



# **OBJECTIVES AND CONTEXT**

# **OBJECTIVES**

The aim of the conference is to gather scientists from many different disciplines (physics, mathematics, computer science, biology, social sciences, arts, etc.) to address fundamental questions about how people express their creativity and innovate both at the individual and collective levels.

# CONTEXT

Innovations are key factors in the evolution of human societies, since they represent the primary motor to explore new solutions in ever-changing and unpredictable environments. New technological artefacts, scientific discoveries, new social and cultural structures, are very often triggered by mutated external conditions. Unfortunately the detailed mechanisms through which humans and societies express their creativity and innovate are largely unknown and no comprehensive mathematical framework has been proposed so far. Creative solutions, novelties and innovation share an important feature: often, innovative events do not happen by chance, rather they seem to be triggered by some previous novelty or innovation. In studies of biological,

technological, and cultural evolution, it has been hypothesized that one innovation can lay the groundwork for another by creating fresh opportunities. In our daily lives, a similar process may account for why one new thing so often leads to another. This idea has been beautifully summarized by the notion of adjacent possible introduced by Stuart Kauffman. In this picture the advance into the adjacent possible is the driving force for correlating innovative events, and novelties are produced through an exploration of a space – physical, conceptual, technological or biological – that enlarges itself whenever one reaches a point of the space never touched before. The Conference will represent the opportunity to assess where we stand by investigating the determinants of innovation processes and their evolution, progressing in their mathematical modelling, understanding their function and identifying the most thriving contexts (institutions, social organizations, business models, etc.) for creativity and innovation.

# **CREDITS**

The Kreyon conference is sponsored by the John Templeton Foundation and organized by Sapienza University in collaboration with ISI Foundation and Complexity Science Hub Vienna.



TIME		WED SEPTEMBER 6TH		THU SEPTEMBER 7TH		FRI SEPTEMBER 8TH	
9.30 9.40 9.50	SESSION 11 CHAIR: VITTORIO LORETO	OPENING	SESSION 5   CHAIR: PIETRO GRAVINO	<b>Ilan Chabay</b>   Understanding opportunities for and consequences of innovation in diverse social contexts	SESSION 9   CHAIR: STEFAN THURNER	François Pachet   Creating music with Al: results and challenges	
10.00 10.10 10.20		Stuart Kaufmann   Beyond physics: the emergence and evolution of life		Andreas Roepstorff   Embodied Collaborative Dynamics		Fiammetta Ghedini   Can comics be used to communicate science?	
10.30 10.40		Andrei Ludu   A geometrical-boundary description of occurrence of novelty		Oana Yuculescu, <b>Carsten Bergenholtz</b> Michela Beretta   The Ikea-effect in collective problem solving <b>Bernardo Monechi</b> , Pietro Gravino, Vito Servedio, Francesca Tria, Vittorio Loreto   Significance and popularity in music production		Haruka Miyazawa   Towards an extension of artificial communication system for self-organized system	
10.50		Heinrich Nax   Learning and decision-making in strategic interactions: an experimental investigation of heuristics		Giulio Tani, Pietro Gravino, Cesare Bianchi, Vittorio Loreto   Unvei- ling innovation dynamics in a web experiment with LEGO bricks		Francesco Rago   IoT vs statistical methodology (the emergence of creativity)	
11.00		COFFE BREAK   POSTER SESSION		COFFE BREAK   POSTER SESSION		COFFE BREAK   POSTER SESSION	
12.00 12.10	SESSION 2   CHAIR: ILAN CHABAY	Luca Peliti   Survival rather than selection: novelty and innovation in evolution	SESSION 6   CHAIR: LUCA PELITI	<b>Stefan Thurner</b>   Towards a statistics of innovation - how statistics appears from noisy search processes - all of statistics - from Gauss to Zipf	SESSION 10   CHAIR: PIETRO GRAVINO	<b>Richard Boyle</b>   Novelty, historical science, time, and the limits of objective language	
12.20 12.30		Nayely Velez-Cruz, Manfred Laubichler   The		Luigi Marengo   Appropriating the outcome of innovation:		William Schueller, Pierre-Yves Oudeyer   Interactive installation for collaborative creation of a language: experimenting how humans actively negotiate new linguistic conventions	
12.40 12.50		phenotype-genotype-phenotype map Pierpaolo Andriani   Exaptation as a critical process for radical		property rights and other incentives <b>Giacomo Vaccario</b> , Mario Vincenzo Tomasello, Claudio Juan Tassona, Frank Schwaitzer L Quantifizier knowledge exchange in		Alessio Emanuele Biondo, Alfio Giarlotta, Alessandro Pluchino, <b>Andrea Rapisarda</b>   Perfect information vs random investigation in the jungle of product differentiation	
13.00		innovation		R&D networks: a data-driven model		Bernardo Monechi, <b>Vito D. P. Servedio</b> , Pietro Gravino, Vittorio Loreto   Intuition and creativity in chess games	
13.10		Miguel Ibáñez Berganza   Facial attractiveness from an information-theoretical perspective		<b>Igor Kanovsky</b>   Professional social network as a media for innovation spreading		Marc Andersen   Expressions of Creativity and Innovation in Ouija Board Sessions	
13.20		LUNCH BREAK   POSTER SESSION		LUNCH BREAK   POSTER SESSION		LUNCH BREAK   POSTER SESSION	
15.00 15.10 15.20	SESSION 3   CHAIR: VITO D.P. SERVEDIO	<b>Giovanni Corazza</b>   The dynamic definition of creativity: potentially adjacent possibles	SESSION 71 CHAIR: FRANCESCA TRIA	Luciano Pietronero   Economic complexity	SESSION 11   CHAIR: LUCIANO PIETRONERO	<b>Massimo Egidi</b>   Mental processes that facilitate or hinder discovery and creativity	
15.30 15.40		<b>Ido Garbi</b>   Method of utilization of depressed mood sessions for creation of positive feedback loop in innovation and creation processes		Andrea Napoletano, Andrea Tacchella, Luciano Pietronero   The language of innovation		Bernat Corominas-Murtra, Rudolf Hanel, Stefan Thurner   Dynamics on evolving sample spaces: sample space reducing and expanding processes	
15.50		Jose Tomaz   Agent-based modeling using a reward system in IT governance		Dario Mazzilli, Andrea Tacchella,Luciano Pietronero   Hidden markovian model for countries' technological development		Giulia Pullano, Bernardo Monechi, Vittorio Loreto   Dynamics of social interactions in a collective creativity experiment	
16.00		COFFE BREAK   POSTER SESSION		COFFE BREAK   POSTER SESSION		COFFE BREAK   POSTER SESSION	
17.00 17.10 17.20	SESSION 4   CHAIR: ANGELO VULPIANI	Francesca Tria   Modeling innovation through the expansion into the adjacent possible	SESSION 8   CHAIR: RAFFAELLA BURIONI	Angelo Vulpiani   The many faces of the predictability	SESSION 12   CHAIR: VITTORIO LORETO	Indaco Biazzo   CityChrone: an interactive platform for urban accessibility and planning support.	
17.30 17.40 17.50		<b>Raffaella Burioni</b>   Old and new ties in social networks evolution: novelty exploration in human interactions		<b>Davide Cassi  </b> Cooking Hackers. The true story of molecular cuisine		CLOSING	

SHORT TALK

INVITED SPEAKER LONG TALK

# **SPECIAL EVENTS**

# **WELCOME COCKTAIL**

Wednesday September the 6th, 6pm Palazzo delle Esposizioni – Sala Forum

# **SOCIAL DINNER**

Thursday September the 7th, 8.30pmRendez-vous directly on site Caffè delle Arti | Via A. Gramsci 73

# **10.00 | INVITED SPEAKER**

# **STUART KAUFFMAN**

#### University of Pennsylvania, USA

Originally a medical doctor, Stuart Kauffman is an emeritus professor of biochemistry at the University of Pennsylvania, one of the founders of the Santa Fe Institute, the legendary center of nonprofit studies where complexity theory has been elaborated. Also a MacArthur Fellow, he holds the Gold Medal of the Accademia Licea in Rome, and is a Fellow of the Royal Society of Canada. He has published five major books, among them are At Home in the Universe: The Search for the Laws of Self-Organization and Complexity (1995) and Humanity in a Creative Universe (2016).

#### **BEYOND PHYSICS. THE EMERGENCE AND EVOLUTION OF LIFE**

Evolution is an historical process in which life literally creates the opportunities into which it then becomes. Evolution is historical because the universe above the level of atoms is vastly non-ergodic. I will discuss the emergence of life based on the new concept of "Constraint Closure" due to Montevil and Mossio. Life is an autocatalytic process in non-equilibrium systems in which boundary condition constraints on the release of energy do work cycles to construct the same set of constraints. Living cells construct themselves and the biosphere. Once proto-cells emerged, their subsequence evolution was unprestatable and entailed by no law whatsoever. The very diversity of species itself creates the ever new niches into which further new species come to exist. Diversity begets more diversity. The biosphere flowers in an open ended process. Some of this is crudely predictable: Higher taxa exist. Retrodictive accounts work. But the specific evolution though Darwinian preadaptations is not even prestatable. Not only do we not know what will happen, we do not even know what can happen. Theory in Evolution must also embrace unprestatable, open-ended becoming.

# **10.30 | LONG TALK**

# ANDREI LUDU

#### Embry-Riddle Aeronautical University, USA

#### A GEOMETRICAL-BOUNDARY DESCRIPTION OF OCCURRENCE OF NOVELTY

The present mathematical models for novelty offer a good enough description of the processes leading to the emergence of innovations. These present models work in spaces created by combinatorics, statistics, and graph theories, and consequently time in these models is considered uniform and discrete. However, a dynamical description of the rate of occurring of novelty, capable of good predictions, should take into account the topological and geometrical properties of such spaces, especially when we consider the adjacent possible spaces. A successful theory on novelty should offer simultaneous and correlated explanations at algebraic, statistic and geometric levels of our mathematical understanding. In this context we developed a new geometrical (hence analytic) model for occurrence of novelty in spaces of variable dimension by using the theory of time variable order of differentiation. Such new tools offer a natural frame for occurrence of memory effects (aging) and triggering events. The first results [1] show an interesting dependence between the occurrence of novelty and the structure of boundaries of various spaces and adjacent possible structures. We apply our model to discuss to what extent the legal and administrative constraints limit or enhance the creativity and production of novelty in the space of patents of invention. [1] A. Ludu "Boundaries of a Complex World" (Springer, Heidelberg 2016)

#### 10.50 | SHORT TALK

#### **HEINRICH NAX**

#### ETHZ, Switzerland

# LEARNING AND DECISION-MAKING IN STRATEGIC INTERACTIONS. AN EXPERIMENTAL INVESTIGATION OF HEURISTICS

Game theory, as the study of the interactive decision-making involving multiple individuals, provides the toolbox to understand the outcomes of human interactions as studied in computational social science. Applications include the

study of cooperation, coalition and network formation, competition, and conflict. In this talk, we will discuss recent advances in the area of dynamics in games. We will focus on experimental and behavioral aspects, and on the longrun outcomes and convergence properties of the resulting dynamics. Our goal is to identify heuristics-based decision rules that can be used to improve the micro-foundations of ABMs.

