LANET 2017

1st LATIN AMERICAN CONFERENCE ON COMPLEX NETWORKS

Applications to social, biological and technological systems

BUAP

1ST LATIN AMERICAN CONFERENCE ON COMPLEX NETWORKS

AND

LANET SCHOOL ON FUNDAMENTALS AND APPLICATIONS OF NETWORK SCIENCE

LANET 2017

25-29 SEPTEMBER 2017 PUEBLA MEXICO

BOOK OF ABSTRACTS

ORGANIZED BY

BENEMÉRITA UNIVERSIDAD AUTÓNOMA DE PUEBLA

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	Monday, September 25	Tuesday, September 26	Wednesday, September 27
8.00-9.00	REGISTRATION	REGISTRATION	REGISTRATION
9.00-9.15	**Edif. Carolino: LANET SCHOOL 1** Intro Networks *Ernesto Estrada*	FORMAL OPENING **CCU**	**Room 1: PT7** The Scale Invariance of Crime Concentration in Cities *Ronaldo Menezes*
9.15-9.30			
9.30-9.45			
9.45-10.00		**CCU: PT3** A unified approach to percolation processes on multiplex networks *Jose F.F. Mendes*	**Room 1: MS3** Explosive Transition in Networks
10.00-10.15			
10.15-10.30			
10.30-10.45	COFFEE BREAK	**CCU: PT4** Symmetric States Requiring System Asymmetry in Network Synchronization *Adilson E. Motter*	
10.45-11.00			COFFEE BREAK
11.00-11.15	**Edif. Carolino: LANET SCHOOL 2** Contagion Processes *Jesus Gomez-Gardenes*		
11.15-11.45		COFFEE BREAK	**Room 1: MS4** Southamerican Network Science
11.45-12.00		**Room 1: MS1** Networks, Games and Human Behavior **Room 2: MS2** Advances in Multiplex Networks	
12.00-12.15			
12.15-12.30			
12.30-12.45	LUNCH BREAK		LUNCH BREAK
12.45-13.00			
13.30-13.45			
13.45-14.00		LUNCH BREAK	Visit to Cantona
14.00-14.15	**Edif. Carolino: LANET SCHOOL 3** Multilayer Networks *Alex Arenas*		
14.15-14.30			
14.30-14.45			
14.45-15.00			
15.15-15.30		**Room 1: PT5** On the influence of competition and mutualism on the biodiversity of mutualistic ecosystems *Yamir Moreno*	
15.30-15.45	COFFEE BREAK		
15.45-16.00			
16.00-16.15	**Edif. Carolino: LANET SCHOOL 4** Brain Networks *Javier Martin Buldú*	**Room 1: C1** Structure **Room 2: C2** Biological Applications	
16.15-16.30			
16.30-16.45			
16.45-17.00			
17.00-17.15		COFFEE BREAK	
17.15-17.30			
17.30-17.45		**Room 1: PT6** Spreading Processes on Networks *Mason Alexander Porter*	
17.45-18.00			
18.00-18.15	MAIN CONFERENCE BEGINS		
18.15-18.30	**Edif. Carolino: PT1** Collective Phenomena Emergin from Interactions Between Dynamical Processes in Multiplex Networks *Alex Arenas*	POSTER SESSION AND COCKTAIL **Conference Hall**	
18.30-18.45			
18.45-19.00			
19.00-19.15	Reception Cocktail and Registration		
19.15-19.30			
19.30-19.45			CONFERENCE DINNER **Hotel Colonial**
19.45-20.00			
20.00-20.30			

	Thursday, September 28	Friday, September 29
8.45-9.00	REGISTRATION	REGISTRATION
9.00-9.15 9.15-9.30 9.30-9.45	**Room 1: PT9** Long-range influences and dynamics on networks *Ernesto Estrada*	**Room 1: PT12** Spatio temporal analysis of language use *Bruno Gonçalves*
9.45-10.00 10.00-10.15 10.15-10.30	**Room 1: PT10** Network-based data analysis tools for identifying and characterizing dynamical transition in complex systems *Cristina Masoller*	**Room 1: PT13** Brain networks: is complexity jumping the shark? *Mario Chávez*
10.30-10.45 10.45-11.00	COFFEE BREAK	COFFEE BREAK
11.00-11.15 11.15-11.30 11.30-11.45	**Room 2: C3** Synchronization and Brain **Room 1: C4** Interdisciplinary Applications	**Room 2: C11** Synchronization **Room 1: C12** Social Dynamics
11.45-12.00 12.00-12.30 12.30-12.45 12.45-13.00 13.00-13.15 13.15-13.30 13.30-13.45	**Room 2: MS5** Colombian Networks **Room 1: MS6** Nonlinear Dynamical and Complex Networks	**Room 1: MS7** Dynamics of Networks **Room 2: MS8** Network Biology Approaches to Understand Complex Diseases
13.45-14.00 14.00-14.15 14.15-14.30	LUNCH BREAK	
14.30-14.45 14.45-15.00 15.00-15.15		LUNCH BREAK
15.15-15.30 15.30-15.45 15.45-16.00	**Room 1: PT11** Synchronization in populations of moving oscillators *A. Diaz-Guilera*	**Room 1: PT14** Dynamics and Effective Connectivity in Neural Cultures *Jordi Soriano-Fradera*
16.00-16.15 16.15-16.30 16.30-16.45 16.45-17.00	**Room 2: C5** Structure **Room 1: C6** Network Dynamics	**Room 1: C13** Statical Physics and Critical Phenomena **Room 2: C14** Network Dynamics
17.00-17.15 17.15-17.30	COFFEE BREAK	COFFEE BREAK
17.30-17.45 17.45-18.00 18.00-18.15	**Room 2: C7** Epidemics **Room 1: C8** Spanish Session	CLOSING
18.15-18.30 18.30-18.45 18.45-19.00	**Room 2: C9** Epidemics **Room 1: C10** Spanish Session	

EXTENDED PROGRAM

LANET SCHOOL REGISTRATION	8.15–9.00
LANET SCHOOL 1: Intro Networks	9.00–10.30
Network Analytics. Traditional vs. non-traditional methods *Ernesto Estrada*	Auditorio (Edif. Carolino)
Coffee break	10.30–11.00
LANET SCHOOL 2: Contagion Processes	11.00–12.30
Contagion Processes *Jesus Gomez-Gardenes*	Auditorio (Edif. Carolino)
Lunch break	12.30–14.00
LANET SCHOOL 3: Multilayer Networks	14.00–15.30
Mutilayer Networks *Alex Arenas*	Auditorio (Edif. Carolino)
Coffee break	15.30–16.00
LANET SCHOOL 4: Brain Networks	16.00–17.30
Brain Networks *Javier Martin Buldú*	Auditorio (Edif. Carolino)
MAIN CONFERENCE BEGINS	18.00–18.15
PT1: Plenary Talk *Chair: Javier M. Buldú*	18.15–19.00
Collective Phenomena Emerging from the Interactions Between Dynamical Processes in Multiplex Networks *Alex Arenas*	Auditorio (Edif. Carolino)
Reception Cocktail and Registration to the Conference	19.00–20.30

8.15–9.00 **Registration**

9.00–9.45 **Formal Opening (Theatre CCU)**

9.45–10.30 **PT3: Plenary Talk** *Chair: Albert Díaz-Guilera*

Theatre CCU **A unified approach to percolation processes on multiplex networks** *Jose F.F. Mendes*

10.30–11.15 **PT4: Plenary Talk** *Chair: Mason Porter*

Theatre CCU **Symmetric States Requiring System Asymmetry in Network Synchronization** *Adilson E. Motter*

11.15–11.45 **Coffee break**

11.45–13.45 **MS1: "Networks, Games and Human Behavior"**

Room 1 *Organizers: Alberto Antonioni and Federico Battiston*

1. **Promoters of Human Cooperation: Results from the Lab** *Yamir Moreno*
2. **How to model the decision making process in Game Theory experiments** *Jelena Grujić*
3. **Investigating the Coevolution of Institutions within an Adaptive Multiplex Network Model** *Francesca Lipari*
4. **Sequence of purchases in credit card data reveal life styles in urban populations** *Marta Gonzalez*
5. **Reputation Drives Cooperative Behavior and Network Formation in Human Groups** *Carlos Gracia-Lázaro*
6. **Spatial patterns in evolutionary games on scale-free networks and multiplexes** *Kolja Kleineberg*

11.45–13.45 **MS2: "Advances in Multiplex Networks"**

Room 2 *Organizers: Sergio Gómez*

1. **Community Structure in Multilayer Networks** *Mason A. Porter*
2. **Communicability geometry in multiplexes** *Ernesto Estrada*
3. **Diffusion and reaction on multiplex networks** *Albert Diaz-Guilera*
4. **Epidemic spreading in localized environments with recurrent mobility patterns** *Clara Granell*

13.45–15.15 **Lunch break**

15.15–16.00 **PT5: Plenary Talk** *Chair: Antonio Méndez-Bermúdez*

Room 1 **On the influence of competition and mutualism on the biodiversity of mutualistic ecosystems** *Yamir Moreno*

16.00–17.00 **C1: Structure**

Room 1

Chair: Alex Arenas

1. **Geometric correlations mitigate the extreme vulnerability of multiplex networks against targeted attacks** *Kaj Kolja Kleineberg*
2. **Beyond classical metrics on complex** *Nethali Fernando*
3. **Mathematical analysis of k-path Laplacian operators on networks** *Ehsan Hameed*

16.00–17.00 **C2: Biological Applications**

Room 2

Chair: Jordi Soriano

1. **The joint influence of competition and mutualism on the biodiversity of mutualistic ecosystems.** *Carlos Gracia-Lázaro*
2. **The use of a drug-gene perturbation network for the study of drug side effects: The case of drug-induced peripheral neuropathy** *Guillermo de Anda-Juáregui*
3. **Regulatory Signaling Networks Related to Fertilization** *Daniel Alejandro Priego-espinosa*
4. **Loss of trans-regulation in breast cancer** *Jésus Espinal-Enríquez*

17.00–17.30 **Coffee break**

17.30–18.15 **PT6: Plenary Talk** *Chair: Javier M. Buldú*

Room 1 **Spreading Processes on Networks** *Mason Alexander Porter*

18.15–20.15 **Poster Session and Cocktail (Conference Hall)**

Registration 8.15–9.00

PT7: Plenary Talk *Chair: Jesús Gómez-Gardeñes* 9.00–9.45
The Scale Invariance of Crime Concentration in Cities *Ronaldo Menezes* Room 1

MS3: "Explosive Transitions in Networks" 9.45–10.45
Organizers: Irene Sendiña-Nadal and Juan A. Almendral Room 1

1. **Emergent explosive synchronization in adaptive complex networks** *Juan Antonio Almendral*
2. **Abrupt transitions in networks of noisy oscillators with asymmetric attractive-repulsive interactions** *Thomas Peron*

Coffee break 10.45–11.15

MS4: "Southamerican Network Science" 11.15–12.45
Organizers: Arturo C. Martí and Nicolás Rubido Room 1

1. **Detecting amplitude and frequency synchronization in global surface air temperature data** *Cristina Masoller*
2. **Information-based immunization strategies on complex networks** *José Luis Herrera Diestra*
3. **Electronically-implemented networks and what can we say about them** *Nicolás Rubido*

Lunch break 12.45–13.45

Visit to Cantona 13.45–19.00

Conference Dinner (at Hotel Colonial) 20.00–23.00

9.00–9.45 **PT9: Plenary Talk** *Chair: Johann H. Martínez*
Room 1 **Long-range influences and dynamics on networks** *Ernesto Estrada*

9.45–10.30 **PT10: Plenary Talk** *Chair: Ricardo Sevilla-Escoboza*
Room 1 **Identifying and characterizing regime transitions with network-based data analysis tools** *Cristina Masoller*

10.30–11.00 **Coffee break**

11.00–11.45 **C3: Synchronization and Brain**
Room 2

Chair: Johann H. Martínez

1. **Module detection on functional brain networks using resting-state fMRI** *Rodrigo Pineda Mondragon*
2. **Inter-layer synchronization in non-identical multiplex networks** *Irene Sendiña-Nadal*

11.00–11.45 **C4: Interdisciplinary Applications**
Room 1

Chair: Osvaldo Rosso

1. **The dynamics of collaboration and its implications - from careers to Europe** *Alexander Michael Petersen*
2. **Hunter-gatherer networks and cumulative culture** *Federico Battiston*
3. **Networks of melody: The complex use of tonal consonance in music** *Rafel Hurtado*

11.45–13.45 **MS5: "Colombian Networks"**
Room 2 *Organizers: Johann H. Martínez*

1. **Multiplexity and robustness of wildlife traffic networks** *Felber Arroyave*
2. **Data driven network analysis confirms U.S. Culture as the main long-term factor to support results of last presidential elections** *Patricia Cifuentes*

11.45–13.45 **MS6: "Nonlinear Dynamical Systems and Complex Networks"**
Room 1 *Organizers: Guillermo Huerta-Cuellar*

1. **On the generalized synchronization of networks with nonidentical nodes** *Juan Gonzalo Barajas-Ramírez*
2. **Dynamics of piecewise contractions: Dominant Vertices, Complexity & Network Reduction** *Edgardo Ugalde*
3. **Sincronización en redes de sistemas complejos por acoplamiento a modelos** *Didier López-Mancilla*
4. **Preserving scrolls via generalized synchronization** *Eduadro Jiménez López*

13.45–15.15 **Lunch break**

15.15–16.00 **PT11: Plenary Talk** *Chair: Bruno Gonçalves*
Room 1 **Synchronization in populations of moving oscillators** *Albert Diaz-Guilera*

16.00–17.00 **C5: Structure**
Room 2

Chair: Nicolás Rubido

1. **Complex networks, Google matrix and quantum chaos** *Leonardo Ermann*
2. **Long Walks and Holes in Networks** *Grant Silver*
3. **Centrality measures in simplicial complexes** *Grant Jamieson*

C6: Network Dynamics 16.00–17.00
Room 1

Chair: Guillermo Huerta-Cuellar

1. **Coherent and incoherent strategists: Evolutionary dynamics on multiplex networks** *Joan T. Matamalas*
2. **Coevolution of Synchronization and Cooperation in Costly Networked Interactions** *Alberto Antonioni*
3. **Neworks underlying the minority game reflects different behavior of the model** *Inés Caridi*

Coffee break 17.00–17.30

C7: Epidemics 17.30–18.15
Room 2

Chair: Gustavo Martínez-Mekler

1. **General Markov Chain Approach for Disease and Rumor Spreading in Complex Networks** *Guilherme Ferraz de Arruda*
2. **Quarantine efficiency in epidemic spreading control on scale-free networks with different power-law exponents** *Juan Gonzalo Barajas-Ramírez*
3. **Disease surveillance on social complex networks** *Jóse L. Herrera*

C8: Spanish Session 17.30–18.15
Room 1

Chair: Javier M. Buldú

1. **Distinguiendo ruido de caos: un criterio objetivo versus subjetivo basado en Grafo de Visibilidad Horizontal** *Osvaldo Rosso*
2. **Dinámicas de Opinión y Enfermedad en Redes Múltiples Interactuantes: Transición de Fase Discontinua y Tiempo de Consenso No Monótono (Interacting opinion and disease dynamics in multiplex networks: Discontinuous phase transition and nonmonotonic consensus times)** *Fatíma Velazquez Rojas*

