*CoS*). We demonstrate that the *system play* is the notion differentiating *SoS* from the standard engineering notion of *CoS*. Issues related to classification of families of *SoS* are considered and this provides the means to characterise *SoS* in terms of different descriptions of the *systems play* notion. Major challenges in the development of *SoS* theory related to *Systems Reengineering* are identified.

**12.00-12.30: Presentation (15): Alexandra Brintrup**

Cranfield University, [a.brintrup@cranfield.ac.uk](mailto:a.brintrup@cranfield.ac.uk)

***" Analysing Complexity and Resilience in Emergent Manufacturing Networks"***

**Abstract:** Manufacturing networks contain designed and emergent elements, the dynamics of which produce complex topologies over time. There are however, few empirical studies that examine arising topology in manufacturing networks. In this talk we will use a measure of order from ecology, called “nestedness”, to analyse the topology of three types of mutualistic networks: distribution of processes in a job-shop, distribution of products and interactions between manufacturers and assemblers in a supplier network. We find that these networks are not randomly assembled but are highly *nested*; that is, specialist nodes interact only with proper subsets of generalists. The pattern has significant implications on system robustness and performance. Nested networks are more robust than non-nested networks as nodes that fail can be substituted - but nestedness also means that specialist node capabilities are redundant. Beyond demonstrating how these characteristics link to topology, we will debate how the field of manufacturing engineering can advance through the application of interdisciplinary approaches from the field of complex networks.

**12.30-13.00: Discussion**

**13.00-14.00: Lunch Break**

**Chairman** (Afternoon Session)**:** George Halikias

**14.00-14.30: Presentation (16): Professor D.W.Stupples**

Systems and Control Centre, City University, [D.W.Stupples@city.ac.uk](mailto:D.W.Stupples@city.ac.uk)

***“Future Surveillance System Technology - for a safer society”***

**Abstract:** Recent world events are requiring responsible countries to rethink radar surveillance system technology. Since its introduction in World War 2, radar systems have migrated through several substantial instantiations driven by developments in micro-electronics, digital signal processing and high-powered computing. Essentially however, our current radar technologies are still relying on moving electromagnet beams. This technology is not addressing threats to cities and airports posed by small slow moving drone air vehicles, and threats to national security posed by stealth military aircraft.  In 2002, Skolnik suggested a ubiquitous radar system - a radar that looks in all directions all of the time; aka a staring radar. Such a radar requires a complete systems rethink to how well established technologies are implemented. A brief overview to the development path of traditional radar systems will be provided and it will be explained why these systems fail to meet drone and stealth threats. We will then provide an introduction to ubiquitous (staring) radar systems with insight on how these threats may be mitigated and controlled. The talk will conclude by identifying the complexity issues linked to the signal processing and extraction of features from large data and explain how this new radar system approach may be used to protect our infrastructure, our borders, and our cities.

**14.30-15.00: Presentation (17): Stathis Kasteridis**

Novocaptis, Greece [kasderidis@novocaptis.com](mailto:kasderidis@novocaptis.com)

**“Smart Systems as Complex Systems: Research and Design Challenges – An overview”**

**Abstract:** The presentation will define the notion of Smart Systems, and the related major sub-categories, as a specialisation of the more traditional IT Systems (which are a form of social-technical systems themselves). To meaningfully compare the increasing levels of complexity in the design process a number of criteria will be presented as possible axes of a description space that characterise the family of the IT Systems. Important sub-categories such as autonomous systems (i.e. systems that self-manage and self-repair in the face of unexpected contingencies), knowledge-based systems (i.e. these that are based on a growing knowledge structure) and self-evolving systems (i.e. the ones that evolve their knowledge structure and decision-making strategies by own self-motivation) will be discussed and related examples of each category will be given (e.g. Internet of Things, Expert/Decision Support Systems, and Cognitive Systems/Robots). The Smart Spaces / Cities paradigm, a large group of Smart Systems with instantiations in all three aforementioned sub-categories, will also be discussed.

Two key questions arise naturally in the context of Smart Systems: How to develop (complex) components with individual complex internal dynamics and how to integrate a population of smart components into an overall system with the envisioned emergent dynamics and properties. While there is guidance for particular problem classes, there is not yet a general methodology that can guide the designer of such systems, in a principled manner, to develop the component and the population level taking into account the context that each level presents to other. Initial thoughts as to how to approach this general problem will be given as a starting point of discussion.