# **12.00 | INVITED SPEAKER**

#### **LUCA PELITI**

#### Institute for Advanced Study, Princeton, USA

I was for 27 years Professor of Statistical Mechanics at the Dipartimento di Fisica, Università "Federico II", Napoli (Italy). I am an Associate Member of the Sezione di Napoli of the Istituto Nazionale di Fisica Nucleare (INFN). I am currently a member of the Editorial Boards of Journal of Statistical Physics and of the IOP electronic journal JSTAT: Journal of Statistical Mechanics. I was a member of the Editorial Board of Physics of Life Reviews for several years. I also act as one of the moderators of the arXiv q-bio archive (Populations and Evolution). I was a member of the Simons Center for Systems Biology, School of Natural Sciences, Institute for Advanced Study, Princeton, New Jersey, USA from 2014 to 2016. Since July 2017, I am Deputy Director of SMRI (Italy).

#### SURVIVAL RATHER THAN SELECTION. NOVELTY AND INNOVATION IN EVOLUTION

In the classical Darwinian evolution scenario, natural selection acts towards the optimization of the species fitness. However, it is hard to corner what exactly determines fitness for a given species, especially in the context of a complex environment, often shaped by the coexistence of a great number of different life forms. In this situation, rather than in the optimization of a few well-defined traits, success is measured by the identification of a workable compromise in the simultaneous accomplishment of a great number of tasks. These ideas lead to a new field of enquiry in evolutionary theory, linking evolution and ecology, and fully recognizing the high-dimensional nature of adaptation dynamics.

# 12.30 | LONG TALK

# NAYELY VELEZ-CRUZ, MANFRED LAUBICHLER

ASU-SFI Center for Biosocial Complex Systems, USA

#### THE PHENOTYPE-GENOTYPE-PHENOTYPE MAP

Here we introduce a robust mathematical and data analytic framework for a mechanistic explanation of phenotypic evolution that is conceptually rooted in developmental evolution theory. We respond to the lack of evolutionary models that integrate multiple simultaneously-occurring mechanisms of inheritance with developmental mechanisms in order to explain the origins of evolutionary novelty. We explore a re-conceptualization and an associated mathematical formalism of the Phenotype-Genotype-Phenotype (PGP) Map, which is based on Laubichler & Renn's framework for extended evolution. Conceptually, rather than to begin with the genotype, as is the case with the genotype-phenotype map, we instead begin with a phenotype—an agent in Laubichler and Renn's extended regulatory network model. A phenotype can be a single trait, a complex of traits, an organism, or a system at any scale. The phenotype is then "decomposed" into a unit of inheritance (genotype, or "features") which passes the generational divide and is then "reconstructed" via developmental processes. Examples of features include, but are not limited to, gene regulatory network motifs, specific interactions between molecular agents (e.g. transcription factor modules), developmental mechanisms, epigenetic interactions, and of course, an organism's genotype. This abstraction avoids later post-hoc assumptions about the genotype-phenotype map in exchange for a model of phenotypic evolution that places the explanatory power in the processes of inheritance and development. The PGP Map framework is thus capable of uniting the proximate/mechanistic explanation with the evolutionary explanation by providing a mechanistic explanation of phenotypic evolution. To accomplish this, we have developed a mathematical and associated computational framework for the PGP Map based on digital signal processing (DSP) and wavelet analysis, as it ensures that the conceptual framework, mathematics, and computational implementation are as identical in structure and logic as possible. The framework integrates concepts and methods from wavelet theory. machine vision, and graph theory and is thus a flexible tool that facilitates the conceptual interpretation and multi-scale modeling of known phenomena of phenotypic evolution (e.g. multiple mechanisms of inheritance, gene regulatory network dvnamics, among others). The PGP Map is implemented in TensorFlow, a machine learning interface used for data analysis via custom designed computational graphs. This makes the PGP Map amenable to empirical test by allowing for the integration of multiple types of biological data, such as single-cell genomics and epigenomics data, gene expression data, and/or phenotype-environment interaction data, to list a few.

# **13.10 | LONG TALK**

# **PIERPAOLO ANDRIANI**

Kedge Business School, France

#### **EXAPTATION AS A CRITICAL PROCESS FOR RADICAL INNOVATION**

To assess the role of exaptation in technological innovation, we measured the radiation of emergent uses for a sample of FDA-approved drugs based on new molecular entities (1998-2000 sample, for a total of 83 drugs). First, we identified all their FDA-approved uses, and the emergent uses later discovered by clinicians as listed in the 2013 version of the Micromedex Drugdex compendium. Second, we associated each FDA-approved and emergent use to the respective disease(s) as classified in the ICD9-CM (WHO's International Classification of Diseases, version 9-CM). Third, we compared each emergent use with the FDA-approved one to understand whether the emergent use represents a new functionality hence an exaptation. Our results showed that:

- Slightly more than 40% of emergent uses appear to be exaptations.
- About 70% of these involve a first-order bifurcation and thus are significantly removed from the original use.
- The distribution of emergent uses and exaptations across drugs is a long-tailed probably power-law distribution.
- A fraction of uses shows a radical impact, as measured by their capability of treating previously untreated diseases or providing substantial improvement over existing treatments. Almost all radical uses are characterized by a large distance from the original adaptive use and are exaptive.
- All the radical uses for which it was possible to reconstruct the history of the discovery indicate that the discovery was unanticipated and resulted from the serendipitous observation of a new function.
- Also, it seems that these radical uses rely on different molecular pathway and (sometimes) phenomena than the
  approved use.
- As an illustration see the pattern of radiation of thalidomide (figure 1). All uses are exaptive, seven of them are radical and rely on different pathways than the approved use. A few uses revealed unsuspected phenomena.
- Overall, we observe that: a) radical uses are exaptive and functionally distant from the approved uses; b) the
  discovery of radical uses appears to be mostly due to serendipitous events; c) radical uses seem to rely on new
  pathway/phenomenon; d) their discovery (radical uses) may lead to systematic research meant to uncover the
  science behind the discovery suggests that exaptation seems to represent a mechanism for discovery of the
  'adjacent possible' that adds further dimension to the complexity of the existing phase-space of technological
  evolution. We speculate that such discoveries occur when the exposure of current artifacts to very distant
  contexts activates 'affordances' in the artifact that reveal new mechanisms of actions and occasionally unknown
  phenomena.
- Interestingly, some of the exaptations discovered in our databases broke existing paradigms or violated accepted
  practices and dominant thinking about plausibility of research directions. This indicates that exaptations
  constitutes a valid avenue for discovery in the hidden part of the adjacent possible.
- Finally, some of the exaptations in our database indicates that discovery via exaptation is neither demand-driven
  nor based on the understanding of new science (what Brian Arthur calls invention via phenomenon discovery). It
  is instead based on the 'intermediation' of an artifact which reveals an unsuspected new function (provided with
  an economic meaning) at the same time a technique for implementing the new function.



Figure 1: functional diversification of thalidomide. In red radical uses. Small circles stand for exaptations.

# 13.10 | SHORT TALK

# **MIGUEL IBANEZ BERGANZA**

Sapienza University of Rome, Italy

#### FACIAL ATTRACTIVENESS FROM AN INFORMATION-THEORETICAL PERSPECTIVE

In the framework of the facial aesthetics research, we propose an experimental setup based on a genetic algorithm which allows the experimental subject to "sculpt" his/her ideal set of facial proportions of a reference female portrait. The analysis of the results may provide quantitative answers to a variety of debated questions in the field: to what extent are our aesthetic criteria universal? What are the properties of the ideal faces? Are there several aesthetic paradigms? Can one infer the "algorithm" that we unconsciously use to assess the attractiveness, and describe it in terms of few facial variables? We address the answer to questions from a machine-learning and information-theoretical point of view.

# **15.00 | INVITED SPEAKER**

# **GIOVANNI CORAZZA**

#### Alma Mater Studiorum-University of Bologna, Italy

Giovanni Emanuele Corazza is a Full Professor at the Alma Mater Studiorum-University of Bologna, Member of the Alma Mater Board of Directors, founder of the Marconi Institute for Creativity, Member of the Marconi Society Board of Directors, Member of the Partnership Board of the 5G Infrastructure Association. He is the originator of the dynamic definition of creativity. His research interests are in creativity and innovation, 5G systems, navigation and positioning.

#### THE DYNAMIC DEFINITION OF CREATIVITY. POTENTIALLY ADJACENT POSSIBLES

According to a recent dynamic definition, creativity requires potential originality and effectiveness. In this view, the creative process entails a dialogue between the creative agent(s) and the estimator(s) of the represented outcomes. When the creative potential takes actual recognition and realization, we are in the presence of a creative achievement; otherwise, we remain in a state of creative inconclusiveness, where the exploration can (and should) continue. This exploration is twofold: on the one hand the agent can continue to refine the outcomes and/or their representation, or can search for further ideas/solutions; on the other hand, the estimators can continue their assessment of the represented ideas, and let their judgment evolve in the varying context. Due to the intrinsic dynamics involved in this process, no one can determine a priori the time/context-dependent boundaries of the adjacent possible, but one can only estimate the potential for certain possibilities to be adjacent to our current common knowledge domain. Fostering creativity becomes therefore an exercise in providing the conditions for increasing its potent.