C9: Epidemics 18.15–19.00
Room 2

Chair: Edgardo Ugalde

1. **Human Mobility and the spread of Vector-Borne Diseases** *Juddy Heliana Arias Castro*
2. **The spread of multipartite viruses** *Eugenio Valdano*
3. **Human mobility network and persistence of multi-strain diseases** *Alberto Aleta*

C10: Spanish Session 18.15–19.00
Room 1

Chair: Jesús Gómez-Gardeñes

1. **La intermediación como estrategia en el análisis de la propagación de un rumor en una red basada en el modelo de Barbell** *Karina Raya Díaz*
2. **Estructura Dinámica de las Redes Complejas Temporales como Herramienta de Evaluación para la Gestión de Proyectos** *Gerard Olivar-Tost*
3. **Agentes persistentes en un modelo de dinámica de opinión considerando indices de difusión e influencia.** *Carlos Cusgüen*

9.00–9.45 **PT12: Plenary Talk** *Chair: Ronaldo Menezes*
Room 1 **Spatio temporal analysis of Language use.** *Bruno Gonçalves*

9.45–10.30 **PT13: Plenary Talk** *Chair: Cristina Masoller*
Room 1 **Brain networks: is complexity jumping the shark?** *Mario Chavez*

10.30–11.00 **Coffee break**

11.00–12.00 **C11: Synchronization**
Room 2

Chair: Irene Sendiña-Nadal

1. **Enhancement of early warning properties in the Kuramoto Model and in an Atrial Fibrillation Model due to an external perturbation of the system** *Joel Mendoza-Temis*
2. **Synchronization in interacting signaling networks** *Daniel Aguilar Velazquez*
3. **Hybrid Model of Pulse-Coupled Oscillators in Dynamic Networks** *Claudia Catalina Caro-Ruiz*
4. **Reconstructing networks of pulse-coupled oscillators from non-invasive observations** *Rok Cestnik*

11.00–12.00 **C12: Social Dynamics**
Room 1

Chair: Enrique Hernández Lemus

1. **Data driven network analysis confirms U.S. Culture as the main long-term factor to support results of last presidential elections** *Myriam Patricia Cifuentes*
2. **Dissecting structural systemic properties of mammalian tissue-specific transcription factor networks** *Jóse Luis Caldu-Primo*
3. **A networked voting rule for democratic representation** *Alexis R. Hernández*
4. **Control-Oriented Modeling of Large-Scale Networked Systems: A Dynamic Mode Decomposition Approach** *Duvan Tellez-Castro*

12.00–14.00 **MS7: "Dynamics of Networks: observability, modeling and synchronization"**
Room 1 *Organizers: Luis A. Aguirre & Christophe Letellier*

1. **Dynamical and structural observability of networks** *Luis Antonio Aguirre*
2. **Assessing the observability of complex networks: a nonlinear theory** *Christophe Letellier*
3. **Detection and formulation of causal couplings: an alternative approach based on global modelling** *Sylvain Mangiarotti*
4. **Global modelling of optimally coupled dynamical systems** *Claudia Lainscsek*

12.00–14.00 **MS8: "Network Biology Approaches to Understand Complex Diseases"**
Room 2 *Organizers: Enrique Hernández Lemus*

1. **Transitions between Dynamic Phases in Fertilization Regulatory Networks** *Gustavo Martínez-Mekler*
2. **Network Community Structure in Breast Cancer Molecular Subtypes** *Sergio A. Alcalá-Corona*
3. **Structure-based control of complex networks with nonlinear dynamics** *Jorge Gomez-Tejeda Zañudo*
4. **The use of a drug-gene perturbation network for the study of drug side effects: The case of drug-induced peripheral neuropathy** *Guillermo de Anda-Juáregui*

14.00–15.15 **Lunch break**

15.15–16.00 **PT14: Plenary Talk** *Chair: Jesús Gómez-Gardeñes*
Room 1 **Dynamics and Effective Connectivity in Neuronal Cultures: from Experiments to Medical Applications** *Jordi Soriano-Fradera*

C13: Statistical Physics and Critical Phenomena 16.00–17.00 Room 1

Chair: Irene Sendiña-Nadal

1. **Inducing self-organized criticality in a network toy model by neighborhood assortativity** *Alfonso Allen-Perkins*
2. **Detecting the critical transition of the Ising model through timeseries-to-networks methods** *Juan Claudio Toledo-Roy*
3. **Phase Transition in the Communicability Clustering Structure of Graphs and Networks** *Najlaa Sadeq Alalwan*
4. **Invariant properties of transport for interconnected linear reservoirs with Markovian inputs** *Jorge Mario Ramirez*

C14: Network Dynamics 16.00–17.00 Room 2

Chair: Christophe Letellier

1. **Influence maximization in complex networks: the role of degree-degree correlation** *Thomas Kaue Dal Maso Peron*
2. **Correlation analysis of random walks in complex networks** *Rogelio Basurto Flores*
3. **Emergent Polarization in Social Networks** *Elisa Schmelkes*

Coffee break 17.00–17.30

Closure (Room 1) 17.30–17.45

POSTER LIST

P1 **Identifying multiple influential spreaders in complex networks through a semilocal method** *Xiaojie Wang*
P2 **Multiplex pagerank based on interlayer mutual information** *Yangyang Liu*
P3 **Identifying Common Biological Processes between Phenotypes using Common Connection Pattern: A new Method Based on Network Biology Approach** *Juan David Henao*
P4 **Competitive-Cooperative-mixed peer-to-peer multiagent based systems** *Leonidas Facundo Caram*
P5 **Diffusion, adoption and transfer of innovations to rural development, a field of social complexity and structural analysis** *Juan Felipe Nuñez Espinoza*
P6 **Random Rectangular Networks** *Ernesto Estrada*
P7 **Fragmentation, integration and macroprudential surveillance of the US financial industry: Insights from network science** *Yarali Carolina Gandica*
P8 **Unveiling stable chaos in synchronization of coupled Bernoulli shift maps** *Rodrigo Frehse Pereira*
P9 **Controlling Quantum Entanglement Study in Quantum Complex Networks through Noise Control** *John Mateus-R*
P10 **study of homogeneity and spatial autocorrelation of homicides in Mexico.** *Jorge Antonio Hernández Casildo*
P11 **Detection of money laundering communities in the banking system through network theory.** *Carlos Alberto Yaruro-G*
P12 **Modeling Temporal Networks as an N-body Problem** *Marco Antonio Rodriguez Flores*
P13 **Synchronization in a network of nearest identical PWL systems coupled with unidirectional links and ring topology** *Andres Anzo Hernández*
P14 **Characterization of resilience in the network of Aedes Aegypti mosquitoes** *Maikol Stive Macias Torres*
P15 **Analysis of a complex network of risk factors.** *Maria Oroselfia Sánchez Sánchez*
P16 **Consistency of nonlinear oscillators using reconfigurable electronic networks.** *Victor Porfirio Vera Ávila*
P17 **The Trend Towards Complex Networks for Industry Sector Goods Transportation** *Gabriel Policroniades Chípuli*
P18 **Dynamical competition between Complex Networks** *Jóse Luis Echenausía Monroy*
P19 **Centrality measures in weakly connected networks: the case of citation networks.** *Juan Antonio Pirchardo Corpus*
P20 **Multifractal dimension analysis of visibility networks** *Carlos Carrizales-Velázquez*
P21 **study of physiological networks of the stomach** *Tania Jetzabel Contreras*
P22 **Using already-solved cases and expert knowledge to prioritize the search of persons** *Inés Caridi*
P23 **Recurrence networks in natural languages** *Edgar Baeza Blancas*
P24 **Input-output networks and economic structure analysis: a study of two economies** *Esteban Durán*
P25 **Regulatory Variation Analysis Tools** *Walter Santana-García*
P26 **New behaviors on parameters a and b of the Gutenberg-Richter relationship in synthetic seismicity.** *Jennifer Pérez*
P27 **Vertex similarities in a complex economy** *Vladimir González Gamboa*
P28 **Political dynamics of the mexican senate** *Ollin Demian Langle-Chimal*
P29 **Synchronization of coupled discrete systems with parameter mismatch** *Brenda Esmeralda Martínez-Zérega*
P30 **Two-walks degree assortativity in graphs and networks** *Alfonso Allen-Perkins*
P31 **Musical Words as Networks using Visibility Graphs** *Miguel Sanchez*
P32 **Noise Effects in the Kuramoto Model: Early Warnings using Networks** *David García-Gudiño*
P33 **Scaling properties of random networks with losses and gain** *Claudia Teresa Martínez-Martínez*
P34 **Weighted random–geometric and random–rectangular graphs: Spectral and eigenfunction properties of the adjacency matrix** *Lázaro Alonso Silva*
P35 **Growth and Use of Bicycle Sharing Systems from a Networks Perspective** *Alfredo González Espinoza*

P36 **Under the waterline of the iceberg: network analysis uncovers factors that moderate stillbirth attributed to Zika Virus Infection** *Patricia Cifuentes*

P37 **On the agreement between Small-World-Like OFC model and real earthquakes from different regions** *Douglas Santos Rodrigues Ferreira*

P38 **How well a graph dissimilarity measure behaves in neuroscience?** *Manuel Julian Arévalo*

P39 **Emergence of Uncooperative Behavior by Interaction Dynamics of Community Networks** *Matthias R. Brust*

P40 **Growth and Use of Bicycle Sharing Systems from a Networks Perspective** *Martín Zumaya*

P41 **Cat's vertebral spinal cord neuronal network dynamics under pain stimuli: Spinographic analysis in phase space** *Ana Leonor Rivera-Lopez*

P42 **Reactive Power Sharing in Isolated Micogrid Using a Controller Based on Information Theory** *Eduardo Mojica-Nava*

P43 **Long-range and short-range spectral correlations of networks using random matrix theory (RMT)** *Ruben Yvan Maarten Fossion*

P44 **Knowledge Transfer Phenomenon from Universities to Regions as a Multilayer Network** *Arturo Melo*

P45 **Visibility Graph analysis for catalogs of synthetic seismicity.** *Lucia Rebeca Moreno-Torres*

P46 **Using multilayered networks to investigate procurement contracts: the case of Mexico** *Mónica Zamudio*

P47 **Is it complex to be a hub?** *Alejandro Tlaie Boria*

P48 **Multi-scale organisation of core-periphery structure in networks** *Sadamori Kojaku*

P49 **Order, preferences and dynamics of illegal trade networks of reptiles in colombia: design elements of strategies to control and sustainability** *Felber Arroyave*

P50 **Synchronization Transitions Induced by Topology and Dynamics** *Lluís Arola - Fernández*

P51 **Electron transport in tight-binding networks with dislocations** *Carlos Ramírez*

P52 **Analysis of Mexico's drug-cartels network** *Ollin Demian Langle-Chimal*

P53 **Modularity Detection in Biological Networks** *Sergio Antonio Alcalá-Corona*

P54 **Whole genome transcription factor analysis reveals long range-functional interactions in breast cancer gen regulatory networks** *Karol Baca-López*

P55 **Prioritizing individuals for identification purposes in base of inferred network** *Inés Caridi*

P56 **Time-reversibility analysis of earthquake magnitude sequences and interevent times series.** *Alejandro Ramírez Rojas*

P57 **Using network science to evaluate cognitive reserve and the interplay between network topology and dynamics in functional brain networks.** *Pedro Ariza*

P58 **Using Ordinal Synchronization to evaluate coordination between dynamical systems.** *Ignacio Echegoyen*

P59 **Horizontal visibility networks procedure to bridge Mexico City pollution data in meteorological time series and chaotic intermittent dynamics** *Rafael Silva Quiroz*

P60 **Entropy Measure as a Key to Determine the Dynamics of a Real Social Network** *Jose Abraham Hernández*

ABSTRACTS

LANET SCHOOL 1: Intro Networks

Network Analytics. Traditional vs. non-traditional methods

Ernesto Estrada

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I will introduce several problems in the traditional network analysis. They are: degree distributions, degree-degree correlation, clustering coefficients, assortativity and shortest path communication. I will discuss the problems that emerge when we try to use these traditional approaches due to the constraints of the data available, the lack of interpretation of the existing indices or wrong initial assumptions about the hypothesis behind the methods. For each case I will show alternative, non-traditional methods, which are based on rigorous mathematical analysis using algebraic, topological and combinatorial methods. All the cases are based on real-world examples and I will make emphasis in the understanding of the methods proposed more than in their technicalities. The students do not require any previous knowledge of network theory and only undergraduate level of mathematics.

LANET SCHOOL 2: Contagion Processes

Contagion Processes

Jesús Gómez-Gardeñes

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In this seminar, we will study the contagion processes in complex networks. First, we will introduce stochastic compartmental models and their analysis through mean field hypotheses. We will also address the generalization of these mean field models to approximate the structure of interactions between individuals (the network) and the calculation of the epidemic threshold [1, 2]. Later we will formalize the dynamics at the individual level, where we consider the particular contacts of each node of the network, formalizing the equations of the Markovian dynamics [3]. We will solve these equations and compare the results with those obtained by means of mean field techniques. Finally, we will cover the study of complex metapopulations [4, 5]. In this case the network nodes represent spatial locations (neighborhoods, cities, regions or countries) and the agents involved in contagion processes inhabit these nodes. Also, the links between the nodes represent the displacements of the agents between the different areas of the system under study. We will study the properties of these systems through Markovian equations and, finally, we will study some real systems for which we have the network of human displacements (origin-destination matrices) and demographic data.

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LANET SCHOOL 3: Multilayer Networks

Mutilayer Networks

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Multilayer networks are attracting large interest because they describe complex systems in formed by several networks indicating interaction of different nature. Examples are ubiquitous from infrastructure to transportation and biological networks. We will describe the state of the art for characterizing and modelling the structure of multilayer networks and for studying their robustness properties.

LANET SCHOOL 4: Brain Networks

Brain Networks

Javier M. Buldú

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Characterizing how the brain organizes its activity to carry out complex tasks is highly non trivial. While early neuroimaging and electrophysiological studies typically aimed at identifying patches of task-specific activation or local time-varying patterns of activity, there has soon been consensus that task-related brain activity has a temporally multiscale, spatially extended character, as networks of coordinated brain areas are continuously formed and destroyed. Up until recently, though, the emphasis of functional brain activity studies has been on the identity of the particular nodes forming these networks, and on the characterization of connectivity metrics between them [1], the underlying covert hypothesis being that each node, constituting a coarse-grained representation of a given brain region, provides a unique contribution to the whole. Thus, functional neuroimaging initially integrated the two basic ingredients of early neuropsychology: localization of cognitive function into specialized brain modules and the role of connection fibres in the integration of various modules. Lately, brain structure and function have started being investigated using complex network theory, a statistical mechanics understanding of an old branch of pure mathematics: graph theory [2]. Graph theory allows endowing networks with a great number of quantitative properties [3], thus vastly enriching the set of objective descriptors of brain structure and function at neuroscientists' disposal. However, in spite of a great potential, the results have so far not entirely met the expectations in that complex network theory has not yet given rise to a major breakthrough, has mainly been used to achieve descriptive goals, and has not yet had an impact on the way neurological or psychiatric pathologies are treated. In this seminar, I discuss possible reasons behind the current state of affairs and point to directions where graph theory could fruitfully be employed. In particular, I illustrate how complex network theory is used to describe functional brain activity, suggest alternatives to current practices, but also propose ways in which it could achieve further fundamental objectives [3, 4, 5].