**15.00-15.15 : Coffee, Tea Break**

**15.15-15.45: Presentation (18): Veselin Rakocevic**

Systems & Control Centre, City University, [Veselin.Rakocevic.1@city.ac.uk](mailto:Veselin.Rakocevic.1@city.ac.uk)

***“Connecting Moving Objects: Managing the Complexity of Movement in Modern Communication Networks”***

**Abstract:** This presentation will focus on research on mobility management in various wireless communication networks scenarios. Modern wireless networks consist or numerous moving objects, ranging from traditional devices like smartphones and laptops, to connected cars, moving sensor networks, underwater objects and flying devices. Managing the operation of the networks with all these moving devices is complex. Traditionally, network protocols are designed to depend on a reliable physical connection to carry data. In the networks of moving objects, this reliability cannot be assumed. Solutions are required to ensure this reliability. This presentation will identify the main challenges, give an overview of solutions for clustering in networks of moving objects, analyse the role of movement prediction in wireless networks, and give results on three research projects we have been involved in, looking at this problem in the environment of 4G, vehicular and sensor networks, respectively.

**15.45-16.15: Presentation (19):**  **Ali G. Hessami**

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***“Smart Safety Assessment for Complex Systems-Abstract”***

**Abstract:** The commonly practiced approach to the safety assessment of complex technology lacks a supporting theoretical foundation as a guiding and supporting backbone. In practice, this results in a confused, poorly conceived and often inadequate application of a mixed bag of methodologies, rules and standards that due to the effort intensive nature give a semblance of adequacy and completeness. In this uncharted landscape, demonstration of compliance with a given rule or standard is broadly regarded as adequate input to the safety assessment, potentially missing on other analysis, effort and evidence.

The principal aim of this research is to give an overview of the principal requirements and qualities for robust and credible assessment to be supported by a host of relevant processes, rules, tools, codes of practice and standards. In the light of a theoretical backbone and roadmap, we can make progress in arriving at a credible and required degree of confidence when applying scientific knowledge, methodologies, reviews, tests and evidence. It will guide us in our judgement about how much confidence we have or need to have in the safety of a product, process, undertaking or service and how best to arrive at this?

In this endeavor, we revisit the current practice from two complementary but critical perspectives comprising the process and the dominant culture that pervades the relationship between the stakeholders. The theoretical architecture/framework will be reviewed, enhanced and deployed to carefully examine and critique the current best practice in safety assessment of complex technological systems. This would hopefully identify processes and activities that can be optimized to bring genuine real value to the cause of safety globally whilst reducing wasteful effort, time scale, cost and scarce resources. We also attempt to tackle the dominant adversarial culture in safety that divides the key stakeholder classes namely the producers /manufacturers/ duty holders and the regulators, approval/certification authorities and the commercial support entities. An optimal solution needs to tackle the soft as well as the hard aspects of this deficit. We develop and present the theoretical foundations and a systems framework for a whole new paradigm referred to as Smart Safety Assessment (SSA), largely for application to complex technological systems.

**16.15-16.45: Presentation (20):**  **George P. Papavassilopoulos**

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***“Energy Policy Using Graph and Game Models”***

**Abstract:** In recent years the liberalization of the energy market has introduced the need for new paradigms which can capture essential features of newly emerged problems. In the new energy structure that is still under formation in technological, regulatory -legal terms, there are many producers and users with inhomogeneous traits. Big and small, erratic entrance and exit, stochastic production and demand changes, coexisting with the need for reliable and continuous supply and of course low cost. The interactions of such an agglomeration of diverse decision makers can be modeled by using graph models at the nodes of which players who interact with their neighbors are situated. Ideas from game theory, graph theory, information theory need to be cross fertilized with a keen eye on staying close to the technological capabilities constraints and demands of the underlying engineering/market problem. In the Game theory model employed, we can attribute future predictive capabilities to the decision makers, or we can use evolutionary game theory concepts in which the decision makers use myopic policies. Some of the issues now are to find what structures of graph /agent interaction can serve as models for representing particular activities, what pricing guideline policies the regulator can use to affect in a desired way the overall behavior, the role of the type of local information available to the decision makers etc. In our group at EE & CS at NTUA we are involved in research in several such directions and we will provide a short overview.

**16.45-17.30: Discussion on possible research initiatives**

**17.30-17.45: Conclusions**