# **15.30 | LONG TALK**

#### **IDO GARBI**

**IGPT Innovation**, Israel

# METHOD OF UTILISATION OF DEPRESSED MOOD SESSIONS FOR CREATION OF POSITIVE FEEDBACK LOOP IN INNOVATION AND CREATION PROCESSES

Creators shift between different mental states during the creation process, including depressive mood sessions innate to the field of innovation (CDMS). Long periods of CDMS are destructive to self esteem, industriousness and motivation, and pose risk for clinical depression to the one enduring them. Repetitive cases of CDMS tend to generate a negative feedback loop, leading to more CDMS periods with increasing severity. Analysis of innovation work done after CDMS period indicated that the most valuable day of innovation is actually the following day of the period, a fact that should have created a self-correcting feedback loop instead of the negative feedback loop of CDMS is that created produce done following CDMS period is often scrapped by its maker due to lower self esteem and self confidence following CDMS period. This phenomenon causes both loss of valuable innovation work and perpetuation of the CDMS, perpetuating the negative feedback loop instead of generating a self-correcting loop. Preliminary data show increased productivity following CDMS and the generation of a positive feedback loop between CDMS and following-day productivity instead of the self-perpetuating negative feedback loop of unattended CDMS when

using psychological reinforcement mechanism in the form of supervisor support and conditioning mechanism linking CDMS to excessive creation produce in the day following CDMS among software development teams undergoing CDMS periods. It seems that CDMS can actually yield positive and valuable innovation produce and form innate self-correction loops once the produce they generate is being taken in consideration by an outside examiner and not by the individual affected by CDMS. Much more research has to follow these initial findings, but it appears this method can generate a new way of referring and using CDMS as a valuable chain in the innovation process instead of a hindering factor.

# MAKING CREATORS INTO INNOVATORS - STREAMLINING UTILISATION OF HYPER CREATIVITY INTO INNOVATIVE PRODUCE USING MULTI-DISCIPLINAL PRACTICAL METHOD

In general terms, innovation is the creation of something that has never been done before, and innovators are simply a specific sub-group of creators separated by their constant iteration with the human idea market. While the creators work in a closed environment and are lesser negatively effected by prior work done in their respective field, the value of innovation produce depends heavily on prior work, both as a technological start point and since innovation work has to contain an innovative component over prior work in order to offer its creator value. While the skill set of the creator can be very similar to the skill set of the innovator, innovators need an additional tool set that will enable then to refine their creation process, in order to generate produce that is truly innovative and does not already exist in the human idea pool. In order to provide optimal results, such tool set must be comprised, in that order, of cognitive components, psychological components, knowledge components and data-based tools that are all built to assist the creator in the process of generating creative work that is also innovative. In the cognitive aspect, the innovative thought process starts with understanding, utilizing and overcoming prior work. Creation of an artificial sandbox innovation environment with added complexity iterations under guide of a seasoned innovator can be useful in this aspect. In the psychological aspect, the future innovator needs to be presented with methods of understanding and utilizing the different mental states that accompany the creation process, as each of them poses other potential benefits and deficits to the innovative work process. Creation of a support group of several future innovators in different fields guided by a seasoned innovator elaborating the different processes can be useful in this aspect. In the knowledge aspect, the future innovator need to be presented with the way of iteration with prior work in the specific field in which the innovator operates. Using a mentor innovator from the respective field seems to be yielding satisfying results in this aspect. In the aspect of data-based tools, the future innovator needs to be presented and provided with ways of accessing prior work in the human idea market, such as patents, research work, products and any other manifestation of innovation relevant to the innovator. While a variety of internet-based tools provides extensive access to such prior work, searching such prior work in the vast amounts of information is a proficiencybased process. This proficiency can be best delivered to the future innovators by professional patent searchers, as their main purpose while performing a search is identical to the one of the future innovator. This method is not meant for creating specific innovation, but rather to create innovators that will be better able to utilize human abstract thinking capabilities as a working tool and hyper productivity as a fuel, with the end result of innovation generation.

# 15.50 | SHORT TALK

# JOSE TOMAZ

**ISCTE**, **Portugal** 

#### AGENT-BASED MODELING USING A REWARD SYSTEM IN IT GOVERNANCE

Business alignment and IT governance using a reward system can be a key success factor in organizations, facilitating business process changes, development of new products, outsourcing, cloud migration or mergers and acquisitions. Empirical research has shown a strong link between effective IT governance and organizational performance: organizations may increase their return on IT investments by as much as 40 % with the help of well-organized IT governance (Weill, 2004). This paper presents a study of an agent-based model simulation using a reward system to study IT governance alignment with business strategy. The model provides a characterization of a business organization (e.g. process maturity level, qualified agents, socio-technical context), IT resources and governance practices used to study governance practices, organizational goals, business risks and resource management. The agent based model simulation is implemented using Netlogo to evaluate agents performance according to each case-study and, to detect emergent behavior in response to risk events and constraints in organizations.

# **17.00 | INVITED SPEAKER**

# FRANCESCA TRIA

#### Sapienza University of Rome, Italy

Francesca Tria is a researcher at the Physics Department of Sapienza University of Rome. She has a background in statistical physics and complex systems. Her research activity includes applications to evolutionary dynamics and phylogeny reconstruction, and to social phenomena, such as language evolution, learning and innovation dynamics. She is currently involved in the Kreyon project, studying the dynamics of creativity and innovation.

#### MODELING INNOVATION THROUGH THE EXPANSION INTO THE ADJACENT POSSIBLE

Novelty is part of our everyday experience more than we usually think. We constantly adopt new technologies, conceive new ideas, meet new people, experiment with new situations. Large databases witnessing human activities allowed the observation that novelties – such as the individual process of using a word for the first time – and innovations – such as the creation of a new page in wikipedia – share striking statistical regularities. I will present a new framework based on Polya's urn to effectively model the emergence of the new. What seems to be key in the successful modeling schemes proposed so far is the idea of looking at evolution as a path in a complex space, whose structure and topology get continuously reshaped and expanded by the occurrence of the new. This will be identified as a process of expansion into the adjacent possible, a concept originally introduced by Stuart Kauffmann in the framework of biological evolution.

# **17.30 | INVITED SPEAKER**

#### RAFFAELLA BURIONI Università di Parma, Italy

Raffaella Burioni is Associate Professor of Theoretical Physics of Matter at the Department of Mathematics, Physics and Computer Science at the University of Parma. Her research is focused on Statistical Physics, Complex Systems and Networks Theory. She is particularly interested in interdisciplinary applications of Statistical Physics to Social Sciences and Biology.

# OLD AND NEW TIES IN SOCIAL NETWORKS EVOLUTION- NOVELTY EXPLORATION IN HUMAN INTERACTIONS

Individuals invest heterogeneously in the maintenance and development of their social interactions. According to diverse strategies, they show different propensity to be active, and they may allocate their social links in different ways, either by favouring the strengthening of a limited number of strong old ties or by the exploration of new weak ties, opening access to new information, new people and communities. We propose and solve a dynamic network model with a rule of links formation that explicitly takes into account heterogeneity in social activity and the exploration of new ties. In particular, we propose a general functional form for the social allocation mechanism, able to fit empirical observations on several dataset. Starting from a generalized version of the Polya's urn, we develop a dynamical model of network evolution and formulate a mechanism, based on the "adjacent-possible" theory, able to catch the many features observed in real growth of the individual's set of social contacts. We then show how our approach can be tuned to reproduce different paradigmatic real-world networks and to describe novelty exploration in different kind of human interactions.

# 9.30 | INVITED SPEAKER

# **ILAN CHABAY**

#### Institute for Advanced Sustainability Studies, Potsdam, Germany

Ilan Chabay is a physicist, currently Senior Fellow at the Institute for Advanced Sustainability Studies in Potsdam, Germany, where he co-directs the project SMART (Sustainable Modes of Arctic Resource-driven Transformations and global interdependencies) and collaborates with the Emerging technologies and social transformations program. He founded and directed in Silicon Valley "The New Curiosity Shop", a company which has invented and produced interactive science exhibitions for more than 200 science centers worldwide.

#### **UNDERSTANDING OPPORTUNITIES FOR AND CONSEQUENCES OF INNOVATION IN DIVERSE SOCIAL CONTEXTS**

How can we better understand creativity, which we need to address the continual rapidly changing global challenges in diverse local contexts, and the processes of innovation? Innovation led us into some of the most vexing global issues. How can creativity enable innovation that leads us on pathways to more sustainable futures for all? Marketdriven technological innovation has had and continues to have tremendous impacts on economic development, as it enables new patterns of work and play across the world. However, innovation has had profound negative consequences in some instances (e.g., air pollution and climate change) and has not been equitable in its distribution of benefits (e.g., access to affordable energy with attendant opportunities for education, jobs, and poverty alleviation). I will discuss these questions with reference to studies of equity, gender, and culture in energy access and from the opportunity for insights from empirical studies in KREYON of creativity in social contexts.

# **10.00 | INVITED SPEAKER**

# **ANDREAS ROEPSTORFF**

#### Department of Culture and Society & Department of Clinical Medicine, Aarhus University, Denmark Interacting Minds Centre (IMC)

Andreas Roepstorff is Professor in Cognition, Communication and Culture in the Department of Culture and Society & Department of Clinical Medicine, Aarhus University. He has formal training in social anthropology and in neurobiology, and he has published widely both within these disciplines as well as in various collaborations across other fields, such as psychology, linguistics, clinical medicine, semiotics, and philosophy. He is the director of the Interacting Minds Centre at Aarhus University and is involved in a number of transdisciplinary collaborations, focusing on aspects of human interaction. He has a long-standing research interest in cognitive aspects of contemplative practices.

#### **EMBODIED COLLABORATIVE DYNAMICS**

Often, we face situations where we must come up with novel solutions together. We have explored simple experiments where people build things together. It seems to require us to coordinate and to diversify, and it appears to affect hearts and minds, brains and bodies. Such collaborations unfold in ways that are sensitive to the rules of the game. These conditions appear to leave a mark on our experience both with the situation and with the outcome of the collaboration.