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PT1: Plenary Talk

Collective Phenomena Emerging from the Interactions Between Dynamical Processes in Multiplex Networks

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Networks are a powerful way to model and study a wide variety of complex phenomena. In the recent years, the study of collective dynamical processes on complex networks has improved our understanding of many complex systems and shed light on a wide range of physical, biological and social phenomena including synchronization, disease spreading, transport and cascades. Of particular interest in these works is the interplay between the structure of the network and its dynamics. In fact, the topology of a network has an effect on the dynamical processes that take place over the network, while some properties of the dynamics can reveal important information on the interaction network. Understanding the relations between structure and dynamics can provide a solid foundation for modeling, predicting, and controlling dynamical processes in the real world. However, save for a few notable exceptions, the majority of the studies so far have considered a single process on a single network, ignoring a very important ingredient: often the components of a complex system interact through two or more dynamics at the same time, and these dynamics usually depend on each other in highly non-trivial ways. In this work we propose a general framework for modelling, through a multiplex network, the coupling of dynamical processes of the same type (e.g. the spreading of two coupled diseases) or of different types (for instance a synchronization dynamics and a diffusion process). Moreover, we demonstrate with a specific example that this coupling mechanism can give rise to the emergence of complex phenomena generated by the interactions between the different dynamical processes.

PT3: Plenary Talk

A unified approach to percolation processes on multiplex networks

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Networks are a powerful tool to represent the heterogeneous structure of interactions in the study of complex systems. But in many cases there are multiple kinds of interactions, or multiple interacting sub-systems that cannot be adequately represented by a single network. Examples include financial infrastructure, informatic and ecological systems. There are many representations of multi-layer networks, appropriate in different Circumstances (see e. g. for a summary). We focus on multiplex networks, which are networks with a single set of nodes present in all layers, connected by a different type of edge (which may be represented by different colours) in each layer. Some interdependent networks, in which different layers have different sets of nodes as well, but the nodes aren't connected between layers by interdependency links, are able to be captured by this construction. One of the fundamental structural properties of a network is its response to damage, that is, the percolation transition, where the giant connected component collapses. In multi-layer networks, interdependencies between layers can make a system more fragile. Damage to one element can trigger avalanches of failures that spread through the whole system. Typically a discontinuous hybrid phase transition is observed, similar to those observed in the network k-core or in bootstrap percolation in contrast to the continuous transition seen in classical percolation on a simplex network. Under a weaker definition of percolation, a more complex phase diagram emerges, with the possibility for both continuous and discontinuous transitions. When invulnerable or seed nodes are introduced, we can define activation and pruning processes, which have different phase diagrams. In a single-layer network (simplex), two nodes are connected if there is at least one path between them along the edges of the network. A group of connected nodes forms a cluster. The giant connected component (GCC) is a cluster which contains a finite fraction of the nodes in the network. The existence of such a giant component is synonymous with percolation. We can study its appearance by applying random damage to the network.

PT4: Plenary Talk

Symmetric States Requiring System Asymmetry in Network Synchronization

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Common wisdom assumes that individual entities are more likely to exhibit the same or similar behavior if they are equal to each other–imagine animals using the same gait, lasers pulsing together, birds singing the same notes, and agents reaching consensus. In this presentation, I will show that this assumption is in fact false in networks of interacting entities. This surprising observation is rooted in a new network phenomenon we term asymmetry-induced symmetry (AIS), in which the state of the system can be symmetric only when the system itself is not. Using spontaneous synchronization as a model process, I will discuss scenarios where the state in which all nodes exhibit identical dynamics (a state of maximum symmetry) can only be realized when the nodes themselves are not identical. AIS can be seen as the converse of the well-studied phenomenon of symmetry breaking, where the state has less symmetry than the system. AIS has far-reaching implications for processes that involve converging to uniform states; in particular, it offers a mechanism for yet-to-be-explained convergent forms of pattern formation, in which an asymmetric structure develops into a symmetric one. AIS also has implications for consensus dynamics, where it gives rise to scenarios in which interacting agents only reach consensus when they are sufficiently different from each other.

MS1: "Networks, Games and Human Behavior"

Network science is the discipline which studies the properties of real-world interacting systems and it describes them as graphs. Network theory has applications in many disciplines including statistical physics, computer science, biology, economics, finance, neuroscience, climatology and sociology, and networks have been found to be ubiquitous in nature and in man-made systems. Evolutionary game theory brings together principles from evolutionary biology with concepts of classical game theory. Evolutionary game theory does not need the assumption of rationality and it describes the dynamics and the evolution of the system. This methodology has been fruitful in modelling complex systems in different fields, spanning from biology to sociology and economy. The intrinsic interdisciplinary framework of both network and evolutionary game theory allows researchers with different backgrounds and points of view to find a broad set of tools useful for solving problems that they face in their respective research areas. In this satellite, in particular, we will focus on applications of network science and evolutionary game theory to human behavior.

Organizers: *Alberto Antonioni and Federico Battiston*

Promoters of Human Cooperation: Results from the Lab

Yamir Moreno

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One of the most elusive scientific challenges for over 150 years has been to explain why cooperation survives despite being a seemingly inferior strategy from an evolutionary point of view. Over the years, various theoretical scenarios aimed at solving the evolutionary puzzle of cooperation have been proposed, eventually identifying several cooperation-promoting mechanisms: kin selection, direct reciprocity, indirect reciprocity, network reciprocity, and group selection. In this talk, we discuss the results of several experiments that were aimed at answering the previous long-standing puzzle, sometimes ruling out some of the theoretical hypotheses and others proposing new mechanisms so far less explored. We conclude by discussing what kind of questions remain and possible ways to tackle them.

How to model the decision making process in Game Theory experiments

Jelena Grujić

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What makes us decide whether to cooperate or not? This subject raised a lot of interest recently, with some papers claiming that pro-social behavior is intuitive and anti-social behavior requires deliberation, and some papers racing a suspicion of the validity of this conclusion. As a main measure for what is intuitive and what deliberate, researchers often use experimental reaction times for one or the other decision. In experimental game theory, no model is provided to fit the distribution of the reaction time (RT), and usually only the mean value and the standard deviations are used. This is clearly wrong, because the RT distribution is not Gaussian. Therefore, a proper model whose parameters have more clear neuroscientific interpretation is necessary in order to answer our original question. Recently, Drift Diffusion Model has been used widely in neuroscience to explain some of the RT in game theory experiments, however only in situations when the player has the full information, like the dictator in the Dictators game. Here we take the Drift Diffusion Model and lift it beyond the scope for which it was originally developed and show that it also explains the data of an iterated Prisoner's Dilemma experiment with human subjects, where the decision is dependant on the on the unknown action of the opponent. Knowing the exact shape of the distribution gives us a new tool to precisely describe the learning process in game theory experiments, isolating the difficulty of the task from personal bias and drop in attention. Using this new tool, we observe that although initially people's intuitive decision is to cooperate, they are not naive and their biases change quickly in an non-cooperative environment. Rational deliberation quickly becomes dominant over an initial intuitive bias towards cooperation, which is fostered by positive interactions as much as frustrated by a negative one. This bias appear however resilient, as after a pause it resets to its initial positive tendency. These results illustrate the potential new insight that can be achieved thanks to a quantitative modeling of human behavior.

Investigating the Coevolution of Institutions within an Adaptive Multiplex Network Model

Francesca Lipari

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The Institutional Theory considers Institutions, Organizations, their populations and families, and their environments as the interdependent outcome of individual actions, culture, institutional influences, and extra-institutional changes. We know that the same institutional change may have differential effects according to different cultural environments. More generally, there have been documented instances where institutions and cultural traits have jointly contributed to the development or the disruption of economic activity like for instance the family in its role as the focal point of social relations and as the foundation of the value system to which descendants refer to. We study socio-economic environments in which culture, expressed in terms of specific informal norms learnt and transmitted by means of socialization and family-practice, and institutions jointly evolve and interact. In order to do that we need a specific representation of the society in which all the players, like economic institutions, organizations, families, are positioned on different and multileveled layers. We characterize conditions under which cultural and institutional dynamics reinforce a specific (e.g., desirable) socio-economic equilibrium pattern, and economies in which on the contrary the interaction between the two weakens this equilibrium outcome. The ending result will depend on specific individual's characteristic and strategies. In fact, for what concerns the first two variables, empirical evidence shows that in our networked society people have a marked tendency to find themselves surrounded by others who are similar to them. Hence the strategies, that they implement to reach the aim of belonging to a specific group, are two: sorting, i.e. people selecting people like them (as in the Schelling's model), and peer effects, i.e. people influenced by people around them (as in the Standing Ovation model). We investigate the dynamics of sorting and peer effects in reaching (or not) mutual coexistence of conventions in a multiplex network topology. We model a social environment through a two-layer multiplex network, in which agents have profiles: a type, i.e. being orange or blue, and a strategy, i.e. rewiring their links or not. The layers can be interpreted as the presence of an informal context, e.g. family, school district, which are mostly fixed over time, and a formal one, e.g. work partnership, in which different agents adaptively restructure their neighbourhood over time. Each agent has a tolerance threshold describing his endurance to a certain level of diversity in its neighbourhood before switching type or strategy. Consequently, agents act according to a mixed motive imitation across the two layers: they conform their strategy to the most frequent one in their neighbourhood on the informal layer and they implement such strategy to their links on the for- mal, adaptive, layer. Strategies and types are randomly distributed in the beginning on two random graph layered topologies. We observe that the initial fraction of rewirers drives multiple and stable final configurations, going from coexistence to polarization of types, through a tipping point. Secondly, the lower the tolerance the more likely segregation takes place. Finally, we relate those results to either choice or opportunity-based homophily in the system.

Sequence of purchases in credit card data reveal life styles in urban populations

Marta González

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Zipf-like distributions characterize a wide set of phenomena in physics, biology, economics and social sciences. In human activities, Zipf-laws are a ubiquitous macro property which can describe for example the words appearance in a text or the purchases type distribution in shopping patterns. In the latter, the overall uneven distribution of transaction type is bound with the micro property of the purchases' temporal relation, typical for each individual. In this work, we define a new framework using a text compression technique on the sequences of credit card purchase to detect ubiquitous patterns of collective behavior. Clustering the consumers by their similarity, we detect five consumer groups. Remarkably, individuals in each consumer group are also similar in age, total expenditure, gender, and the diversity of their social and mobility networks extracted by their mobile phone records. By properly deconstructing transaction data with Zipf-like distributions, this method uncovers sets of significant sequences that reveal insights on collective human behavior.

Reputation Drives Cooperative Behavior and Network Formation in Human Groups

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Cooperativeness is a defining feature of human nature. Theoreticians have suggested several mechanisms to explain this ubiquitous phenomenon, including reciprocity, reputation, and punishment, but the problem is still unsolved. Here we study, through experiments conducted with groups of people playing an iterated Prisoner's Dilemma on a dynamic network, the role of reputation in cooperation. While this mechanism has already been observed in unstructured populations, we find that it acts equally when interactions are given by a network that players can reconfigure dynamically. Furthermore, the observations reveal that memory also drives the network formation process, and cooperators assort more, with longer link lifetimes, the longer the past actions record. The analysis demonstrates that reputation can be very well quantified as a weighted mean of the fractions of past cooperative acts and the last action performed. In addition, the experiments show that the punishing mechanism implicit in the network plasticity requires knowledge of the partner's reputation in order to work as a cooperation driver. Otherwise, rewiring simply leads to cooperation levels similar to those found in rigid networks. This conclusion aligns nicely with the experimental observation that good reputation and having more social supporting partners are correlated.

Spatial patterns in evolutionary games on scale-free networks and multiplexes

Kaj Kolja Kleineberg

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The evolution of cooperation in social dilemmas on structured populations has been studied extensively in recent years. Whereas many theoretical studies have found that heterogeneity of the network of contacts favors cooperation, the impact of spatial effects in scale-free networks still lacks understanding. In addition to being heterogeneous, real contact networks exhibit a high mean local clustering coefficient, which implies the existence of an underlying metric space. Here, we show that evolutionary dynamics self-organize into spatial patterns in the underlying metric space of scale-free networks. In particular, cooperators form clusters that can survive in social dilemmas, similar to the case of lattice-like topologies. We show that under certain conditions spatial clusters are more efficient than the most connected nodes in sustaining cooperation and that heterogeneity does not always favor—but can even hinder—cooperation in social dilemmas. Finally, we discuss the existence of similar mechanisms in heterogeneous multiplexes.

MS2: "Advances in Multiplex Networks"

The existence of different types of connections between nodes in real networks has promoted the study of the emergent properties that arise from this particular structural characteristic. These multiplex networks represent nowadays one of the most fascinating paradigms in complex networks, where the many unexpected or peculiar results found in the last years have contributed to the existence of a large community of researchers contributing to their understanding. This minisymposium gathers a few of the top researchers in the field of multiplex networks, which will explain recent advances in the analysis of their structure and dynamics.

Organizers: *Sergio Gómez*

Community Structure in Multilayer Networks

Mason A. Porter

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In the study of networks, mesoscale features such as "communities" (dense sets of nodes that are connected sparsely to other parts of a network) can lead to insights into ideas such as friendship circles synchronized brain regions, migration patterns, and more. In this talk, I'll discuss some approaches for detecting multilayer community structure (including a local method based on dynamical processes on networks), a new flexible generative model that can be used for testing community-detection methods, and various applications.

Communicability geometry in multiplexes

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I will start making a gently introduction to the concept of communicability in networks. Then, I will prove analytically how a Euclidean geometry emerges from the way in which information diffuses on a network. This induces an embedding of any network on a (n-1)-dimensional Euclidean sphere in which the separation between the nodes in the surface of the sphere is provided by the communicability distance. The average angle between the position vectors of the nodes in the sphere-the communicability angles-accounts for the spatial efficiency of the network as a whole in the communicability space. Then, I will extend all these concepts to the study of multiplexes. In this case we will describe shortest communicability paths inside a layer and between layers, the spatial efficiency of a layer in the multiplex and of the multiplex as a whole. I will provide some illustrative examples of their implications.

Diffusion and reaction on multiplex networks

Albert Díaz-Guilera

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Multiplex networks are systems where activator and inhibitor species occupy separate nodes in different layers. Species react across layers but diffuse only within their own layer of distinct network topology. This multiplicity generates heterogeneous patterns with significant differences from those observed in single-layer networks. Remarkably, diffusion-induced instability can occur even if the two species have the same mobility rates; condition which can never destabilize single-layer networks. The instability condition is revealed using perturbation theory and expressed by a combination of degrees in the different layers. Our theory demonstrates that the existence of such topology-driven instabilities is generic in multiplex networks, providing a new mechanism of pattern formation.

Epidemic spreading in localized environments with recurrent mobility patterns

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The spreading of infectious diseases has been proved to be radically dependent on the population networked structure of interactions and on the mobility of individuals. A particularly interesting scenario is that where the structure of the social contacts of the individuals is not completely well mixed nor completely structured, but offers an intermediate level of description. In this work we present a discrete-time markovian formulation for the spreading of epidemics in bipartite metapopulations with particular recurrent mobility patterns. The source of inspiration for this model is understanding the effect of the mobility dynamics and social interactions of college students on the spreading of influenza-like illnesses in a college campus. In the majority of U.S. universities, most of the students live inside campus, in residence halls and dorms. The main activity of the students is dominated by a recurrent pattern of mobility that consists on attending classes and going back to the dorms. This recurrent pattern of mobility between the bipartite structure of dorms and classes, is identified as a major player on the endogenous spreading of diseases between students. Here we create a theoretical model that allows us to quantify the final spreading of a disease taking into account the distribution of individuals in locations, the flow of individuals between these locations, and the mobility of the students. This model as well allows us to discuss which are effective measures of containment of an infectious disease in this scenario.