# 10.30 | SHORT TALK

# OANA VUCULESCU, CARSTEN BERGENHOLTZ, MICHELA BERETTA

Aarhus University, Denmark

#### THE IKEA-EFFECT IN COLLECTIVE PROBLEM SOLVING

Individuals in a collective can engage in both individual and social learning to improve their current problem solving performance (Boudreau and Lakhani 2015; Derex et al. 2015; Morgan et al. 2012; Muthukrishna et al. 2016). While it is often argued that social learning is beneficial (see e.g. Rendell et al. 2010), recent prominent papers have showcased stark disagreement on what types of social networks will benefit performance the most. For instance, some studies find that inefficient networks can outperform efficient ones in collective problem solving (Lazer and Friedman 2007, Derex and Boyd 2016), while others show the opposite result (Mason and Watts 2012). This opens up the question of how these contradictory results can be explained. We will address this challenge in the present paper based on an agent-based simulation that embodies a bias that prioritizes individual learning over social learning; what one could call the 'Ikea effect' of how individuals participate in collective problem solving behavior.

# 10.40 | SHORT TALK

#### > BERNARDO MONECHI

**ISI Foundation, Turin, Italy** 

#### **PIETRO GRAVINO**

Sapienza University of Rome, Italy

#### **VITO D. P. SERVEDIO**

Complexity Science Hub, Vienna, Austria

#### **VITTORIO LORETO**

Sapienza University of Rome, Italy, ISI Foundation, Turin, Italy, Complexity Science Hub, Vienna, Austria

# SIGNIFICANCE AND POPULARITY IN MUSIC PRODUCTION

In the world of artistic production there is a constant struggle to achieve fame and popularity. This fierce competition between artistic creations results in the emergence of highly popular elements that are usually well remembered throughout the years, while many other works that did not achieve that status are long-forgotten. However, there is another level of importance that must be considered in order to have a more complete picture of the system. In fact many works that have influenced the production itself, both due to their aesthetic and cultural value, might have not been or might not be popular anymore. Due to their relevance for the whole artistic production, it is important to identify them and save their memory for obvious cultural reasons. In this paper we focus on the duality between popularity and significance in the context of popular music, trying to understand the features of music albums belonging to one or both of these classes. By means of user-generated data gathered on Last.fm [1], an on-line catalog of music albums, we define a growing conceptual space in the form of a network of tags representing the evolution of music production during the years. This network represents the growing conceptual space of the global music production, inspired by recent works on the dynamics of expanding spaces in innovation dynamics models and the "Adjacent Possible Expansion" theorized by Stuart Kaufmann. Starting from 1950, the growth of the network occurs whenever an album is released each year until 2015, so that new tags or links are added to it or preexisting links are reinforced. We use this network in order to define a set of general metrics, characterizing the features of the albums, their relations and their impact on the global music production. We then use these metrics to implement an automated prediction method of both the commercial success of a creation and its belonging to expert-made lists of particularly significant and important works. We show that our metrics are not only useful to asses such predictions. but can also highlight important differences between culturally relevant and simply popular products. Finally, our method can be easily extended to other areas of artworks creation.

### **10.50 | SHORT TALK**

#### > GIULIO TANI

Sapienza University of Rome, Italy

#### **PIETRO GRAVINO**

Sapienza University of Rome, Italy

#### **CESARE BIANCHI**

Sapienza University of Rome, Italy

#### **VITTORIO LORETO**

Sapienza University of Rome, Italy, ISI Foundation, Turin, Italy, Complexity Science Hub, Vienna, Austria

#### UNVEILING INNOVATION DYNAMICS IN A WEB EXPERIMENT WITH LEGO BRICKS

The emergence of novelties and of new trends in many different contexts ranging from arts to technology is currently a matter of interest for many studies [1-6]. The availability of large crowd-sourced datasets from the web has allowed to study these dynamics in ways not possible with usual volunteer based experiments [1,2,7]. On the other hand this kind of datasets offer little control to the researcher on which and how data are gathered. To get control over the data while keeping the advantages offered by the web, we designed and realized an experiment in the form of a web game hosted on our platform specifically built for these purposes. The game was designed to involve the

players via a system of levels and rewards and allow us to collect data on how they innovate, imitate and create 2-D drawings with LEGO® bricks. To gain levels players had to represent selected concepts with LEGO® bricks with the possibility of taking other players' compositions as starting point. This experiment allowed us to gather data keeping all (or at least most part) of the influence within the experiment itself and keeping trace of most part of the interaction between players: who inspired who and, through likes and shares, how they valued compositions by other authors. We registered every action performed by the players with high temporal resolution together with every mistake or change of mind: this is a kind of information usually not available on large web datasets and yet useful to determine the dynamics. Analyzing words occurrences over the 4k+ compositions and 30k+ guesses we get results (see Figure 1) in line with those known from the literature (see [8]) that suggests us that the dataset is self consistent. We then introduce a distance between compositions in a consistent way analyzing not only shapes and colours of the compositions but also number and kind of the bricks used and proportions. This distance function was at the base of our analysis: we show the relation between creativity and influence over subsequent compositions (how they have been valued by other players), the dynamics of the emergence of novelties and how they clusterize in time (see [7]). Thanks to the same distance we built an influence network (see Figure 2, see [1]) from which we were able to derive the network characteristics such as degree distributions and clustering coefficients. The results reached so far give us the hope that even more detail of what makes a trend setter may be unveiled with further investigation.

[1] Gravino, Pietro, Bernardo Monechi, Vito D. P. Servedio, Francesca Tria and Vittorio Loreto. "Crossing the horizon: exploring the adjacent possible in a cultural system." ICCC (2016).

[2] Monechi B, Ruiz-Serrano Ã, Tria F, Loreto V (2017) Waves of novelties in the expansion into the adjacent possible. PLoS ONE 12(6): e0179303. https://doi.org/10.1371/journal.pone.0179303

[3] Arthur WB. The nature of technology: What it is and how it evolves. Simon and Schuster; 2009.

[4] Diamond J., Guns, Germs and Steel: A short history of everybody for the last 13,000 years. W. W. Norton; 1997

[5] O'Neale DRJ, Hendy SC (2012) Power Law Distributions of Patents as Indicators of Innovation. PLoS ONE 7(12): e49501. https://doi.org/10.1371/journal.pone.0049501

[6] Arbesman S, Kleinberg J, Strogatz S (2009) Superlinear scaling for innovation in cities. Phys Rev E 79: 016115.
 [7] Tria F, Loreto V, Servedio VDP, Strogatz SH. The dynamics of correlated novelties. Scientific Reports. 2014; 4:5890. https://doi.org/10.1038/srep05890 PMID: 25080941

[8] Cattuto, C., Loreto, V. & Pietronero, L. (2007). Semiotic dynamics and collaborative tagging. Proceedings of the National Academy of Sciences, 104(5): 1461–1464.

# **12.00 | INVITED SPEAKER**

# **STEFAN THURNER**

#### Medical University of Vienna, Austria Head of the Section for Science of Complex Systems

Stefan Thurner is a theoretical physicist and economist. His main scientific area is complex systems, the regulation of financial markets to the analysis of big data in the medical and social. He is professor of science of complex systems at the University of Vienna medicine, external professor at the Santa Fe Institute, and senior research scientist at IIASA.

# TOWARDS A STATISTICS OF INNOVATION – HOW STATISTICS APPEARS FROM NOISY SEARCH PROCESSES – ALL OF STATISTICS – FROM GAUSS TO ZIPF

Innovation has a lot to do with the exploration of possibilities. In particular it can be seen as search processes on networks. Here we show that the theory of sample space reducing (SSR) processes, which allows to understand the origin and ubiquity of power-laws in countless path-dependent complex systems, is related to search processes on networks. SSR processes exhibit generic power-laws — Zipf's law in particular. We show that SSR processes exhibit a much wider range of statistical diversity. Assuming that noise in the search processes is not uniformly strong across its life-span, but depends on the trajectory, we demonstrate that practically any distribution function can be naturally derived from SSR processes: No noise gives Zipf's law, constant noise leads to exact power-laws, linear noise functions gives exponential or Gamma distributions, a quadratic noise function yields the normal distribution. Also the Weibull, Gompertz and Tsallis-Pareto distributions arise as a natural consequence from relatively simple noise functions. We shortly discuss further areas of application of SRR processes that range from fragmentation processes, language formation and cascading processes.

# **12.30 | LONG TALK**

# LUIGI MARENGO

LUISS University, Italy

#### APPROPRIATING THE OUTCOME OF INNOVATION- PROPERTY RIGHTS AND OTHER INCENTIVES

Economists assume that the generation of useful ideas, especially if it requires the costly investment of resources, requires economic incentives. Homo oeconomicus does not do anything for free. Our societies have developed and made it stronger and stronger (and more and more diffused) a system of intellectual property rights to serve this purpose. If one creates a useful innovation he or she has the right to a monopoly of all the stream of gains generated by the economic exploitation of this idea for a given amount of time (usually 20 years). Monopoly rents are designed to provide incentives to innovation. Indeed they generate a social cost (higher prices and lower quantities typical of monopolies) but on the other hand without them it is believed that society would incur the higher social cost of not having innovations at all. The claim is that it is better to pay a new useful drug a higher price rather than not having this drug at all.

In this paper I question this assumption on two related grounds. First we show that the exclusion right, which is one of the fundamental rights implied by property, has no economic justification when knowledge, rather than physical and depletable resources are the object of property. Second, by means of a computational model, I show that when "complex" knowledge domains are at stake the use of intellectual property rights may actually stifle rather than foster innovation.

In this paper we propose an evolutionary simulation model, or rather a general framework for a breed of possible simulation models, of industry dynamics centred upon the interplay between market competition and product innovation as search in a complex space. The model is meant to be a first step towards a broader understanding of how competition shapes technological innovation, and how innovative patterns affect the competitive environment. The model structure is made of two overlapping modules: market competition and technological innovation. The competitive environment is represented by a demand formed by a population of consumers with heterogeneous tastes for product characteristics whose purchasing decisions are represented by a standard utility function comprising products' quality, prices and individual tastes. The novelty of the model in respect of economic competition lies in the representation of suppliers as endowed with two complementary strategies: innovation/imitation and pricing. The former strategy allows firms to improve the appeal of their products to consumers, while the latter varies prices depending on the relative competitive condition. In particular, contrary to most of the evolutionary models based on mark-up pricing, in our model prices are endogenously determined by each firm in order to exploit technological leadership, or to compensate for technological inferiority, in order to maximize the expected profits. The link from competitive conditions to technological innovation are the (realized) profits that determine the amount of resources available for innovation. The reverse link, from innovations to products' quality affecting consumers' decisions, depends on the complexity of the technological space, that is central in our model. Products are made of many interdependent components and possess many interdependent characteristics. Firms can innovate by introducing better performing components and/or by introducing new combinations of components. Components can be improved by means of innovation (search for a new product) and imitation (copy the products of more profitable firms). Both innovation and imitation, operated at the level of components, are difficult and uncertain, in the sense that interdependencies among components generate complex trade-offs and there is no guarantee that better components will necessarily increase the overall performance of the product.

# **12.50 | LONG TALK**

# > GIACOMO VACCARIO, MARIO VINCENZO TOMASELLO, CLAUDIO JUAN TESSONE, FRANK SCHWEITZER ETH Zurich, Switzerland

#### QUANTIFYING KNOWLEDGE EXCHANGE IN R&D NETWORKS. A DATA-DRIVEN MODEL

How do firms collaborate to create innovation? To answer this question, we propose a model that reflects two important processes in R&D activities of firms: the formation of R&D alliances and the exchange of knowledge. In a data-driven approach, we analyse two large-scale data sets extracting unique information about 7500 R&D alliances and 5200 patent portfolios of firms.

This data is used to calibrate the model parameters for network formation and knowledge exchange. We obtain probabilities for incumbent and newcomer firms to link to other incumbents or newcomers which are able to reproduce the topology of the empirical R&D network. The position of firms in a knowledge space is obtained from their patents using two different patent classification schemes.

Our dynamics of knowledge exchange assumes that collaborating firms approach each other in knowledge space at a rate for an alliance duration .

Both parameters are obtained in two different ways, by comparing knowledge distances from simulations and empirics, and by analysing the collaboration efficiency .

This is a new measure, that takes also in account the effort of firms to maintain concurrent alliances, and is evaluated via extensive computer simulations.

We find that R&D alliances have a duration of around two years and that the subsequent knowledge exchange occurs at a very low rate.

Hence, a firm's position in the knowledge space is rather a determinant than a consequence of its R&D alliances. From our data-driven approach we also find model configurations that can be both realistic and optimised with respect to the collaboration efficiency .

To foster innovation, our model suggests that policies should incentivise shorter R&D alliances and higher knowledge exchange rates.

#### 13.10 | SHORT TALK

#### **IGOR KANOVSKY**

#### Max Stern Academic College of Emek Yezreel, Israel

#### PROFESSIONAL SOCIAL NETWORK AS A MEDIA FOR INNOVATION SPREADING

We proposed a new model, which capture the main difference between information and innovation spreading in professional social networks. In the case of information spreading additional exposure to certain information has a small effect. Contrary, when a specialist is exposed to 2 professionals accepted an innovation, the probability to adopt the innovation is significantly higher than in the case of contact with one such professional (called by J. Kleinberg "the 0-1-2 effect"). In our model in each time step for a person which does not accepted innovation, we randomly choose 2 his/her network neighbours. If one of them is an innovator, the person adopts innovation with some low probability, if two – with a higher probability.

Innovation spreading was simulated on different real world social networks and similar random scale-free networks. The results show that small world structure (existing links between neighbours) has a crucial impact on tipping point time. The "0-1-2" effect causes a significant difference between person's ability to start innovation spreading. Person is an influencer according to his topological position in the network.

Known person's characteristics in a network cannot indicate if he or she is a potential influencer. It's clear that an influencer must not have a small number of neighbours (a low degree) and must have a big number of connected neighbours (a high clustering coefficient value). To become an influencer, a special position of a person in the network is needed and this position is not a local property of the person.

#### 15.00 | INVITED SPEAKER

#### **LUCIANO PIETRONERO**

#### Sapienza University of Rome, Italy

Luciano Pietronero is an Italian physicist (statistical physics) and full professor at the department of Physics at University of Rome "Sapienza". He is also Director of the Institute of Complex Systems of CNR and consultant for the World Bank. In 2008 he received the Fermi Award from the Society 'Italian Physics. He recently developed the method of "Economic Complexity" where economy is seen as an ecosystem in a highly changing environment where evolutionary concepts apply.

#### **ECONOMIC COMPLEXITY**

Economic Complexity (EC) is a new field of research that consists in a radically new methodology. It describes economics as evolutionary process of ecosystems made of industrial and financial technologies that are all globally interconnected. The approach is multidisciplinary addressing emerging phenomena in economics from different points of view: analysis of complex systems, scientific methods for systems and the recent developments in Big Data. This approach offers new opportunities to constructively describe technological ecosystems, analyse their structures, understand their internal dynamics, as well as to introduce new metrics. This approach provides a new paradigm for a fundamental economic science based on data and not on ideologies or interpretations, which is

becoming a necessary choice in a highly interconnected and globalized world, especially after the great financial and economic crisis of recent years. Economic Complexity, in addition to a new vision for a data-based scientific approach for fundamental economics, offers a new set of metrics able to quantify the competitiveness of countries. of technological sectors, measuring future development prospects for nations as well as for large companies. Those metrics have already shown to have a major impact for policy makers and for industry applications economics and finance. Over the last year, the World Bank (WB) has extensively tested and adopted this new methodology for its strategic analysis. A crucial element of our methodology is a radically new approach to the problem of Big Data. Big Data is often associated with "big noise" as well as a subjective ambiguity related to how to structure the data and how to assign them a value that should reflect many arbitrary parameters. In the case of the evaluation of the industrial competitiveness of a country, the required parameters for such an analysis could more than one hundred. A key point approach EC is to go from 100 parameters to zero parameters and obtain results which can be tested in a scientific perspective. This is done by focusing on the data in which the signal to noise ratio is optimal and developing iterative algorithms in the spirit, but other than Google, and optimized to the economic problem in question. In particular the study of a country or a company is not done at the individual level but through the global network in which it is inserted. In this way you get the Fitness of the countries and the Complexity of the products. The dynamics in the new GDP-Fitness space opens up to a completely new way for monitoring and forecasting. Then, the taxonomy of products and their evolutionary dynamics is built through machine learning methods. Finally, the same thing is applied to patents and technologies, two elements that open up the possibility of analyzing the core elements of the innovation process.

# 15.30 | LONG TALK

# > ANDREA NAPOLETANO

Sapienza, University of Rome, Italy

# **ANDREA TACCHELLA**

Consiglio Nazionale delle Ricerche, Italy

### **LUCIANO PIETRONERO**

Sapienza, University of Rome, Italy

#### THE LANGUAGE OF INNOVATION

Predicting innovation is a peculiar problem in data science. Following its definition, an innovation is always a neverseen-before event, making the usual approach of learning patterns from the past a useless exercise. Here we propose a strategy to address the problem in the context of innovative patents. We think of technological codes present in patents as a vocabulary and the whole technological corpus as written in a specific, evolving language. We define radical innovations as the first occurrence in the same patent of couples of technological codes never associated before. We leverage such structure with techniques borrowed from Natural Language Processing by embedding technologies in a high dimensional euclidean space where relative positions are representative of learned semantics. We define and measure codes' similarity through the scalar product of their vector representations and argue that it is informative on how likely a potential innovation is to be patented in the close future, showing that the dynamic on this space forecasts specific innovation events. Radical innovations are anticipated by the approach of their vector representations in the euclidean space, quantifiable through the growth of their similarity during the years preceding the innovation. When the similarity of a potential innovation increases more than one standard deviation above the mean value calculated on all possible couples, thus leaving the shaded gray area depicted in the example figure below, that couple will quite likely be patented shortly after. We discuss how to exploit this fact to make systematic predictions and give an estimate of the quality of aforesaid predictions. We believe these methods provide a completely new way of understanding and forecasting innovation, by tackling it from a revealing perspective and opening interesting scenarios for a number of applications and further analytical approaches.

# 16.00 | SHORT TALK

#### > DARIO MAZZILLI

Max Stern Academic College of Emek Yezreel, Israel

#### ANDREA TACCHELLA

Consiglio Nazionale delle Ricerche, Italy

#### **LUCIANO PIETRONERO**

Sapienza University of Rome, Italy

#### HIDDEN MARKOVIAN MODEL FOR COUNTRIES' TECHNOLOGICAL DEVELOPMENT

Several new approaches to economics use export as a proxy of the internal countries' production. One of the main goals of these studies is to evaluate the technological level required to make a product and the one actually possessed by each country. This level can be estimated with algorithms based on the world trade network of the world. The main problem in this approaches is the high level of noise in the data and the strong instability of the export time series. For example can be found a country always exporting a product seems to stop its production for a certain time period or poor countries, that have never exported a very technological product, show very large export in just one year. Obviously the capabilities that a country possesses cannot be so mutable during the time, so such rapid export's fluctuations can't reflect some technological or competitive instabilities of a country. To solve this problem we make two simple assumptions. First we assume that each country is in a production state for each commodity. We assume 4 states that represents the competitiveness of the country in a given product, from 1, the less competitive, to state 4, the most competitive. These states are hidden and non-observable and have to be stable during the time in order to represent the capabilities possessed by a country. The second assumption is that each state has a given probability to realize an export value. We divide the export's data in quartile and then we build probability distributions to emit each quartilee for each state. The most competitive state (4) should realize almost only the last quartile of export and the lowest state should emits mostly the first quartile. So we are assuming that there are different states for countries that can realize the same export value but with different probability for each state. This is mathematically described by a Hidden Markov Model (HHM), where a Markov chain describes the hidden states' dynamic, with a transition matrix, and each state has a fixed probability distribution to realize any quartile of export. In our model we found that the states of each country, in the production of each commodity, are actually much more stable than the export's quartile data, having high probability to remain in the same state and gradual transition towards more (or less) competitive ones. The stability of the hidden production states is necessary to a description of countries' capabilities and make us confident that this is a good model for the production system. This description leads to a very low level of noise in the data but also can give reliable probability distributions for the production's states' dynamic that can be used to infer which country is about to produce a commodity in the near future. Given the time series of export for each country we can distinguish between those who are in the first state, that are less likely to jump to higher states, and those who are in the second or third state, that have non-zero probability to jump in state 4, even when the export values of the last years for these countries are quite similar.