PT5: Plenary Talk

On the influence of competition and mutualism on the biodiversity of mutualistic ecosystems

Yamir Moreno

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Relations among species in ecosystems can be represented by complex networks where both negative (competition) and positive (mutualism) interactions are concurrently present. Recently, it has been shown that many ecosystems can be cast into mutualistic networks. However, the role of competitive and mutualistic relations on the species' biodiversity is not fully understood. Here, we discuss a framework based on the concept of multilayer networks, which naturally accounts for both mutualism and competition. Hence, we abandon the mean field hypothesis and show, through a dynamical population model and numerical simulations, that there is an intricate relation between competition and mutualism. Specifically, we show that when all interactions are taken into account, mutualism does not have the same consequences on the evolution of specialist and generalist species. This leads to a non-trivial profile of biodiversity in the parameter space of competition and mutualism. Our findings emphasize how the simultaneous consideration of positive and negative interactions can contribute to our understanding of the delicate trade-offs between topology and biodiversity in ecosystems and call for a reconsideration of previous findings in theoretical ecology, as they may affect the structural and dynamical stability of mutualistic systems.

C1: Structure

Geometric correlations mitigate the extreme vulnerability of multiplex networks against targeted attacks

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We show that real multiplex networks are unexpectedly robust against targeted attacks on high degree nodes, and that hidden interlayer geometric correlations predict this robustness. Without geometric correlations, multiplexes exhibit an abrupt breakdown of mutual connectivity, even with interlayer degree correlations. With geometric correlations, we instead observe a multistep cascading process leading into a continuous transition, which apparently becomes fully continuous in the thermodynamic limit. Our results are important for the design of efficient protection strategies and of robust interacting networks in many domains.

Beyond classical metrics on complex

Nethali Fernando

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A “metric” is a function that defines a distance between each pair of elements of a given set. It *metric* is an ordered pair (M,d) where M is a set and d is a function$d : M \times M \rightarrow \mathbb{R}$ such that for any $x, y, z \in M$, the following hold:

- $d(x, y) \geq 0$ (non-negative)
- $d(x, y) = 0 \Leftrightarrow x = y$ (non-degenerate)
- $d(x, y) = d(y, x)$ (symmetric)
- $d(x, z) \leq d(x, y) + d(y, z)$ (triangle inequality)

We can define a metric(s) on the node set of a given network. Such metrics on networks play a vital role in applications as well as in the study of intrinsic characteristics of complex networks. The theory of modulus of curve families in the plane was originally introduced by Beurling and Ahlfors to solve famous open questions in function theory. It has then been extended over the years to families of curves in Euclidean spaces and to abstract metric spaces as well. Given a network, modulus of a family of walks tells us how "rich" this family is by taking both the length and the number of walks into account. For families of walks that connect two nodes, p-Modulus generalizes and interpolates known classical notions such as shortest path distance (the reciprocal of ∞-Modulus), effective conductance (2-Modulus) and min-cut (1-Modulus). It is known that effective resistance (the reciprocal of effective conductance) and shortest-path distance on networks serve as metrics. We prove that the reciprocal of the p^{th} root of p-modulus is a metric for $1 < p < \infty$. We also prove that at p=1, the reciprocal of min-cut is an “ultrametric", which is a much stronger version compared to a normal metric (a metric d is an ultrametric if for every a,b,c in the set we have: $d(a, b) \leq \max\{d(a, c), d(c, b)\}$). We further explore the characteristics of this metric through the introduction of “antisnowflaking exponent". This is the supremum of $t \geq 1$ such that the metric raised to the power “t" is still a metric on all families of networks. Our main result is that this supremum is the Holder conjugate exponent of p. We first observed this fact through our numerical experiments and then in simple cases, by looking at cycles and complete graphs. Our proof relies on the theory of Fulkerson duality.

Mathematical analysis of k-path Laplacian operators on networks

Ernesto Estrada[1], *Ehsan Hameed*[2], *Naomichi Hatano*[3] *and Matthias Langer*[4]

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In this work we focus on dynamical process on networks in which nodes not only interact to its nearest neighbours but also through some long-range influences (LRIs) [1]. Here we study a diffusive process controlled by the generalised k-path Laplacian operators (LO) L_k.The introduction of the k-path LOs can help in conducting more precise studies of a network's dynamics in different applications.The main goal of this research is to study a generalised diffusion equation using the transformed generalised k-path LOs for locally finite infinite networks.
First, we prove a few properties of these operators, such as their boundeness and self-adjoitness [2].We studied three different transformations of the k-path LOs, namely, Laplace, factorial and Mellin. We proved that all three transformed k-path LOs are also in general bounded and self-adjoint. Finally, we used the transformed k-path LOs to obtain a generalised diffusion process for an infinite path graph. We prove analytically here that under the Mellin transform of these k-path LO for certain values of the parameter, $1 < s < 3$, a superdiffusive dynamics appears. On the contrary, the generalized diffusion equation using Laplace and Factorial transformed operators always produce normal diffusive processes.
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C2: Biological Applications

The joint influence of competition and mutualism on the biodiversity of mutualistic ecosystems.

Carlos Gracia-Lázaro[1], *Laura Hernández*[2], *Javier Borge-Holthoefer*[3] *and Yamir Moreno*[4]

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The origin and the consequences of the nested structure of mutualistic ecosystems as well as the pertinent characterisation of such ordering are a matter of strong debate in the ecological community. The relationship between the structure of mutualistic ecosystems and the dynamics that led to this structure is still an open problem. In the seminal paper of May [1], the ecosystem is described by a dynamical linear model, with a random matrix interaction. His results show that a large ecosystem with high conectivity (the connectivity being associated to the complexity of the system) is unstable. Since then, special attention has been paid to the structure of the interaction matrix. Bastolla et. al [2] study a population dynamics model that includes both types of interactions. Two regimes are analysed : weak mutualism, leading to a linear population equation and strong mutualism, where the mutualistic interaction term is non-linear. All interactions are treated in mean-field approach except for the case of weak mutualism, where a more realistic mutualistic term is built based on natural bipartite interaction matrices. They conclude that the nested character of the interactions minimizes competition allowing for an increase of biodiversity. In the terms of May's work, the nested structure of the interaction network allows for a larger ecosystem to be stable. A recent article [3] discusses the importance of structural stability of mutualistic ecosystems. As the parametrization of the studied models is quite arbitrary, it becomes crucial to assess how the obtained results behave face to the variation of these parameters. Here, we introduce a framework based on the concept of multilayer networks, which naturally accounts for both mutualism and competition. Hence, we abandon the mean field hypothesis and show, through a dynamical population model and numerical simulations, that there is an intricate relation between competition and mutualism. Specifically, we show that when all interactions are taken into account, mutualism does not have the same consequences on the evolution of specialist and generalist species. This leads to a non-trivial profile of biodiversity in the parameter space of competition and mutualism. Our findings emphasize how the simultaneous consideration of positive and negative interactions can contribute to our understanding of the delicate trade-offs between topology and biodiversity in ecosystems and call for a reconsideration of previous findings in theoretical ecology, as they may affect the structural and dynamical stability of mutualistic systems.

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The use of a drug-gene perturbation network for the study of drug side effects: The case of drug-induced peripheral neuropathy

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In the drug discovery process, the evaluation of both therapeutic efficacy and safety are considered equally important. Nonetheless, many available drugs in the market therefore are capable of causing undesirable side effects. The consequences of these can range from minor discomfort to therapeutic inefficacy, and all the way to serious complications. In many cases, it is difficult to identify a mechanism through which the drug may produce these effects. An example of this is drug-induced peripheral neuropathy, a loss of function in the axons of the peripheral nervous system. Through literature mining of drug labels, we previously collected 234 U.S. FDA-approved drugs causing treatment-associated peripheral neuropathy (neuropathy-inducing drugs or NIDs). From Connectivity Map (CMap), a collection of gene expression signatures obtained from drug perturbation assays on cell lines, we collected transcriptional perturbation data for 98 NIDs and constructed a drug-gene perturbation network. A NID is linked to a gene, when it has either an up- or down-regulation effect in the gene's expression. As gene expression signatures take the form of ranked lists based on differential expression, we define an up- or down-regulated gene as one above or below a rank threshold. Therefore, each drug is connected to a defined number of genes in the network; however, each gene may be connected to any and up to the total number of drugs in the network. With this model, we constructed a bipartite network consisting of 98 drug and 7,138 gene nodes with 19,600 interactions among them. This network was evaluated against a null model based on 5,000 networks of randomly ranked expression profiles, effectively reconnecting each drug to randomly selected genes. The structure of our NID network was significantly different from those of the randomly generated networks. We hypothesized that the most connected genes in this network (degree >= 10) were more likely to be involved in neuropathy driving mechanisms, and identified 64 such genes. To determine if these genes are highly connected only to NIDs, or whether they are generally susceptible to any drug perturbation, we generated 5,000 drug-gene perturbation networks derived from CMap profiles for randomly selected non-NIDs. Then, we constructed frequency distributions of degree for a given gene across the non-NID networks, and evaluated whether the degree observed in the NID perturbation network was expected. We found 27 out of the 64 highly connected genes were specifically associated with NIDs. These NID-specific genes are involved in cellular mechanisms such as cytoskeleton organization, mitochondrial function, solute transport, signaling, and transcriptional regulation, which can be linked to neurological damage and therefore neuropathy. We also discovered that these NIDs can affect wound healing and circadian function, whose role in a neuropathic setting remains to be studied.In conclusion, we integrated literature and experimental data to study neuropathy as a drug side effect. Our network-based approach allowed us to identify candidate genes that may be involved in the development of drug induced neuropathy, as well as generate hypotheses regarding the molecular mechanisms behind this condition.

Regulatory Signaling Networks Related to Fertilization

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In order for a spermatozoon to meet and fertilize an egg, it must regulate its motility in response to specific molecular cues from the medium. Regarding marine external fertilizers such as sea urchins, their spermatozoa respond to egg-released peptides by means of a signal transduction pathway located at their tails (flagella) that ultimately leads to oscillations in the intracellular calcium concentration $\left(\left[Ca^{2+}\right]_i\right)$; the latter signal is capable of changing flagellum curvature and therefore modulates sperm swimming path. Disentangling the set of molecules and biochemical processes that generate these calcium fluctuations has been a challenging task for experimental research during last decades. For a better understanding of this signaling pathway, we have constructed a family of logical regulatory network models that differ in the set of ion channels being considered in order to test contrasting hypothesis; after having explored such scenarios, we have found one that manages to reproduce biochemical and electrophysiological behaviors previously observed as well as to provide predictions, some of which we have confirmed within our research group with new experiments. With our systems biology approach, we have gained insight on how drugs acting on ion channels might alter the calcium fluctuation temporal behavior and, furthermore, we have been able to predict that CatSper is the dominant calcium channel. This latter channel is a matter of intense research in mammals since it offers an attractive target for contraceptives development. Overall, our results may be relevant to fertility issues. We also present preliminary work on mammals. Additionally, we comment on a reduction method based on dynamical regime features of the network such as robustness, redundancy and criticality, that coincides with an alternative continuous model built with a bottom-up approach.

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Loss of trans-regulation in breast cancer

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Breast cancer is a complex heterogeneous disease. Common hallmark features of cancer can be found. Their origin may be traced back to their intricate relationships governing regulatory programs during the development of this disease. To unveil distinctive features of the transcriptional regulation program in breast cancer, a pipeline for RNA-seq analysis in 780 breast cancer and 101 healthy breast samples, at gene expression and network level, was implemented. Inter-chromosomal relationships between genes resulted strikingly scarce in a cancer network, in comparison to its healthy counterpart. We suggest that inter-chromosomal regulation loss may be a novel feature in breast cancer. Additional evidence was obtained by independent validation in microarray and Hi-C data as well as supplementary computational analyses. Functional analysis showed upregulation in processes related to cell cycle and division; while migration, adhesion and cell-to-cell communication, were downregulated. Both the BRCA1 DNA repairing signalling and the Estrogen-mediated G1/S phase entry pathways were found upregulated. In addition, a synergistic underexpression of the gamma-protocadherin complex, located at Chr5q31 is also shown. This region has previously been reported to be hypermethylated in breast cancer. These findings altogether provide further evidence for the central role of transcriptional regulatory programs in shaping malignant phenotypes.

PT6: Plenary Talk

Spreading Processes on Networks

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Diseases, rumors, memes, "alternative facts", and many other things spread on networks, whose structure has a significant effect on spreading processes. In this talk, I will give an introduction to spreading processes on networks. I will discuss several generalizations of "threshold" contagion models, in which spreading occurs when some kind of peer pressure matches or exceeds some kind of internal resistance of nodes. Generalizations that I will discuss include multi-stage contagions, synergy from nodes other than nearest neighbors, incorporation of timers to augment stubbornness thresholds, and the modeling of hipsters. I will also briefly discuss current challenges, such as studying spreading processes on multilayer networks and developing signal-based models of spreading dynamics.

Poster Session and Cocktail (Conference Hall)

Identifying multiple influential spreaders in complex networks through a semilocal method P1

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Spreading phenomenons in networks have been studied in many literatures, such as the propagation of disease, the spreading of rumor, the cascading failure of power grid, the advertisement of products, etc. Among all the theoretical and experimental researches, how to effectively identify a set of influential spreaders in complex networks is of great value, which can help to inhibit the rapid spread of epidemics, promote the sales of products by word of mouth advertising, and so on. In the research field of social networks, such kind of problem about how to select a small subset of nodes as initial spreaders to achieve the maximum influence is often referred to as Influence Maximization. Traditionally, a naive strategy is to select the top ranked nodes as identified by some centrality indices, and other strategies are mainly based on greedy methods and heuristic methods. However, as most of those approaches did not concern the connections between nodes, the distances between the selected spreaders are very close, which leads to a serious overlapping of their influence. As a consequence, the global influence of the spreaders in networks will be greatly reduced, which largely restricts the performance of those methods. In our work, a simple and efficient method is proposed to identify a set of discrete yet influential spreaders. By analyzing the spreading paths in the network, we present the concept of local effective spreading paths and measure the influence of nodes via expectation calculation. Extensive experiments conducted on various undirected and directed networks ranging from thousands of node to hundreds of thousands of nodes all show that our method is superior to other comparison methods. With the increase of spreaders and effective spreading rate, the advantage of our method becomes more and more significant. To verify the adaptability of our method, we tested it on other two spreading models, and the results also demonstrate its effectiveness. Though our method is a parameterized algorithm, further experiments confirm the stability of our method over a wide range of the parameters. Actually, the conduction of our method is not so rigorous, which slightly limits the accuracy. In the future, we will make more in depth analysis of spreading dynamics and leverage the accuracy further.