# **17.00 | INVITED SPEAKER**

# ANGELO VULPIANI

#### Sapienza University of Rome, Italy

Angelo Vulpiani was born in Borgorose (Rieti) 08/08/1954, graduated from Rome University in 1977, the supervisor being Gianni Jona-Lasinio. He has been CNR Fellow (1978-1981), Assistant Professor at Rome University (1981-1988), Associate Professor at University of L'Aquila (1988-1991) and then at the University of Rome (1991-2000).

At the present he is Full Professor of Theoretical Physics at the Physics Department of the University of Rome "Sapienza", and is a Fellow of the Institute of Physics.

He was a visiting fellow in several research institutes and universities in France, Belgium, Sweden, Denmark, and United States.

His scientific interests include chaos and complexity in dynamical systems, statistical mechanics of non- equilibrium and disordered systems, developed turbulence, phenomena of transport and diffusion and foundations of physics.

He has written about 250 scientific papers on international journals and nine books, including: T. Bohr, M.H. Jensen, G. Paladin and A. Vulpiani Dynamical Systems. Approach to Turbulence (Cambridge University Press, 1998); P. Castiglione, M. Falcioni, A. Lesne and A.Vulpiani Chaos and Coarse Graining in Statistical Physis (Cambridge University Press, 2008); S. Chibbaro, L. Rondoni and A. Vulpiani Reductionism, Emergence and Levels of Reality (Springer-Verlag, 2014).

#### THE MANY FACES OF THE PREDICTABILITY

The claim that chaos is a severe limitation for the the possibility to make a prediction is part of the scientific folklore. The growth of infinitesimal perturbations is well characterized by the Lyapunov exponents. In many situations of interest, however, important phenomena involve finite amplitude perturbations, which are ruled by nonlinear dynamics out of tangent space, and thus cannot be captured by the standard Lyapunov exponents. In this talk I'll review the application of the finite size Lyapunov exponent (FSLE) for the characterization of non- infinitesimal perturbations in a variety of systems. In particular, I'll illustrate their usage in the context of predictability of systems with multiple spatio- temporal scales of geophysical relevance, in the characterization of nonlinear instabilities, and in some aspects of transport in fluid flows.

# 17.30 | INVITED SPEAKER

# DAVIDE CASSI

#### Università di Parma, Italy

Davide Cassi is Professor of Physics at Matter at the University of Parma, where he has founded and actually directs the Laboratorio di Fisica Gastronomica and its spin-off Future Cooking Lab. He has been also the first president of the first Degree Course in Gastronomic Science in an Italian University.

For more than 25 years, he has been studying cuisine and gastronomy from a scientific point of view, collaborating with the world's best chefs and confectioners, developing new products and new techniques of science based on scientific research.

In 2002, together with chef Bocchia, he introduced the idea of molecular cooking, as defined in the book II gelato estemporaneo ed altre invenzioni gastronomiche (2005), the first manual on this theme in the world (the book has been translated in Spanish with the title "La ciencia en los Fogones"). The Manifesto of Italian Molecular Cookies is presented in that text.

He has participated in numerous public events and radio and television broadcasts, collaborates with Italian and foreign magazines and is responsible for of the II Gastronomo Scientifico (gastronomoscientifico.blogspot.it) blog.

For his research on science and gastronomy he was awarded the Caterina de 'Medici International Prize, the Tarlati Prize and the Grand Prix de la Science de l'Alimentation de l'Académie Internationale de la Gastronomie.

#### COOKING HACKERS. THE TRUE STORY OF MOLECULAR CUISINE

During the last twenty years cooking art has evolved significantly thanks to the contribution of scientific research. Here, we retrace the milestones of this collaboration and look at the most important innovations that have been introduced.

Ref.: D.Cassi, Science and cooking: the era of molecular cuisine, EMBO Reports 12(3):191-6 (2011)

# 9.30 | INVITED SPEAKER

#### FRANÇOIS PACHET Spotify

François Pachet is director of Sony Computer Science Laboratory in Paris. He also leads the music research team, which conducts research on interactive music listening, composition and performance. His current goal is to create a new generation of authoring tools able to boost individual creativity. These tools, called Flow Machines, abstract "style" from concrete corpora (text, music, etc.), and turn it into a malleable substance that acts as a texture. He has a music diploma (guitar and composition), and has released two albums (jazz and pop) as a composer and musician.

#### **CREATING MUSIC WITH AI- RESULTS AND CHALLENGES**

Spectacular results were obtained recently concerning the modeling and generation of music in various styles. These results combine machine-learning algorithms (deep learning, Markov processes, combinatorial optimisation) both at the symbolic level (scores) and audio level (waveforms). The quality of these models is such that we can now envisage creation tools that redefine the very concept of creative act. I will illustrate these results on concrete examples, and will emphasize the conceptual and technical challenges at stake.

# **10.00 | INVITED SPEAKER**

#### FIAMMETTA GHEDINI SONY-CSL, Paris, France

Born in Bologna, Italy, Fiammetta completed a PhD thesis on perceptual illusions (SSSUP, Pisa and UCL, London), then moved to Paris, where she began working in science communication. Becoming a comic artist has always been her secret plan so she thought of putting it all together: science + art = ERCcOMICS!

#### CAN COMICS BE USED TO COMMUNICATE SCIENCE?

Comics can be used in many ways to communicate science and to fill up the "science gap" which separates the general public from the academic world. In this talk Fiammetta Ghedini presents the ERCcOMICS experiment: a 4-year project that uses cartoons to communicate top level research funded by the European Research council. Fiammetta will describe some examples of how cartoons can be used to give a clearer description of complex scientific issues than a conventional scientific article can, as well as "put into practice" the conclusion of abstract research by imagining its consequences in the real world through the power of storytelling, as well as being a gate into more in-depth content.

# **10.30 | LONG TALK**

# HARUKA MIYAZAWA

Osaka University, ATINER, Japan

#### TOWARDS AN EXTENSION OF ARTIFICIAL COMMUNICATION SYSTEM FOR SELF-ORGANISED SYSTEM

Despite its obvious relationship, it is rather difficult to completely apply the whole picture of information theory to the essential process in biology (i.e. transcription, translation, replication etc) due to the lack of some correspondences. According to the original paper by C. Shannon (1948), general communication system is composed of the following 5 parts; 1. an information source, 2. a transmitter, 3. the channel, 4. the receiver and 5. the destination. As pointed out by S. Ito & T. Sagawa (2015), there is no explicit channel coding within a cell if one focuses on the robustness of signal transduction against noisy environment. Likewise, if one regards genome (DNA) as an information source, then there is no counterpart to channel coding or decoding, and even more if cellular state (a set of protein expressed at given time within a cell) is regarded as information source, it's hard to find such correspondent as information coding in central dogma. One of the plausible reasons why this discrepancy can be observed is that the original theory was developed for the engineering purpose, while biological system is self-organized. Here, I clarify the difference between artificial communication system and self-organized or biological communication system and the limit of applicability of standard information theory to self-organized system. I also try to construct extended information theory, which can be applied to the system discussed. Due to its properties (non trivial interaction, non ergodicity,

non additivity), recent advances on generalized entropy should be incorporated into the theory. This research will stimulate the studies on self-organized communication system, not only biological phenomenon but also natural language.

# 10.50 | SHORT TALK

# FRANCESCO RAGO

Megatris Comp. IIc, USA

#### IOT VS STATISTICAL METHODOLOGY (THE EMERGENCE OF CREATIVITY)

This presentation explores statistical properties of some machine learning approach integrated to IoT data. All topics covered have the common feature that the properties of the similarity or dissimilarity function on the data play an important role in learning to generate some sort of creativity also.

As a software designer, we are constantly searching new ways to produce software. Computers actually don't help a lot. They have a very simple conceptual basis whose potentiality was not completely exploited. Computers are simple (Von Neuman architecture). We need complex systems where emergent behavior cannot be simply inferred from behavior of the components.

May creativity derives from emergence?

Juxtaposition causes to reconsider the meaning of granules of information through contrasting images/ ideas/motifs. The cognitive mechanisms of creativity — namely juxtaposition of dissimilar and de conceptualization — are difficult for us people because we are constrained by the associations of our concept networks that we inherit and learn in our lifetime. So it requires a significant amount of cognitive effort to break away from these associations.

Computers do not have native conceptual associations. Conceptual associations can be described by Semantic networks, Frames, Scripts etc. They are formalisms developed to capture associativity. It follows that it could be easier for the computers to break away from existing conceptual associations than it is for the people.

Requirements for Computational Modelling of Creativity.

We require that there be multiple cognitive/perceptual layers with gradually increasing degrees of abstractions.

We require that there be top-down and bottom-up mechanisms working together to connect the conceptual representations to the perceptual data: we refer to these inter-level connections as interpretations. The top-down mechanism is a projection, and the bottom-up mechanism is an accommodation.

We require that both the conceptual and the perceptual layers have their own autonomous structures. The structure of the conceptual layer reflects the conceptual associations that we normally acquire through experience, and the structure of the perceptual layer reflects the historical series of input data. There is an autonomous memory for each layer where the associations or structures of the respective layers are stored.

We can elaborate on how 'juxtaposition of dissimilar' might lead to creative insights. The source concepts interact with the target image to create a new representation (with new features) of the target in the conceptual layer.

The topic concepts evoke the imagery of the associated objects. As a result, a new set of concepts get activated for the topic, and constitutes a new perspective on it. Thus, we see that juxtaposition of dissimilar requires essentially modeling the top-down mechanism of projection.

STATISTICAL METHODOLOGY applies at all times that has to do with a COLLECTIVE PHENOMENON that interests A PLURALITY of "objects", meant in the most as wide as possible sense. Such "objects" can be people, concrete objects of the real world, but also events, times of time, etc. For example, a HISTORY SERIES is an orderly succession of "numeric values" attributed to a series of successive time instances. In our terminology, we will call these "objects" STATISTICAL UNITS. We have a set of relationships between objects that changes dynamically depending on systems experience. IoT continuously sends data and depending on statistical algorithms the variables and their relations will be adapted. How tho value relationships? How to value their fitness? We use a genetic approach. This approach doesn't provide the creativity of Leonardo but helps to create new objects in a machine. A little step for mankind, a big step for machines.

# **12.00 | LONG TALK**

# **RICHARD BOYLE**

**United Kingdom** 

NOVELTY, HISTORICAL SCIENCE, TIME, AND THE LIMITS OF OBJECTIVE LANGUAGE

Philosophical arguments are developed concerning the definition and manifestation of novelty, from the perspective of long-term life/environment coevolution:

1) Novelty is most usefully defined as discontinuity in the distribution of cause and effect relationships over time (where a causal relationship is defined in a broad sense as a repetitive temporal association between changes, and a change is in turn defined as the conjunction of identity and temporality).

2) A pragmatic reading of the history of life on Earth (and, more generally, any non-steady state cosmology) justifies the claims that novelty, according to this definition:

(a) Is unequivocally real, but also rare and step-like in nature.

(b) Is the natural phenomenon that imparts direction to time - both in terms of objective application of the scientific method to the past, and the unique importance of time in consciousness/human subjectivity.

(c) Exhibits a closer analogy to symbiosis, in the biological sense, than to any other natural phenomenon.

3) A necessary, but not necessarily sufficient, condition for novelty to occur is the prolonged interaction of systems within congruent function but qualitatively different structure.

(a) (Where function is defined, with respect to a given system, as causal repetition unique to and within that system, as opposed to the more general structural repetition dictated by the nature of that system's material constituents).
(b) The actual instant at which novelty occurs is identifiable by the fact that changes that initially occur in a temporally inconsistent manner, due to random consequences of the structural difference between the systems, begin to occur consistently (i.e. Kauffman's order at the edge of chaos observation), at the level of the two initial systems combined.

(c) Both the phenomena of symbiosis and of genetic assimilation may be relevant analogy.

4) The reality of novelty provides a metaphysical grounding for the fact that all objective language must continuously semantically evolve, reconciling the early and late works of Ludwig Wittgenstein, and having implications for philosophical treatments of subjectivity relative to linguistic expression.

5) Although empirically speaking, novelty can only ever be identified retrospectively, it is suggested that development of a mathematical framework for the tracking of causal discontinuity within contexts that give rise bottlenecks of prolonged interactions between unrelated systems, may be of exploratory value.

# **12.20 | LONG TALK**

# > WILLIAM SCHUELLER, PIERRE-YVES OUDEYER

#### **INRIA Bordeaux Sud-Ouest, France**

# INTERACTIVE INSTALLATION FOR COLLABORATIVE CREATION OF A LANGUAGE- EXPERIMENTING HOW HUMANS ACTIVELY NEGOTIATE NEW LINGUISTIC CONVENTIONS

How do humans agree and negotiate linguistic conventions? This question is at the root of the domain of experimental semiotics, which will be the context of this experiment/installation.

Typically, the experiments of this field consist in making human subjects play a game where they have to learn how to interact/collaborate through a new unknown communication medium (such as abstract symbols). In recent years, such experiments allowed to see how new conventions could be formed and evolve in population of individuals, shading light on the origins and evolution of languages. The rules of these interactions are derived from a class of computational models of language emergence, the Language Games, where a population of communicating agents have to refer to given meanings using a certain type of signals or words. We consider here a version of those models called the Naming Game, focusing on the influence of active learning/teaching mechanisms on the global dynamics. In particular, agreement is reached sooner when agents actively choose the topic of each interaction.

Through this experiment, we want to confront existing topic choice algorithms to actual human behavior. Participants will interact through the mediation of a controlled communication system (through a website), by choosing words to refer to objects. Similar experiments have been conducted in previous work to study the agreement dynamics on a name for a single picture [1]. We will here make several pictures or interaction topics available, and quantify the extent to which participants actively choose topics in their interactions.

[1] Damon Centola and Andrea Baronchelli. The spontaneous emergence of conventions: An experimental study of cultural evolution. Proceedings of the National Academy of Sciences, 112(7):1989–1994, 2015.

# 12.40 | LONG TALK

# **ALESSIO EMANUELE BIONDO, ALFIO GIARLOTTA**

Dipartimento di Fisica e Astronomia, Università di Catania, Italy

# > ANDREA RAPISARDA, ALESSANDRO PLUCHINO

Dipartimento di Fisica e Astronomia, Università di Catania and INFN, Italy

#### PERFECT INFORMATION VS RANDOM INVESTIGATION IN THE JUNGLE OF PRODUCT DIFFERENTIATION

We present a graph-based theoretical model of consumer choice, where final decisions are shown to be influenced by information and knowledge, in the form of individual awareness, discriminating ability, and perception of market structure. Building upon the distance-based Hotelling's differentiation idea, we describe the behavioral experience of several prototypes of consumers, who walk a hypothetical cognitive path in an attempt to maximize their satisfaction. Our simulations show that even consumers endowed with a small amount of information and knowledge may reach a very high level of utility. On the other hand, complete ignorance negatively affects the whole consumption process. In addition, rather unexpectedly, a random walk on the graph reveals to be a winning strategy, below a minimal threshold of information and knowledge.

#### References

1. Biondo AE, Giarlotta A, Pluchino A, Rapisarda A, (2016) Perfect Information vs Random Investigation: Safety Guidelines for a Consumer in the Jungle of Product Differentiation. PLoS ONE 11 (1): e0146389. doi:10.1371/journal. pone.0146389

### 13.00 | SHORT TALK

# **BERNARDO MONECHI**

**ISI Foundation, Turin, Italy** 

#### > VITO D. P. SERVEDIO

Complexity Science Hub, Vienna, Austria

# **PIETRO GRAVINO**

Sapienza University of Rome, Italy

# **VITTORIO LORETO**

Sapienza University of Rome, Italy, ISI Foundation, Turin, Italy, Complexity Science Hub, Vienna, Austria

#### INTUITION AND CREATIVITY IN CHESS GAMES

The origins of the game of chess date back more than ten centuries ago with modern rules and intensive playing activity starting from the 19th century. Despite the uncountable number of games played in the last 200 years, it still offers players an unlimited freedom of original moves and configurations (the so called Shannon number representing the game-tree complexity of chess is estimated to be 10 to the power 120). From a given position, professional players have to decide how to move further and base their choice upon different factors, e.g., the achievement of a better position, strategical considerations, psychological considerations, etc.

Nowadays, computer hardware and software have evolved to the point that it is almost impossible for a human to beat the machine, and grandmasters even use chess software extensively for training purposes and to assess the goodness of a given position. In this work we leverage on the machine analysis at different analysis depths (the higher the depth, the more precise is the estimation of the position on the chessboard) of a database of chess games played by professionals and non professionals, to discover how they explore the space of playable legal moves while being under pressure during a match. Surprisingly, we detect a set of moves that are generally sub-optimal in terms of objective positional evaluation at low depths but that are extremely likely to result in a victory in favour of the player who plays them. The fact that this kind of moves are not the best playable choice at a given position when analysed at low depths, points in the direction of a sort of an intuitive creative reasoning that distinguishes professional players from all others.

# 13.10 | SHORT TALK

#### **MARC ANDERSEN**

#### Interacting Minds Centre, Aarhus University, Denmark

#### EXPRESSIONS OF CREATIVITY AND INNOVATION IN OUIJA BOARD SESSIONS

Ouija board sessions are a fascinating phenomenon that sits squarely in the intersection between play, creativity, and deep seriousness, where two players will pose questions to the board, seemingly answer it themselves by moving a planchette to relevant letters on the board, only to collectively claim that an invisible agent was really the one responsible for creating the response. For this reason, Ouija boards are frequently referenced within certain research fields in cognitive science, despite the fact that no empirical study of the phenomenon in a natural setting has ever been conducted (e.g. Wegner & Wheatley, 1999; Carruthers, 2010; Moore & Fletcher 2012).

One influential theory claims that feelings of control mainly arises from predictive processes that inherently serve motor control (Blakemore, Wolpert & Frith, 2002;). In Ouija boards sessions, reports that the planchette moves by itself may therefore be caused by difficulty predicting the board's responses. This, however, seems like an obvious paradox: how can participants on the one hand produce coherent and meaningful responses through the board while on the other hand be unable to predict those very same responses?

In a recent field experiment, we used mobile eye tracking technology to compare predictive gaze behaviour in Ouija Board sessions with a voluntary action condition in which participants in pairs were asked to voluntarily spell words on the board with the planchette. Our results show that while individual participants indeed have major difficulties visually predicting the responses from the board, meaningful responses seem to be creatively constructed through unconscious collaborative efforts at the collective level of participant pairs. In other words, participants are not only seemingly telling the truth, when they individually claim that they are not producing the responses from the Ouija board, they also seem to be unaware that they are part of a creative and innovative process in which meaningful responses from the Ouija board emerge as a property of interacting and predicting minds that increasingly impose structure on initially random events in Ouija sessions. Our findings sits well with Kauffman's idea of the adjacent possible, and we believe that a presentation of the study may stimulate fruitful dialogue at the Kreyon Conference.

# **15.00 | INVITED SPEAKER**

# MASSIMO EGIDI

#### LUISS University, Italy

He is Emeritus and professor of Behavioral Economics and Psychology at LUISS Guido Carli University, Rome, where he has served as Rector for ten years (October 2006 to October 2016). He has also served as Rector of University of Trento (from1996 to 2004) and was President of FBK – the Bruno Kessler Foundation in Trento, serving from December 2010 to December 2014.

He has been Visiting Professor in some qualified Universities and research centers (Center for Research on Management at the Graduate Business School, University of California at Berkeley, , IIASA, (Laxenburg), Stanford University, Santa Fe Institute.

His main research interests are related to the study of bounded rational behaviour in organizations and institutions, as well as of organizational learning. Most of his papers released in the last decade concern, in particular, biases in decision making and problem solving. On these topics he has published around 100 papers, and got 3000 citations).

He is considered to be a distinctive voice in the academic and institutional frameworks; as such, he has often been involved in the debates on issues concerning university governance, relations between research and industry and the European policies for technology transfer and innovation.