P2 Multiplex pagerank based on interlayer mutual information

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In many natural and industrial complex systems, the complex and diverse interaction of time-varying characteristic and other types among entities, shows the ' multilayer' features. Multiplex networks is hence a new model to describe these features where the same nodes interacting with each other on different layers. Ranking nodes in multiplex networks is challenging due to the multiple links and layers and seeking a measure that reflect the importance of nodes in all layers is necessary. In this paper, a ranking algorithm is proposed to assess the central node in multiplex networks. In particularly, we use the interlayer mutual information to characteristic the intensity of the interaction between layers. Considering the effect of node centrality in each layer, we develop a multiplex pagerank algorithm(Multirank). Applying this algorithm to two emprical social multiplex networks, the results show that, Multirank, extended from pagerank in single networks, shows the considerable ability to find central node in multiplex networks, and also uncover the hidden information that is unable to obtain from pagerank.

Identifying Common Biological Processes between Phenotypes using Common Connection Pattern: A new Method Based on Network Biology Approach P3

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Network biology has allowed the study of complex molecular relationships existing in a cell, by means of data obtained from high-throughput techniques, with that, some hypothesis about underlying biological processes about the origin and/or development of specific phenotypes have been generated. On the other hand, the typical approach in order to generate molecular hypothesis relating two or more phenotypes has been carried out by identifying common molecular elements, such as genes, between phenotypes. Recently, the methodologies based on network theory allow us to go beyond the shared component paradigm to the shared biological process between phenotypes. These methodologies are based on the detection and comparison of network modules. In most cases, this approach ignores the stored information in the totality of network or multi-omic information is joined to create a unique network which can generate background noise in the final results. Hereby, we developed a method called Common Connection Pattern (CCP) which permits the identification of common connectivity patterns between phenotypes from a specific molecular information (Co-expression, protein-protein interaction, regulation, among others) obtaining, for each of them, the sub-networks with diameter greater than zero, being considered each of them as a CCP. In order to asses the predictibility of the CCP approach, we compared four neuronal disorders: Alzheimer's disease (AD), Parkinson's disease (PD), Multiple Sclerosis (MS) and Amyotrophic Lateral Sclerosis (ALS) sen at the molecular abstraction layers of co-expression and protein-protein interaction. In the co-expression layer, we were able to establish the existence of 1 CCP between MS and ALS, 3 CCPs between PD and ALS, 1 CCP between PD and MS and 1 CCP between AD and ALS. Additionally, we identified the solitary components in the intersection networks between the different comparisons getting 7 shared components between AD and PD, 5 components between AD and MS, 1 component between AD and ALS, 26 components between PD and MS, 11 component between PD and ALS and 16 components between MS and ALS. In the protein-protein interaction layer, we identified 4 CCPs between ALS and MS, 2 CCPs between PD and ALS and 2 CCPs between PS and MS. In the case of shared components, we identified 2 components between AD and MS, 2 components between AD and ALS, 31 components between PD and MS, 22 components between PD and ALS and 17 components between MS and ALS. Moreover, enrichment analysis for GO categories showed that, for example, one CCP between PD and ALS in the co-expression layer is related to the signal recognition particle process. Additionally, through an exhaustive search in the literature, we were able to establish the component LASP1 related to ALS with experimental data published previously. The Common Connection Pattern method has shown to be ideal for the identification of possible common biological processes between phenotypes through a network biology approach. CCP also allows to discern between molecular abstraction layers to generate more accurate hypothesis and permits the addition of new biological layers that can aid into the interpretation of phenotypes without changing previously obtained results.

P4 Competitive-Cooperative-mixed peer-to-peer multiagent based systems

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Evolutionary game theory and network theory are approaches leading to models and analysis of human or animal cooperation and competition patterns [1-2]. On one hand, competition markets that ensure general equilibrium with great efficiency on how economic resources are used, lead to monopolies (or oligopolies). In this scenario, agents compete among each other driving economic growth that lean toward a more efficient market, but of course may induce layoffs and agent disappearance [3]. On the other hand, cooperation in ants or bees colonies can be observed in Nature [9]. It has been shown that when all agents act in good faith prioritizing the common good, they receive a mutual benefit allowing them to surpass their capacity [6].While pure competitive or collaborative multiagent systems have been studied in previous works, the mixed scenario has not been investigated yet. In this work we propose a model that considers competition and collaboration between different sets of agents in the system.A multiagent based model for a system of competitive-cooperative agents aiming at growth is discussed, generalizing previous investigations [4-6]. It is based on a set of prey-predator-like Verhulst-Lotka-Volterra differential equations. Competition and cooperation mixed schemes are allowed between agents; the strength of the interaction type depends on the “agent size", thereby establishing a peer-to-peer modulated interaction scheme [7]. Through an exhaustive numerical simulation based analysis, we investigate the dynamics of a network with 10 agents who can be fully all cooperating, all competing or conform to a mixture of such attitudes.It is emphasized that in the fully collaborative scenario, agents are able to increase their size beyond the no-interaction case limit, in marked contrast with the competitive case. Interestingly, for the 50/50 competition/collaboration scenario, a chaotic behavior is found. We present a thorough phase space analysis, illustrating the “size trajectories” of coupled cooperative of collaborative agents.Pertinent applications of the model and present results can be imagined from crystal growth to economic performance. The influence of external fields, geophysical or media [8], for example, is still an open question.

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Diffusion, adoption and transfer of innovations to rural development, a field of social complexity and structural analysis P5

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The systems of diffusion and adoption of innovations (as well as the transfer of technology), to rural development, in México and Latin America, they ended up considering the classic model of Everett Rogers as a norm to follow without taking into account the complexity of social processes and the different dynamics of the social actors that are involved in these processes. There is no doubt that in each social system each person is responsible to make their own decision about what to adopt, transfer and diffuse. But this decision is not made it in an isolated way but in a social way, is meant in a sistemical continuum among the individual and the socio-institutional system. Thus, the transfer, diffusion and adoption of technologies and knowledges are community experiences and dynamical works which are in constantly change. These experiences are determined by central facts like the social actors and the structures of social links that prevail between them. Unfortunately, the non critical application of the classical model of transfer, diffusion and adoption of innovations produced a partial point of view about the social complexity of the peasants and farmers, thus they were been considering by the institutions and researchers as isolated actors and classified around time in which each peasant could adopt, transfers and diffuse a technology and knowledge. This derived to established a unilateral paradigm of development and diffusionism based much more in the technologization and technicity of the processes in which the communication it was only an instrument but not a complex social process. Thus, the peasants stopped being considered as part of a structured and structurant social system in which exist constantly processes of linkage between the social actors. With the Social Network Analysis we are trying to recuperate the profile of the process of transfer, adoption and innovation of technologies and knowledges, to rural development, as a process of the social complexity. A process in which are involved multiple social actors: peasants (women and men), farmers, rural organizations, public and private institutions, local and international organism, banks, enterprises, non government organizations, universities and research institutions, among others. With this, we are assuming that the process of transfer, adoption and innovation of technologies and knowledge scale in a different way. To do the latest, we analyzed different social structures of linkages that were built by a group of farmers and rural producers at México to maintain their agriculture and livestock production microenterprises in force. This permitted us visualize and measure the structure of social support around these enterprises as well the conception about the technology innovation as a social network process.

P6 Random Rectangular Networks

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Many real-world networked systems are embedded into geometrical spaces. These include urban street networks, wireless sensor networks, the networks of channels in fractured rocks, and crops in fields. For modelling these spatial networks it is necessary to have a model that captures the spatial embedding of these of systems. The random geometric graph (RGG) model has been widely used for this purpose. The RGG is a random graph model in which the nodes are distributed uniformly at random in a unit hypercube, and each pair nodes is connected if the distance between them is no larger than a fixed radius r. Previous work has focussed mostly on an infinite limit of the number of nodes, and with toroidal boundary conditions. Such assumptions are not realistic in many real-world applications. Although some of these systems are roughly square shaped, such as San Francisco, others are more elongated, such as Manhattan. Then, it is desirable to investigate the effects of having a finitely many nodes, closed boundary conditions, and varying the shape where the nodes are distributed. As a first step in generalising the model, we considered unit rectangles $[0, a] \times [0, a^{-1}]$ and observed that the elongation affects important structural parameters of the graph [1]. Obviously, other spatial graph models can be consideredin rectangular regions, such as the relative neighbourhood graph (RNG).Here we investigate RRGs and determine analytical expressions for the expected value of the average node degree, and bounds on the diameter, the average path length, the algebraic connectivity, the connectivity, and the largest eigenvalue of the adjacency matrix. We have also investigated the RNG, finding bounds for the diameter and the algebraic connectivity. We then applied these rectangular models to rock fracture networks from core samples taken from the Gulf of Mexico (Fig. **??**), and found the optimum values of the elongation parameter to best reproduce the rock fracture networks, which varied between rocks. These were then compared to the Erdős-Rényi and Barabási-Albert models, and we determined that the rectangular RNG model was the most suitable.

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Fragmentation, integration and macroprudential surveillance of the US financial industry: Insights from network science P7

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Drawing on recent contributions inferring financial interconnectedness from market data, our paper provides new insights on the US financial industry over a long period of time by means of several tools coming from network science. To that end, we retrieve unobserved directed links among financial institutions and represent the resulting network by applying a Time-Varying Parameter Vector AutoRegressive (TVP-VAR) model as well as Granger causality statistical tests on stock market returns. This procedure enables us to reconstruct a fully dynamic network in the sense that connections are let to evolve through time. The resulting financial system consists in a large set of 154 financial institutions, embedding all the banks, broker-dealers, insurance and real state companies listed in the Standard $\&$ Poor's 500 index over the $1993 - 2014$ period. Looking alternatively at the individual then sector-, community- as well as system-wide levels, we are able to support well-known features of the financial markets such as the dramatic fall of connectivity following Lehman Brothers' collapse. More importantly, by means of less traditional metrics such as sectoral interface or measurements devoted to the analysis of contagion/difussion processes. Our results document the co-existence of both fragmentation and integration between firms independently from the sector to which they belong, and doing so, question the relevance of exisiting macroprudential surveillance frameworks which have been mostly developped on a sectoral basis. Overall, our results improve our understanding of the US financial landscape and may have important implications for risk monitoring as well as macroprudential policy design.

P8 Unveiling stable chaos in synchronization of coupled Bernoulli shift maps

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The Bernoulli map is possibly the simplest example of chaotic system and it is widely used as a prototype for chaos in applications since it is relatively easy to deal with, both numerically and analytically. Also, usually models for high-dimensional chaotic systems are built by coupling several chaotic low-dimensional maps. It is natural to combine both approaches and study the dynamics of coupled Bernoulli maps. Among several phenomena that arise in such systems, chaos synchronization is probably the most studied and remarkable example. One mathematical approach to necessary conditions under the coupling scheme in order to observe synchronization is the computation of the Master Stability Function (MSF) of the synchronized state (S) - it provides the conditional (transversal) Lyapunov exponents whose negativity implies the transversal stability of S. Once the Bernoulli map is uniformly expanding, MSF analysis predicts uniform convergence to S. However, it is observed that typical trajectories experience several detours from the uniform convergence. This is heuristically explained due to discontinuity of the Bernoulli map: when a trajectory is close to a discontinuity, it can occur that two maps are at "different sides" of it, generating a "jump" away of S. The magnitudes of such jumps as well as their frequencies are uncorrelated and aperiodic despite the negativeness of the transversal Lyapunov exponent. Thus, it is said that transversal dynamics exhibit stable chaos. It is possible only if the distance to S is finite. Since it is a finite-size phenomenon, one could expect that the local (linear) analysis would be "blind" to it. However, finite-size analysis usually introduces a new parameter, the size scale, which makes the analytical study difficult or even unfeasible. Hence, it would be convenient to develop a tool to handle this phenomenon at a local level. To this end, some recent ideas of constructing hybrid chaotic dynamical systems by adding a discrete-time switching into a continuous-time (otherwise periodic) oscillator are applied to create a hybrid system which reproduces the dynamics of a system composed of two coupled Bernoulli maps. The main advantage is that the dynamics of this new, “expanded”, system is continuous: thus those unexpected “jumps” are mapped to finite-time but continuous deviations to S. That is, now one can associate those excursions away from S to local transversal instabilities in the vicinity of a subspace that is, on average, transversely stable. Emphasis here on “on average”: there are finite-time attractions and repulsions to S depending if the trajectory is close to a transversely stable or unstable region of S, but the net effect is attraction. This effect can be explained by, and in fact is due to, the coexistence of atypical unstable periodic solutions embedded in S with different transversal stabilities, a phenomenon called unstable dimension variability (UDV). Several consequences of the occurrence of UDV are discussed here but it is its local nature the main point of this work: the introduction of the extended hybrid system provides a local, i.e. linear, explanation to the observed dynamical behavior associated to stable chaos.

Controlling Quantum Entanglement Study in Quantum Complex Networks through Noise Control P9

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We investigate the propagation of noise in a quantum complex network of mixed states consisting of N stations each one with N-1 qubits. Each station represents a node of the network while the links are established by a maximal entanglement state of two qubits of different stations using local measures assisted by classical communication between nodes (LOCC). The structure of the network is based on the Erdös-Rényi model taking the degree distribution of the scale-free networks and assigning a connection probability p given by the entangled state of the qubits. The short-path-lengths and clustering distributions of the network and subgraph formation thresholds, network bridges, giant components and hubs are calculated. The network's dynamic is studied through phase transitions in the network mediated by the degree of perturbation due to the decoherence of the entangled states (treated as noise in the network), measuring the resilience of the network due to possible failures in the stations. Finally, we study the controllability parameters for the system that reduce the networks's sensitivity to noise, optimizing as far as possible the transmission of information through the network.

study of homogeneity and spatial autocorrelation of homicides in Mexico. P10

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The Gini index (G) is a measure of inequality. Here we use this index to evaluate the murder rates per 100,000 habitants, in each of the 32 entities of Mexico. For the evolution of G between 1997 and the beginning of 2017, we observe that there are important variations in the murders rate. Particular cases were evaluated per year an per month. Our results show both stability and unstability in the evolution of G for the observed period. Moreover, this study also proposes to find correlations between neighbor states. We use the Moran's index to quatify global and local spatial autocorrelations in our data of murder rates. We find different levels of correlation.

P11 Detection of money laundering communities in the banking system through network theory.

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Money laundering is a worldwide problem that has been classified as a financial weapon of war given that can be used not only to hide ill-gotten gains but also to finance further criminal operations, and current methods to detect this behaviour tends to focus on individuals and especially those who have some kind of criminal history. Which isn't enough to detect money laundering given that usually involves individuals who cooperate to perform this action, and therefore the existence of this activity may be only apparent when it is considered the collective behaviour of many individuals.
Given that this activity is very prominent in the banking system, this work focus on a method that allows to study a large number of banking transactions to analyse suspicious behaviour to detect the existence of fraudulent communities and also to minimize the risk of false positives.
Said method first must consider two types of transactions common to laundering operations: international funds transfers and large cash deposits. The raw data provide details of each transaction (amounts, requested currency, geological location of accounts and companies, etc.) and provide additional information on the sending or receiving parties.
To be possible to construct the network, every transaction is modelled as a set of edges connecting sending parties with receiving parties and transactions may include multiple senders and receivers, thus each transaction may be represented by multiple edges connecting all sending parties to all receiving parties. Also cyclic edges are allowed, as parties may deposit cash into their own accounts, or transfer funds between accounts held in different countries/companies.
Thus the network is weighted and directed, and the method is based in the study of community detection using generalised clustering coefficient, weighted rich-club effect, and the understanding of social/economic networks growth mechanisms.