#### MENTAL PROCESSES THAT FACILITATE OR HINDER DISCOVERY AND CREATIVITY

We explore the creativity of individuals – in the limited definition of capacity to discover new strategies – in a context of card games . We have exposed two groups to different sequences of game configurations in such a way that each group could easily learn and become familiar with a different strategy. After this preliminary phase, all players were exposed to the same card configurations. A clear pattern then emerged, in which a consistent number of players remained locked into the familiar strategy even when inefficient; while only a part of them were able to get out from the cognitive trap. In both experiments player's attention was artificially manipulated. In fact after the training phase the key cards of one strategy were familiar to the players, and therefore more accessible than the key cards of the alternative strategy. Thus the differential accessibility explains why a large number of players continued to use the familiar strategy even when inefficient: they simply did not pay attention to the key card of the unfamiliar strategy. In consequence, it could reasonably be expected that the effort taken to discover the second strategy

varies in relation to the extent to which the first strategy governs the player's attention. The ease with which the first strategy comes to the mind of a player can help or hinder the discovery of the second. We claim that two conflicting processes are active: one the one hand the automatization of one strategy reduces the mental load permitting the exploration of new alternatives; on the other hand, automatization implies high accessibility to the familiar strategy and this, in turn, leads the attention to the strategy's key-cards. Both processes are not accessible to the subjects' awareness. A recent confirmations in this respect, is due to Schuck et alii (2015). Through multivariate neuroimaging analyses (MPFC) they show that before the spontaneous change to an alternative strategy, the medial prefrontal cortex encoded information that was irrelevant for the current strategy but necessary for the new one. The balance between exploitation (of the old strategy) and exploration (of a new strategy), first highlighted by Jim March (1991), seems then to be at least partially out of the control of subjects' deliberation.

# 15.30 | LONG TALK

#### > BERNAT COROMINAS-MURTRA, RUDOLF HANEL, STEFAN THURNER Medical University, Vienna, Austria

#### DYNAMICS ON EVOLVING SAMPLE SPACES. SAMPLE SPACE REDUCING AND EXPANDING PROCESSES

Systems with the ability of innovate have no known predefined space of potential future configurations. New configurations emerge and eventually collapse over time. Novelties emerge in a highly path-dependent fashion: Depending on the evolutionary trajectory up to time t, one or another set of new potential configurations opens. Consequently, the equations governing the dynamics of the system –if any– are unbalanced, meaning that the system is far away from equilibrium. Time-dependent phase spaces, path dependent trajectories and unbalanced dynamical equations critically compromise standard statistical mechanics to understand the dynamics of innovative systems. In this talk we will review a general family of minimally path dependent stochastic processes, defined over reducing or growing phase spaces in a totally unbalanced way. The simplest example is the so-called Sample Space Reducing (SSR) process, shown in the figure. The predicted statistical patterns depart dramatically from the ones found in the standard theories, and show a universe dominated by power-laws, , with a special role reserved to  $\alpha = 1$  (Zipf's law) and to  $\alpha = 2$ . Such processes have many applications, including non-standard diffusion [2], cascading processes [3], linguistic time series [4] or generalised statistical mechanics [5]. The family of History-dependent Sample Space processes might help to understand the dynamics of innovation systems.



FIG. 1: The simplest process with history-dependent phase space, the Sample Space Reducing (SSR) process: The outcome of the dice at time t, determines the dice to be used at time t + 1 –i.e., the sampling space–. In this case, if at t the outcome is "n", the dice to be used at t + 1 will contain only "n – 1" faces. In the example, we start with a dice of 20 faces, 1). After throwing this dice, suppose we get "13". The dice to be used in the next run will thus contain only 12 faces. We throw this dice and suppose we get "9", 2). Therefore, the dice to be used in the next run will contain only 8 faces. The process runs until the number "1" appears. After a large number of trials, the histogram of visits follows a power-law , with  $\alpha = 1$  [1], i.e., Zipf's law.

[1] Corominas-Murtra, B, Hanel, R, Thurner S (2014) Understanding scaling through history-dependent processes with collapsing sample space. Proc Natl Acad Sci USA 112, 5348–5353.

[2] B. Corominas-Murtra, R. Hanel, and S. Thurner (2016) Extreme robustness of scaling in sample space reducing processes explains Zipf-law in diffusion on directed networks. New Journal of Physics 18 (9), 093010.

[3] B. Corominas-Murtra, R. Hanel, and S. Thurner (2017) Sample space reducing cascading processes produce the full spectrum of scaling exponents. ArXiv e-print: arXiv:1703.10100 [cond-mat.stat-mech]

[4] S. Thurner, R. Hanel, B. Liu, and B. Corominas-Murtra (2016) Understanding Zipf's law of word frequencies through sample-space collapse in sentence formation. Journal of the Royal Society Interface 12, 20150330.
[5] S. Thurner, B. Corominas-Murtra, and R. Hanel (2107) The three faces of entropy for complex systems information, thermodynamics and the maxent principle. ArXiv e-print: arXiv:1705.07714 [cond-mat.stat-mech]

# 15.50 | SHORT TALK

# > GIULIA PULLANO

**ISI Foundation, Turin, Italy** 

#### **BERNARDO MONECHI**

**ISI Foundation, Turin, Italy** 

#### **VITTORIO LORETO**

Sapienza University of Rome, Italy, ISI Foundation, Turin, Italy, Complexity Science Hub, Vienna, Austria

#### DYNAMICS OF SOCIAL INTERACTIONS IN A COLLECTIVE CREATIVITY EXPERIMENT

The study of the dynamics behind the emergence of novelties and innovation is a relatively recent field of study in Complex Systems, fostered by the abundance of data about the creation and sharing of artworks, about online collaborative activities and social, economic and technological development in general. Despite the recentness of the topic, many works have been able to discover and characterize many interesting statistical patterns related to the emergence of new creative elements and a very general mathematical framework describing the collective process of discovering and sharing novelties has been developed. However, a lot has still to be discovered concerning the conditions, either historical and social, fostering the emergence of creative elements from a group of interacting individuals. From a social perspective, many hypotheses have been suggested and tested regarding the relations between individuals, like the presence of "weak ties" in social networks or the "folding" of different social groups into larger ones sharing a common goal. To the best of our knowledge, Complex Systems Science has given little contributions to the understanding of how the dynamics of social interactions can contribute to promoting the emergence of creativity.

In this work, we present the results of a collective social experiment in which individuals were asked to collaborate in the realization of a certain number of LEGO bricks sculptures. The participants were provided with particular RFID tags developed in the framework of the SOCIOPATTERNS project (http://www.sociopatterns.org), that enabled a quite precise mapping of the social interactions occurring during their activity within the experiment. The interactions with the LEGO Sculptures were similarly mapped by means of other RFID tags placed around the sculptures, and their growth in volume has been recorded with the aid of infrared depth sensors. The RFID sensors allowed for the reconstruction of the dynamical network of social interactions between the participants in the experiment. We looked for correlations between the evolving structure of this network and the growing patterns of the sculptures, spotting the local social structures more prone to a rapid growth of the volume in small amounts of times and in long term periods. In this way, we were able to identify the social patterns more fruitful in terms of "local consensus" around the development of the collective artwork, indicating a shared vision around the actions to be performed on it. Moreover, we were able to identify how the presence of "influential individuals" in a work group characterized by means of information spreading models favored the growth of the sculptures in small amounts of time and in the long-term. The novelty of the proposed approach could contribute to shed light on the phenomena related to the emergence of creativity and could innovate in the way in which collective creativity experiments are conceived and designed.

# **17.00 | INVITED SPEAKER**

#### > INDACO BIAZZO

Sapienza University of Rome, Italy

**BERNARDO MONECHI** 

ISI Foundation, Turin, Italy

**CESARE BIANCHI** Sapienza University of Rome, Italy

#### **ELISABETTA FALIVENE**

Sapienza University of Rome, Italy

### VITO D. P. SERVEDIO

Complexity Science Hub, Vienna, Austria

# FRANCESCA TRIA

Sapienza University of Rome, Italy

# **VITTORIO LORETO**

#### Sapienza University of Rome, Italy, ISI Foundation, Turin, Italy, Complexity Science Hub, Vienna, Austria

### CITYCHRONE: AN INTERACTIVE PLATFORM FOR URBAN ACCESSIBILITY AND PLANNING SUPPORT

In the last decade the Open Data movement has reached the maturity, becoming more and more an used practice to release data by public institutions and private companies. In the public transport domain, for instance, the creation of the GTFS standard, which has fostered hundreds of public transport companies to release their schedules, or the OpenStreetMap project, allowed to enhance our knowledge about cities. This great availability of new data about cities and transports calls for adequate visualization and analytical instruments. The Javascript language with its huge set of open-source libraries is nowadays an essential tool for this purpose. Moreover, in this last five years a big step forward was made in the development of efficient routing algorithms for scheduled transport [1,2]. The Citychrone Project [citychrone.org] shows public transport measures about accessibility and efficiency in cities in an interactive and easy-to-use way. The starting point is the computation of isochrones, i.e. the area reachable from a starting point after a given time using public transport. Citychrone allows for the interactive exploration of accessibility with the visualization of such isochrones centered on each point in a given city. In order to enhance the characterization of the accessibility of a point provided to users, Citychrone shows multiple layers of information integrated with the computation of the isochrones:

- The Velocity Score, i.e., the velocity we move out of a point on average through public transportations;
- The Sociality Score, i.e., the average number of people that is possible to meet starting from a given point;
  The isochrone layer.

This set of observables allows for a straightforward comparison of different areas in a city or different cities. CityChrone provides interactive tools for the exploration of different scenarios about public transportations. Thanks to the high efficiency of the algorithms used, as well as the performance of the client side javascript library, the user can modify the public transport network, e.g., by adding a metro line, and see, in nearly real time (less than 1min), how the introduced modifications affect the accessibility measure of the cities. The goal of this feature is twofold. The first one is for planning support. It is possible to explore the ample space of feasible scenarios of new public transport networks in a fast way, using the computational and cognitive resources of the users connected to the platform. The second aim is to enhance the awareness of people about the complexity of modern cities and their transportation systems. Therefore, the Citychrone platform incorporates gamification aspects in order to foster the participation of a vast audience. The routing core algorithms of the platform are implemented in javascript and run on client side, so that the Citychrone platform is easily scalable to large number of users without the need of extreme computational resources. The CityChrone platform can be used in combination with an interactive Table, through an interactive projector, that allows people to physically interact with the platform, enhancing in this way participation, interest and collaborative work [https://youtu.be/I6sm8VOwJSA].

1. Dibbelt, Julian, et al. "Intriguingly simple and fast transit routing." International Symposium on Experimental Algorithms. Springer Berlin Heidelberg, 2013.

2. Delling, Daniel, Thomas Pajor, and Renato F. Werneck. "Round-based public transit routing." Transportation Science 49.3 (2014): 591-604.