Modeling Temporal Networks as an N-body Problem P12

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Temporal networks that arise due to the interactions between mobile agents, like certain kinds of temporal social networks (e.g., face-to-face interaction networks), can be modeled in 2-dimensional Euclidean spaces. In these spaces, each node is a random walker whose motion is biased by the attractiveness of other nodes in close spatial proximity. While such simple models can accurately reproduce some basic universal properties of temporal networks, e.g., the bursty nature of interactions, they cannot accurately reproduce more complex properties. Motivated by the observation that mobility (especially human) is not random, but often driven by node similarities, in this work we show that temporal networks can be modeled as an N-body problem. Specifically, we assume that nodes are particles whose motion is driven by pairwise similarity forces. We consider potentials between nodes that do not depend on their physical location in the space, but instead are determined by a hidden metric space where distances abstract node similarities. Our N-body simulations show significant improvements over random walk based approaches, capturing more complex properties of real temporal networks. Temporal networks that arise due to the interactions between mobile agents, like certain kinds of temporal social networks (e.g., face-to-face interaction networks), can be modeled in 2-dimensional Euclidean spaces. In these spaces, each node is a random walker whose motion is biased by the attractiveness of other nodes in close spatial proximity. While such simple models can accurately reproduce some basic universal properties of temporal networks, e.g., the bursty nature of interactions, they cannot accurately reproduce more complex properties. Motivated by the observation that mobility (especially human) is not random, but often driven by node similarities, in this work we show that temporal networks can be modeled as an N-body problem. Specifically, we assume that nodes are particles whose motion is driven by pairwise similarity forces. We consider potentials between nodes that do not depend on their physical location in the space, but instead are determined by a hidden metric space where distances abstract node similarities. Our N-body simulations show significant improvements over random walk based approaches, capturing more complex properties of real temporal networks. Temporal networks that arise due to the interactions between mobile agents, like certain kinds of temporal social networks (e.g., face-to-face interaction networks), can be modeled in 2-dimensional Euclidean spaces. In these spaces, each node is a random walker whose motion is biased by the attractiveness of other nodes in close spatial proximity. While such simple models can accurately reproduce some basic universal properties of temporal networks, e.g., the bursty nature of interactions, they cannot accurately reproduce more complex properties. Motivated by the observation that mobility (especially human) is not random, but often driven by node similarities, in this work we show that temporal networks can be modeled as an N-body problem. Specifically, we assume that nodes are particles whose motion is driven by pairwise similarity forces. We consider potentials between nodes that do not depend on their physical location in the space, but instead are determined by a hidden metric space where distances abstract node similarities. Our N-body simulations show significant improvements over random walk based approaches, capturing more complex properties of real temporal networks. Temporal networks that arise due to the interactions between mobile agents, like certain kinds of temporal social networks (e.g., face-to-face interaction networks), can be modeled in 2-dimensional Euclidean spaces. In these spaces, each node is a random walker whose motion is biased by the attractiveness of other nodes in close spatial proximity. While such simple models can accurately reproduce some basic universal properties of temporal networks, e.g., the bursty nature of interactions, they cannot accurately reproduce more complex properties. Motivated by the observation that mobility (especially human) is not random, but often driven by node similarities, in this work we show that temporal networks can be modeled as an N-body problem. Specifically, we assume that nodes are particles whose motion is driven by pairwise similarity forces. We consider potentials between nodes that do not depend on their physical location in the space, but instead are determined by a hidden metric space where distances abstract node similarities. Our N-body simulations show significant improvements over random walk based approaches, capturing more complex properties of real temporal networks.

P13 Synchronization in a network of nearest identical PWL systems coupled with unidirectional links and ring topology

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In this work the collective dynamics of N-coupled piecewise linear (PWL) systems with different number of scrolls and coupled in a sequence master-slave configuration is studied, i.e. a ring connection with unidirectional links. Itinerary synchronization is proposed to detect synchrony behavior with systems that can present generalized multistability. Itinerary synchronization consists in analyzing the symbolic dynamics of the systems by assigning different numbers to the regions where the scrolls are generated. It is shown that if the inner connection between nodes is given by means of considering all the state variables of the system, then it achieves itinerary synchronization and the coordinate motion is determined by the node with the smallest number of scrolls. Thus the behavior in each node of the network is determined by the node with less scrolls in its attractor leading to generalized multistability phenomena which can be detected via itinerary synchronization. Furthermore, results about attacks to the network are presented when the PWL system is attacked by removing a given link (open ring configuration), thus depending on the inner connection properties, the nodes present multi-stability or preservation in the number of scroll attractors.

P14 Characterization of resilience in the network of Aedes Aegypti mosquitoes

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We present a study of the resilience in the network of Aedes Aegypti mosquitoes. We started with a network model where the number of nodes were initially defined in the network, each node represents a niche with potential characteristics to become a breeding place of this vector,A load was assigned to each node that depended on the number of elements in each state of the gonotrophic cycle of the vector (egg, larva, pupa and adult), according to the population dynamics model presented in 1993, the interactions between nodes in the network were defined as the probability that a determined fraction of the load of one node was directed to another, this interaction represents the creation of new breeding sites for this vector. The network structure was evaluated by calculating the distribution of degree, average degree, shortest path leng, centrality measures and mainly measures of vitality, The disturbances to the network were made taking into account the most effective controls currently applied for the reduction of the mosquito population (insecticides and removal of the breeding place), with these measures and applying the function developed in 2016, we characterize the network resilience.

Analysis of a complex network of risk factors. P15

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In this work, we propose a network that includes the factors and sub-factors of different types of risk (and sub-risks) with the purpose to analyze the interrelation between them. With the analysis of the structural properties of the network, we seek to know the interrelationship that exists between the intentional and causal factors of risks. The identification of the factors of operational, legal, political and programming risks are performed in separately form. Once every causes and values for each risk are known, a complete network is established containing all the factors of all the risks. The contribution of this work, is the use of complex network techniques to deal with risk factors in an integral way. The analysis of this network of factors, corresponds to the most critical risks that the operational process of a private organization could have. The most common tools for risk characterization are Ishikawa Diagram, Bow-Tie, among others, where each risk is analyzed in isolation, unrelated to other risks. However, this work seeks to use techniques that allow to know the interrelationship of several causes of various types of risk through complex network techniques.

Consistency of nonlinear oscillators using reconfigurable electronic networks. P16

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The present work shows experimentally the phenomenon of dynamical consistency in a network of nonlinear oscillators. Dynamical consistency is defined as the ability of a dynamical system to respond in the same way when it is perturbed by an external signal, but only when this signal is repeated. The phenomenon has been studied in single oscillators (e.g., lasers or electronic circuits) but just a few works have focused on oscillators connected through a nonregular network. The kind of oscillator used in this work is an electronic version of the Rössler system, which is used to describe the dynamics of the nodes of the network. Using an electronic array we can connect circuits to create a complex network, where all nodes could be coupled to each other and to an external signal and the strength of the connections is reconfigurable. The advantage of reconfigurable electronic networks is that we can choose the structure of the network, the weight on the links of the nodes, the degree of each node, the coupling between nodes and the coupling with the driven signal. Next, we can vary the coupling of the network and investigate how synchronization and consistency of the whole ensemble arise. Variations in both couplings, i.e. (i) between oscillators and (ii) with the external signal, show the existence of a region where electronic circuits respond in the same way despite they are not synchronized with the external signal. We use the correlation coefficient to measure the correlation between output signals for the same external input, and the correlation between the external input and the output signals. When the correlation between the output signals is high enough and the correlation with the input signal is low, consistency arises through the whole network.

P17 The Trend Towards Complex Networks for Industry Sector Goods Transportation

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One of the main challenges and objectives of the different transport models, is to build adequate mathematical models for a more realistic approach to industry requests. The more commonly used models frequently omit key variables due to lack of information and, also, to the inability to handle diverse types of agents and their interaction rules not considered in traditional network approaches. Facing these shortcomings, contemporary trends in the study of networks paves the way for a solution, using complex networks. However, these have not been used enough to address transport problems with high complexity, both in their environment and in the systems. The objective of the present research is to show the advantages of using complex networks approach for transport models in real situations, such as in industrial sector products transportation, known as Vehicle Routing Problems (VRP). It is important to mention that these transport models considered as VRP, are part of the models considered with an NP-Hard complexity.

P18 Dynamical competition between Complex Networks

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Recent studies have been focused in the analysis of structural properties from dynamical systems, such as synchronization, robustness, cooperation, transport, when are considerated the networks of networks instead of the single networks. In this work it's analized the effect in synchronization in networks when two identical networks, topologically random, are interconnected under four scenarios of competition: i) The connection of a HUB node from network 1 to a peripheral node from network 2. ii) The behavior of the system when a peripheral node from network 1 is connected with a HUB node from network 2. iii) The interconection of the HUB nodes from both networks and iv) The interconnection of the peripheral nodes. The election of the node, HUB and peripheral, is developed by the analysis of the eigenvector centrality of the adjacency matrix from the network. The results shown, numerical as experimental, are the result of individual units of Rössler-like oscillators.

Centrality measures in weakly connected networks: the case of citation networks. P19

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Centrality measures are fundamental in network science, since with them it is possible to find the most important node in the network. Some measures were developed since the middle of last century, as the Katz centrality and the eigenvector centrality. Closeness and betweenness were studying later in the seventies. These measures were used in the context of social networks. On the other hand, Page Rank and Hits were proposed at the end of the nineties in the context of web ranking and research. More recently, the subgraph centrality and the total communicability were worked out in the study of protein-protein interaction networks and many other contexts. There are formal relations between some measures. They can be viewed as matrix functions and the behavior of them has been analyzed with precision. The results are valid in undirected networks and strongly connected networks; the case of weakly connected networks is different since the adjacency matrix is reducible. In that direction, the study of centrality measures in weakly connected networks is important. We present the case of citation networks. The citation network is a network built between scientific papers, the nodes are papers and the edges are citations between papers. It is a directed network, if paper B was cited by paper A there is an arrow from A to B. In this case the study of centrality measures is crucial since it can be used for ranking papers and measure their influence or impact in the network. There is research in that direction, but most used the Page Rank or a variation of it. We present a comparison between exponential centrality, Katz centrality and Page Rank viewing as parametric centrality measures. The calculations were performed on the citation network of the American Physical Review, it has more than five hundred thousand nodes and more than six million of edges. We present some formal results and a conjecture related to them.

Multifractal dimension analysis of visibility networks P20

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In this work we introduce a multifractal dimension method (MDM) which is based on the q-order moments of the partition function obtained from the length of a nonstationary signal at diferent scales. Our approach represents a generalization of the monofractal dimension method for the analysis of nonstationary signals. Our results show that the MDM is applicable to very short time series with an acceptable estimation of the multifractal spectrum in terms of the Holder exponent. We apply our method to sequences of node's degree obtained from visibility graphs. We find that visibility degree sequences display multifractality related to the temporal correlations observed in the original time series. We also discuss our results in terms of the generalized Renyi dimensions.

P21 study of physiological networks of the stomach

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The increase of cases of syndromes like diabetes mellitus has led to the search for new methods in order to characterize the effects of this type of diseases in the human body. Through the theory of physiological networks we have the possibility to analyze the dynamics of systems like the stomach from the point of view of a complex system. In this work we analyze the temporal fractal organization of peak to peak $(p-p)$ variations of electrogastric signals from two groups of individuals: healthy and diabetic subjects. We use the Fano and Allan factor methods for the evaluation of correlations in $p-p$ sequences, which are considered as point processes. We find that temporal correlations in $p-p$ sequences are expressed by a power-law scaling with exponents within the range of correlated behavior for healthy dynamics, while the diseased data resemble uncorrelated fluctuations. Moreover, we analyze the level of syncronization between signals from different regions of the stomach. We observe different levels of coordinated behavior in the network interaction representation for healthy and disease conditions. Finally, we discuss our results within the context of physiological networks and neuro-autonomic control.

P22 Using already-solved cases and expert knowledge to prioritize the search of persons

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This work presents a new viewpoint of the problem related to the identification of human remains of missing people, applying a framework of Bayesian inference and complex networks to deal with non-genetic variables and to learn from the already-solved cases of a particular mass event of death. The specific goal of this work is to construct prioritized rankings of victims that could correspond to the unidentified human remains samples of a certain mass event of death. The process involves formalizing non-genetic variables mathematically and detecting patterns in the solved cases which may lead to carry out new searches. The methodology was applied to the problem of the "disappeared" during the last dictatorship in Argentina, from 1976 to 1983, although the method is general and can be applied to other contexts. This work is a collaboration with the Argentine Forensic Anthropology Team (EAAF), who has been working on the identification of the "disappeared" using a multidisciplinary and comprehensive approach since 1984. The first challenge to build scores within the set of candidate victims is to select the informative non-genetic variable or variables to learn about from the already-solved cases. Considering this, a partition within the complete space of the non-genetic variables was defined on a grid and every cell on the grid is associated with a combination of values of these variables. The probability of each cell is updated after the information of the already-solved cases to make the first ranking score. After carrying out extensive sensitivity analysis involving cross-validation, the best result is obtained using the date and geographical location of the kidnappings as the relevant non-genetic variables for the events under study. Finally, individuals who have strong relations with others who obtain better score values in the ranking than themselves, improve their place in the ranking. Prioritizing victims can ease the task of constructing hypotheses of identity to be evaluated later through genetic evidence.

Recurrence networks in natural languages P23

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As a extension of the Correlation Dimension, the Approximate Entropy (ApEn) was introduced in the 90's of the last century and used since then to calculate the regularity of a time series. Recently we have been interested in the application of the ApEn to the study of some natural languages. We consider the similarity between patterns of length m based on the Hamming distance among them. We define a distance (r in the context of ApEn) and define a "matching" between two subseries if the Hamming distance is equal or less than a value r. In this way, we calculate the adjacency matrix, where a connection between two nodes exists when a matching occurs. We also construct the recurrence network for texts in different european languages and calculate the degree distribution, clustering, assortativity and betweness centrality. We compare these network metrics of actual data with their corresponding randomized versions. Our calculations show the relation among different linguistic families and macrofamilies by means of the repetition of the so called m-grams.

Input-output networks and economic structure analysis: a study of two economies P24

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Input-output tables describe the relationships between economic sectors represented by flows of goods and services. We consider Costa Rican input-output matrix as a weighted directed network that shows the linkages within the country's production system. Using this network approach, it is possible to analyze production from the perspective of the two existing regimes: special and definitive. The first regime was created by the Estate to benefit export companies and provide incentives for the country's exports, for example, Free Trade Zones, with the objective of promoting Direct Foreign Investments, trade exchange and the generation of employment for the country. The latter includes the rest of the sectors that are more traditional and do not receive any special treatment. We examine the interactions between nodes that belong to different regimes and analyze how the structure of the economy varies when networks are built for each regime. We also study how these nodes interact with the economic sectors that are part of the network. Thus it is possible to examine how a specialized state policy creates different dynamics within the same economy. These dynamics are reflected in the network's interactions and in the end derive in the development of two economies with particular characteristics.

P25 Regulatory Variation Analysis Tools

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While Genome-wide association studies (GWAS) have successfully pinpointed thousands of genetic variants linked to disease and other traits, there is still not a clear understanding of how most of these variants might be contributing to the prevalence of such complex phenotypes. To date, >24,000 single nucleotide polymorphisms (SNPs) have been reported in the NHGRI-EBI GWAS Catalog from which the vast majority are found outside genome coding sequences. In addition, regulatory elements reported by ENCODE have shown to be enriched by GWAS-variants, suggesting altered regulatory events as the underlying mechanisms diseases act through. Transcription Factors (TF) are DNA binding proteins that modulate gene expression by recognizing specific DNA motifs. Genetic variants can modify TF affinity when changes are introduced to bases relevant for DNA-TF contact which could affect the Regulatory Program. TF binding motifs are usually modeled with Position-Specific Scoring Matrixes (PSSM), which can be used to estimate TF affinity to a specific DNA sequence. Here, we present a user-friendly tool module incorporated into Regulatory Sequence Analysis Tools (RSAT; http://metazoa.rsat.eu//) to predict the impact of genetic variants on TF binding. This module is made of four tools, convert-variations, retrieve-variation-seq, variation-info and variation-scan which can be used independently or integrated as a pipeline to address the functional implications of regulatory variants. Convert-variations performs variation file format interconvesion between GVF, MAF, VCF and varBed, an RSAT-specific format for storing variant data. Variation-info returns annotations about variants given a set of dbSNP IDs or for a given set of genomic coordinates. Retrieve-variation-seq retrieves sequences from the genome of interest and integrates into them either user supplied variants or fetched dbSNP variants within the queried coordinates. Finally, variation-scan assesses the impact of variants on TF-binding, estimating and comparing the affinity between a pair of variant alleles. Given its modular design, performance and flexibility to work with a wide variety of genomes, we are confident that these tools will be of great relevance for the scientific community.

P26 New behaviors on parameters a and b of the Gutenberg-Richter relationship in synthetic seismicity.

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As is well known, both Gutenberg-Richter's relationship and even more, seismicity as a critically self-organized phenomenon have been extensively studied. This work resumes the classic model of Olami-Feder and Christensen, reproducing a cellular automaton that allows to generate synthetic earthquakes. The automaton reproduces the expected seismic behavior, as are the slopes close to one that would be expected. Also very interesting behaviors have been found in the parameters a (y-intercepts) and b (slopes) of the classic form of Gutenberg-Richter law. Such behaviors give us information about the close relation that these parameters keep and that has not been studied from the approach that is addressed here and that constitutes the contribution of this study.

Vertex similarities in a complex economy **P27**

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Network analysis has shown that the costarrican economy is quite much complex as what has been studied until now. It has been conducted a network analysis of the input-output matrix, to understand the role of the products in the matrix, a *jaccard index* of structural similarity demonstrates that products tend to be similar as the products have a higher graph strength (higher amounts of transactions in monetary terms) and higher *indegree*. That is, products that receive inputs tend to be structurally similar as they demand higher amounts of input products in monetary terms. Besides, the products of the economy tend to be more similar or to share more contacts as they have a higher indegree. These results put in evidence that some traditional sectors of the economy such as the agricultural tend to have low structural similarity. This may show that they tend to demand specific inputs, therefore, they share less contacts. A quite different behaviour have the new and modern sectors of the economy such as new services, they tend to have higher Jaccard index among them.
Following the same analysis, vertex similarity according to the product *outdegree* demonstrates that most of the products in the economy, with the role of providing other products, tend to be structurally dissimilar. This shows that most of the products serves as input with small amount of money to many different demanders. However, as the products provide higher amounts of money, they tend to be structurally similar, they relate with similar others. But as the economic transactions tend to be higher in monetary terms, the products tend to share more contacts. These results depict a high clusterized and low centralized economy.

P28 Political dynamics of the mexican senate

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With the vast amounts of data available freely about virtually any field of knowledge, one of the greatest challenges for today's scientists is to be able to store, organize and analyze this data and to use it for novel and useful applications. Political sciences and legislation are fields that have seen such an increase.
The Mexican government and several of its dependencies have made a lot of their databases publicly available online, with the Chamber of Senators being the main focus of this work. New oportunities to be aware of the actions that decision makers are taking are arising and showing if a real representative democracy is being held. In this work we present a framework for automatic data acquisition, construction of a graph oriented data base and statistical modeling of data taking advantage of the capabilities of cloud computing.
The data collection was though the Mexican Senate's official website, so everything is completely open. The information gathered consist of the names of the senators and their alternates, party and comissions they belong to, entity they represent, the edicts, how did the senators vote, attendance and the dates in which the above happened. Followed by this a graph oriented database was build which allows to performm an analysis of the senators actions and find communities in a temporal basis.
A distance matrix between each senator was created from the votes which was used to perform statistical analysis such as multidimensional scaling for the projection of the vectors asociated with the senators and the construction of a weighted network in order to find communities amog them and study it's topological properties. Another network was also built from the joint proposals of the edicts by the commissions because each edict is proposed by one or more commissions. A new analysis of communities was carried out for this network, finding 3 great subjects that after a manual review we determined that they reflect the following topics; governance, foreing affairs and social issues.
The final part of the paper is to determine if it is possible to predict the vote of a particular senator through his or her history and the metadata we have. Obtaining the best accuracy by means of logistic regression with a value of 0.7082, surpassing the 0.6608 of predicting that they always vote for pro.

Synchronization of coupled discrete systems with parameter mismatch P29

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The emergence of order from chaos is one of the greatest mysteries of the universe. In the late 20th century, when the computational techniques became an important scientific tool, the efforts of many scientists focused on finding methods to stabilize chaos. The regularity of a chaotic system can also be improved by noise. This effect known as noise-induced coherence resonance was observed in both excitable and bistable systems. Later, similar coherence enhancement was discovered in a completely deterministic chaotic system, without any noise. In a bistable system chaos plays role similar to noise by inducing switches between coexisting states; the switches become more regular at certain amplitude of the chaotic signal. This effect referred to as deterministic coherence resonance was also observed in monostable chaotic systems in the presence of time-delayed feedback; the increasing feedback signal induces optimal regularity in the chaotic system. On the other hand, synchronization is an example of self-organization in nature, and it is usually assumed that interaction between oscillators enhances their synchronization. However, this is not always true. The increasing coupling between chaotic systems may result in unexpected behaviors, such as, e.g., oscillation death or coherence enhancement. The latter was theoretically predicted in two coupled oscillators. Surprisingly, adequate coupling can force a chaotic oscillator towards regular oscillations, so that although coupled oscillators have the same dominant frequency in their power spectra, they follow different phase space trajectories. In terms of synchronization theory, this means that the oscillators are in a phase synchronization state, i.e. They develop a certain relation for relatively weak coupling, although their amplitudes remain almost uncorrelated. Phase synchronization is abundant in science and found to play a crucial role in many weakly interacting natural systems, including lasers, electronic circuits, cardio-respiratory rhythm, neurons, behavioral psychology, and ecology. Chaos suppression in coupled chaotic oscillators was found in two cases, when there exists either an asymmetry in coupling or a mismatch between natural frequencies of the coupled oscillators. While the former was observed in bidirectionally coupled identical systems, the latter was theoretically predicted in unidirectionally coupled oscillators [A.N. Pisarchik and R. Jaimes-Reategui, Phys. Rev. E 92, 050901(R) (2015)]. This phenomenon resembled “stabilization of chaos by chaos”, i.e., the chaotic system at certain coupling strength and frequency mismatch behaved more regular, almost periodic in two coupled oscillators and completely periodic in a ring of three oscillators. Dynamical mechanisms underlying coherence enhancement in coupled chaotic systems are still unknown. In continuous systems the improved regularity is attributed to the conventional Lyapunov exponents that took negative values in the parameter range where the coherence resonance is observed. The aim of this work is to study coupled discrete chaotic systems with parameter mismatch, where their synchronization and coherence are analyzed using Fourier spectrum analysis. Since these systems allow more simple analytical and numerical description, this study may help to reveal mechanisms inherent to the coherence resonance behavior in coupled chaotic systems.

P30 Two-walks degree assortativity in graphs and networks

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Networks represent the topological skeleton of complex systems that are formed by many interacting-elements. The understanding of these structures and their patterns of connections is crucial for comprehending the evolutionary, functional, and dynamical processes taking place in these systems. It is well known that, generally, links do not connect nodes regardless of their characteristics. Assortativity is a global metric of a graph that characterizes the nodes's tendency to link to other nodes of similar (or different) type. Usually, this concept is applied to the degree of a node (i.e. the number of its adjacent nodes). Thus, degree assortativity is the tendency for nodes of high degree (resp. low degree) in a graph to be connected to high degree nodes (resp. to low degree ones). It is commonly quantified by the Pearson correlation coefficient of the degree-degree correlation. In this work we propose an extension of the concept of degree assortativity to one that account for the correlation between the degrees of the nodes and their nearest neighbours in graphs and networks. For this purpose, we consider the two-walks degree of a node as the sum of all the degrees of its adjacent nodes. The two-walks degree assortativity of a graph is then the Pearson correlation coefficient of the two-walks degree - two-walks degree correlation. We found an analytical expression for this new assortative index as a function of contributing subgraphs, and we also proved that there are a few more fragments contributing to the two-walks degree assortativity than to the degree assortativity. This clearly indicates that the new quantity accounts for more structural information than the previous one. We then study all the 261,000 connected graphs with 9 nodes and observe the existence of assortative-assortative and disassortative-disassortative graphs according to degree and two-walks degree, respectively. More surprisingly, we observe a class of graphs which are degree disassortative and two-walks degree assortative. We explain the existence of some of these graphs due to the presence of certain topological features, such as a node of low-degree connected to high-degree ones. More importantly, we study a series of 49 real-world networks, where we observe the existence of the disassortative-assortative class in several of them. In particular, all biological networks studied here were in this class. We also conclude that no graphs/networks are possible with assortative-disassortative structure.

Musical Words as Networks using Visibility Graphs **P31**

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Musical compositions can be characterized by words that can be determined from its time series. Here are analyzed musical melodies from several classical composers by the time series associated to its MIDI format. Time series corresponds to the note value as function of time. As first approximation, the generated time series is made only of the principal voice, i.e. merely the highest note of the musical chord is considered, the other notes played at the same time are neglected. Time series is transformed to a complex network by the visibility algorithm introduced by Lacasa et. al. (2008). In general, the classical music networks generated behave like scale-free networks. Musical words are defined as natural visibility sub-networks (connected pieces in the graph found). These words follow a Zipf law. They can be used to find compositional characteristics of different composer and led us observe the musical evolution through historical periods.

P32 Noise Effects in the Kuramoto Model: Early Warnings using Networks

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One of the most important properties that is common to complex systems is the presence of critical thresholds in its dynamics [1] at which the system shifts abruptly from one state to another. There is a growing interest to understand how a complex system behaves near catastrophic shifts to predict and eventually to control the timing and evolution of such transitions [2, 3, 4, 5, 6]. The search for indicators that can predict these shifts has been quite fruitful, with the discovery of the so-called early warning (EW) signals [1]. In a recent work we studied the effect of introducing an external perturbation, in the form of noise of various types and intensities, on the detectable EWs in two systems: a cellular automata that replicates atrial fibrillation and a system of coupled oscillators, whose dynamics is governed by the Kuramoto model [7]. The Kuramoto model has extensively been used as the paradigm to study synchronization [8, 9, 10], it provides a simple theoretical framework to study how synchronization may emerge spontaneously in the dynamics of a many-body interacting system. This model is widely used in biology to study the behavior of very different systems, including fireflies and even neurons[8, 9, 10]. For the specific case of the Kuramoto model we analyzed the time series obtained with this model and found that as the intensity of perturbation is increased some EWs are enhanced (with the effects being more readily evident in the memory-based EWs) [7]. Even when the time series analysis techniques have been fruitful, there is a considerable research toward developing novel metrics that capture additional information or quantify time series in new ways. One of the most interesting advances is mapping a time series into a network, based on different concepts such as correlations, visibility graphs, recurrence analysis, transition probabilities and phase-space reconstructions [11]. These studies have demonstrated that distinct features of a time series can be mapped onto networks with distinct topological properties. With this goal, we have followed the algorithm presented by Campanharo et al. [12] to construct networks from the time series obtained with the Kuramoto model. Considering the results obtained in [13], where they used the visibility algorithm to create the networks, we have analyzed several properties of the networks to establish differences between the various states of the system by studying the EW criteria. Finantial funding for this work was supplied by UNAM under grant DGAPA-PAPIIT- IV100116 and CONACYT under grant 2016-01-2277.

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Scaling properties of random networks with losses and gain P33

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In this work we study spectral properties of a random network model based on Erdös-Rényi graphs including losses and gain. This model is characterized by three parameters: The network size N, the network connectivity α, and the loss and gain magnitude γ. By the use of numerical simulations we propose a scaling parameter $\xi \equiv \xi(N, \alpha, \gamma)$ that fixes the spectral properties of our random network model. This model can be considered as a reference model for realistic networks with losses and gain such as power networks, electronic networks, etc.

Weighted random–geometric and random–rectangular graphs: Spectral and eigenfunction properties of the adjacency matrix P34

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Within a random-matrix-theory approach, we use the nearest-neighbor energy level spacing distribution $P(s)$ and the entropic eigenfunction localization length l to study spectral and eigenfunction properties (of adjacency matrices) of weighted random-geometric and random–rectangular graphs. A random-geometric graph (RGG) considers a set of vertices uniformly and independently distributed on the unit square, while for a random-rectangular graph (RRG) the embedding geometry is a rectangle. The RRG model depends on three parameters: The rectangle side lengths a and $1/a$, the connection radius r, and the number of vertices N. We then study in detail the case $a = 1$ which corresponds to weighted RGGs and explore weighted RRGs characterized by $a \sim 1$, i.e. two-dimensional geometries, but also approach the limit of quasi-one-dimensional wires when $a \gg 1$. In general we look for the scaling properties of $P(s)$ and l as a function of a, r and N; indeed, we find that the ratio r/N_γ, with $\gamma(a) \approx -1/2$, fixes the properties of both RGGs and RRGs. Moreover, when $a \geq 10$ we show that spectral and eigenfunction properties of weighted RRGs are universal for the fixed ratio r/CN_γ, with $C \approx a$.

P35 Growth and Use of Bicycle Sharing Systems from a Networks Perspective

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Urban mobility is one of the most important problems big cities face and, as vehicle density and traffic keeps increasing constantly, bicycle sharing systems have gained popularity and importance in recent years as an attractive alternative. Understanding how these systems are used and adopted by the population is important as it may help to improve urban planning and management policies of such systems, as well as to envision new ways to improve the security of users and to encourage more people to use this means of transportation. In this work we present an analysis of the bicycle sharing network in Mexico City characterizing its use and growth; we use open data provided by the local government (which consist of the historical record of users' journeys since the system was introduced) to construct networks in which the nodes correspond to bike stations and edges represent the directed flow between them within a certain time span. These networks are dynamic in nature, both in terms of size and topology, as the number of bike stations varies with time and the way in which the network is used shows seasonal trends at different time scales. As a result of the analysis performed, we were able to identify bike stations clusters, analogous to communities, which concentrate the network load and which correlate to specific geographical areas related mainly to touristic or economic activities. The spatio-temporal patterns obtained might be useful to suggest where new bike stations should be installed to improve network connectivity and to give insight in how cycling infrastructure could be improved to ensure commuters' security and promote this means of transportation for urban mobility.

Under the waterline of the iceberg: network analysis uncovers factors that moderate stillbirth attributed to Zika Virus Infection P36

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Central nervous system malformations in newborns and impairment of neural function in adults have been the visible severe manifestations of Zika Virus (ZIKV) disease that kept worldwide attention during the last 2015-16 outbreak in Latin America and the Caribbean and which still constitutes a threat in the near future. However, the range of manifestations related with ZIKV disease range from mild symptoms to death. As a vector born disease involving multiple agents and being amplified with additional routes of vertical and sexual transmission, the solely virus infection would not explain the diverse range of signs and symptoms. Consequently, it is hypothesized that several factors can contribute to shape and moderate these manifestations. Interdependent factors of disease define an additional scale of complementary networks which are located underneath social networks made by links among individuals and above molecular networks studied by omics. Using surveillance open data enriched with other official sources of information about several factors that determine health from Brazil´s municipalities (5,565), we reconstructed such type of network of quantitative controlled associations among 382 non-redundant variables from an initial set of near 700 variables. The network mapped controlled and non-spurious relationships between several factors of the social and individual scales and ZIKV and non-ZIKV related outcomes. We extracted a case subnetwork of direct neighbor variables linked with the variable of incidence of ZIKV-related stillbirth and control subnetworks of direct neighbor variables linked with variables of incidence of non-ZIKV-related stillbirth and infant mortality. By customary indices, node groupings and community formation we used statistical inferential methods to compare the aligned subnetwork structures. Detailed analyses compared each aligned and non-aligned node and the fingerprint patterns formed by the weighted associations. Conversely to previous results that revealed diagnostic inaccuracies as patterns of factors of ZIKV-related incidence of microcephaly were almost equal to patterns of non-ZIKV-related microcephaly, incidence of stillbirth with diagnosed ZIKV infection just had 0.59 common factors with non-ZIKV-related stillbirth and the distribution of weights was opposite (-0.98). Despite a dissimilar pattern of connected factors between incidence of Infant Mortality and ZIKV-related stillbirths (-0.561), there was a proportional distribution of link weights (0.786), which contrast with low similarity of weights between Infant mortality and non-ZIKV-related stillbirth (0.13). We concluded that incidence of ZIKV stillbirths involve more environmental and social factors than non-ZIKV stillbirths, but less than incidence of infant mortality that captures the full range of the diverse policy, social, economic, environmental and health care system determinants. By additionally comparing these subnetworks with previous results from subnetworks of ZIKV related and non-related microcephaly, we found that a strong connection with incidence of poisonings with metals and toxic substance used in agriculture are common to severe neurologic incidence of microcephaly and stillbirth with and without ZIKV confirmed infection.

P37 On the agreement between Small-World-Like OFC model and real earthquakes from different regions

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Despite all the existing knowledge about the production of seismic waves through slips on faults, much remains to be discovered regarding the dynamics responsible for these slips. A key step in deepening this knowledge is the study, analysis and modeling of the seismic distributions in space and time. The concept of self-organized criticality (SOC), widely used in statistical physics, refers, generally, to the property that a large class of dynamical systems has to organize spontaneously into a dynamic critical state without the need for any fine tuning of some external control parameter. A signature of self-organized criticality in a system is the invariance of temporal and spatial scales, observed by power-law distributions and finite size scaling. Aiming to contribute to the understanding of earthquake dynamics, in this work we implemented simulations of the model developed by Olami, Feder and Christensen (OFC model), which incorporate characteristics of self-organized criticality and has played an important role in the phenomenological study of earthquakes, because it displays a phenomenology similar to the one found in actual earthquakes. We applied the OFC model for two different topologies: regular and small-world where in the latter the links are randomly rewired with probability p. In both topologies, we have studied the distribution of time intervals between consecutive earthquakes and the border effects present in each one. In addition, we also have characterized the influence that the probability p produces in certain characteristics of the lattice and in the intensity of border effects. Furthermore, in order to contribute the understanding of long-distance relations between seismic activities we have built complex networks of successive epicenters from synthetic catalogs produced with the OFC model, using both regular and small-world topologies. In our results, distributions arise belonging to a family of non-traditional distributions functions (Tsallis family). We also performed the complex network analysis for real earthquakes, taking in account two different ways. The first one, considering only regional earthquakes separately (in regions with high seismicity, as Japan and California, and low seismicity, as Brazil). In the second, considering events for the entire world, with magnitude larger or equal than 4.5, in Richter scale. It is noteworthy that we have found a good agreement between the results obtained for the OFC model with small-world topology and the results for real earthquakes. Our findings reinforce the idea that the Earth is in a critical self-organized state and furthermore point towards temporal and spatial correlations between earthquakes in different places.

How well a graph dissimilarity measure behaves in neuroscience? P38

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While it is well known that graph isomorphism is a NP problem, simplest proposals have come up to answer the question of how similar are two graphs. Among these, dissimilarity measures bet to be computable in polynomial time making a bit efficient the comparison of network toy-models. In this vein, we tested a dissimilarity measure based on divergences of node distance distributions and their centralities in order to evaluate the capability of differentiate among several groups of functional networks. 54 healthy subjects performed a one-minute resting state experiment under eyes closed (EC) and eyes opened (EO) conditions. 56 scalp sensors recorded EEG signals building up functional networks based on mutual information in the typical four cognitive frequency bands. We thresholded functional networks in each group by keeping a balance between the efficiency of a network and its wiring cost. We defined the set of intra (inter) dissimilarities as the non-euclidean distances among subject's networks in the same (different) condition(s). We computed the statistical differences of the probability distributions of such sets of intra-dissimilarities: EC, vs EO; and then we repeated this procedure in all bands. Our results expect to validate the use of this dissimilarity measure in functional networks and see whether this can be used as a simple way to discern among groups of conditions and frequency bands in theoretical neuroscience.

P39 Emergence of Uncooperative Behavior by Interaction Dynamics of Community Networks

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Online communities for shared interests such as health, sports, and education have been growing at an increasing rate. Recent research investigates various aspects of these so-called community networks in an attempt to gain a deeper understanding of contributing factors that sustain and harm the growth of the network. Most community networks are self-organizing on the information-flow level and fundamentally based on cooperative behaviors to maintain equilibrium and stability. One important aspect is that members of these communities often share information on a peer-to-peer basis or within a local group only. In general, valuable information will be forwarded and shared with the remaining network. However, if valuable information is not shared for long enough, it fails to benefit and sustain the entire community. Uncooperative behavior caused by willingly blocking valuable information or even by behavior such as trolling and harassment disintegrates the network which can lead ultimately to its entire dissolution. To gain a deeper understanding of the impact of specific behavior on the information-flow layer of a network, we propose a basic interaction model that, despite its simplicity, gives interesting insights into the emergence of uncooperative behaviors in online community networks and the role of the underlying community network structure. The proposed model consists of an undirected network for which we assume that a unique information item will initially be assigned to each node, i.e., each item exists only once in the entire network. During the network lifetime, the information is shared based on basic interaction strategies, while each node continues to keep its information items. The interaction strategies applied are (a) random-choice and (b) reciprocated altruism. In the random-choice mode, two nodes choose, uniformly at random from their information items repository, which item to exchange. In this model, there is no further communication assumed, therefore situations happen when one node receives a new item, while the other node receives an item already in its repository. In the reciprocated altruism mode, an additional communication ensures that the two nodes strike a deal on exchanging only information items with value for both. If they do not reach an agreement, no further interaction will take place. We apply this model with both interaction strategies to networks constructed based on the Erdős-Renyi, Watts-Strogatz and Barabási-Albert network models. Results show that the information-flow patterns caused by the interaction strategies are characteristic of each network model. Interestingly, even when reciprocated altruism is applied, the very structure of the network often constrains the community-wide distribution of information causing the emergence of uncooperative behavior because valuable information is blocked. Based on our model, we discuss the differentiating behavior in the early phase of the community interactions and the behavior during the life-time of the community network. Simulations indicate that the functioning of the community is greatly influenced by the underlying structure, even if a basic form of altruism is applied on the information-flow level. Such results are important for the creation and maintenance of successful online communities.

Growth and Use of Bicycle Sharing Systems from a Networks Perspective P40

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Urban mobility is one of the most important problems big cities face and, as vehicle density and traffic keeps increasing constantly, bicycle sharing systems have gained popularity and importance in recent years as an attractive alternative. Understanding how these systems are used and adopted by the population is important as it may help to improve urban planning and management policies of such systems, as well as to envision new ways to improve the security of users and to encourage more people to use this means of transportation. In this work we present an analysis of the bicycle sharing network in Mexico City characterizing its use and growth; we use open data provided by the local government (which consist of the historical record of users' journeys since the system was introduced) to construct networks in which the nodes correspond to bike stations and edges represent the directed flow between them within a certain time span. These networks are dynamic in nature, both in terms of size and topology, as the number of bike stations varies with time and the way in which the network is used shows seasonal trends at different time scales. As a result of the analysis performed, we were able to identify bike stations clusters, analogous to communities, which concentrate the network load and which correlate to specific geographical areas related mainly to touristic or economic activities. The spatio-temporal patterns obtained might be useful to suggest where new bike stations should be installed to improve network connectivity and to give insight in how cycling infrastructure could be improved to ensure commuters' security and promote this means of transportation for urban mobility.

P41 Cat's vertebral spinal cord neuronal network dynamics under pain stimuli: Spinographic analysis in phase space

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Spinography monitors spontaneous cord dorsum potentials (CDPs) present in various lumbar sections of a cat, reflecting the adaptive control mechanisms of the nervous system. This has been studied previously in time domain (Manjarrez et al. 2000, 2003; Chavez et al. 2012; Contreras et al. 2015; Martin et al. 2017). These works have led to the hypothesis that CDPs are generated by a distributed network of dorsal horn neurons. In this work, the spinography of electrical pulses of an anesthetized cat under a pain stimulant (capsaicin) and a tranquillizer (lidocaine) were compared with control ones. The CDPs generated by a neuronal network, recorded with 11 dorsal electrodes and 2 intra-spinal channels, were analyzed in phase-space using the Wigner-Ville distribution. The Wigner-Ville transform was used to find the maximum correlation time between channels in phase space, allowing the study of the channel trajectories of CDPs events. Individual CDPs events lose synchronization and tuning correlations induced by the intradermic injection of capsaicin, reflecting a neuronal network detuning when the cat suffers pain. When the lidocaine is injected, the characteristics of the spinography return to the control levels, but after one hour the correlations resemble those of capsaicin. **References**

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Reactive Power Sharing in Isolated Micogrid Using a Controller Based on Information Theory P42

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The environment information has a relevant value in multi-agent learning processes as it is demonstrated in multiple algorithms where actions, states and rewards have a continuous change according to it. However, this environment information is always taken without a distinguishable border in which it becomes redundant or misunderstood, increasing the amount of information that must be stored in order to make decisions. In this regard, we propose a multi-agent learning framework based on information theory concepts such as rate distortion (RDT) and maximum entropy (MaxEnt). As a study case, we implement it to control the reactive power sharing between 4-distributed generators (Dgs) for a microgrid, operating in an isolated way. The framework can be described mathematically through the rate distortion minimization problem to obtain the minimum mutual information between the environment and each agent, by means of the expression,

$$\begin{aligned} \underset{p(x|c)}{\text{minimize}} \quad & I(x;c) = \sum_{x,c} p(x|c)p(c)\log\frac{p(x|c)}{p(x)} \\ \text{subject to} \quad & \sum_{x,c} p(x)p(x|c)d(x,c) \leq D \\ & \sum_{x,c} p(x|c) = 1 \\ & p(x|c) \geq 0, \end{aligned} \tag{1}$$

whose first constraint defines a fitness function for every agent in terms of the distortion of their information about the environment. Then, if c represents the environment behavior and x the internal state of each DG, we have

$$\begin{aligned} D &\geq \sum_{x,c} p(x)p(x|c)\mathcal{F}(x,c) \\ &= \sum_{x,c} p(x,c)\mathcal{F}(x,c) \\ &= \mathbf{E}(\mathcal{F}(x,c)) \\ &= \langle \mathcal{F} \rangle \end{aligned} \quad , \tag{2}$$

i.e, the minimum value for D, is the expected value of the agent fitness ($\mathcal{F}$). Having (2) into account, the RDT minimization process in (1) to obtain the conditional probability $p(x|c)$ becomes in

$$p(x|c) = \frac{p(x)e^{-\lambda\langle\mathcal{F}\rangle}}{\sum_x p(x)e^{-\lambda\langle\mathcal{F}\rangle}}, \tag{3}$$

whose solution is less complex using the Blahut-Arimoto algorithm. Here, in order to reduce the uncertainty about the environment, we modify the first step calculating $p(x)$ by means of the MaxEnt principle, which, using Lagrange multipliers method is given by

$$p(x) = e^{-\lambda-\mu g(x)}, \tag{4}$$

where $g(x)$ is a function of the internal variable on each agent, which is defined as the reactive power in this case. The expected value $\langle g(x) \rangle$ is determined by the reactive power in which each DG normally operates. The environment knowledge obtained through (3), is used as a fitness function in a replicator dynamics context, which in the implemented case, allows the identification of the nodes (Dgs) having better conditions to provide reactive power support when the system capacity is overloaded. The results show a proportional power sharing between Dgs, especially when considerable overloads are present in some of them, avoiding focused supply in nodes located just in the neighborhood. In contrast, the voltage variation is not as grater as in other approaches where consensus methods are used, allowing the nodes maintain their deviations close to a nominal value.

P43 Long-range and short-range spectral correlations of networks using random matrix theory (RMT)

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Random matrix theory (RMT) was first proposed in nuclear physics to describe the universal properties of the spectral fluctuations of excitation spectra with as a main assumption that the energies of the constituent protons and neutrons can be taken as random numbers. More recently, RMT has been applied as well to complex system such as finance, the climate and brain signals, indicating that major parts of the dynamics can be interpreted as due to random effects, and where deviations from the universal predictions of RMT indicate system-specific contributions. Network analysis is another new field of application where RMT analysis of the eigenspectrum of the adjacency or Laplace matrix can distinguish between the universal properties of random connections between nodes and the system-specific properties of regular connections. Unfortunately, the statistical results of RMT may depend on the arbitrary Â«unfolding processÂ» to separate the global Â«trendÂ» part of the spectrum from the local fluctuations. We recently proposed a method to study spectral fluctuations without the need for any a-priori unfolding (Fossion et al., 2013), which in this contribution we apply to several network models. We show that we can calculate in a non-ambiguous way short-range and long-range spectral correlation properties, and that we can quantify the proportions of random and regular connections at different scales. In particular, in a transitional model where several sub-networks grow towards a single globally connected nerwork, we demonstrate that the transition can be recognized in the short-range correlations already for weak connection intensities, whereas the long-range correlations saturate only for strong connections.

Knowledge Transfer Phenomenon from Universities to Regions as a Multilayer Network P44

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Colombia is working to improve Science Technology and Innovation (STI) in its 33 geopolitical regions. For this reason, the Government are trying to foster and develop Regional Innovation Systems (RIS). The purpose is to generate an economic and social development based on production and application of knowledge (Colombia-DNP, 2015a, 2015b). In the same vein, it is necessary to generate qualifications of STI at regional levels through the Knowledge Transfer (KT) phenomenon from universities to productive base, and community of those regions (Fernández-Esquinas & Pérez-Yruela, 2015; Göransson & Brundenius, 2011; Jaeger & Kopper, 2014). Furthermore, this transfer is carry on five channels; diffusion of scientific publications, graduated people, regional entrepreneurial initiatives, STI cooperative researches, mobility and collaborative relationships; where the (KT) has a strength relationship with the performance of these type of socio-technical systems (Hamm et al., 2012; Jaeger & Kopper, 2014; Lau & Lo, 2015; Miguelez & Moreno, 2015). The knowledge contribution is the scientific explanation of KT University-Region, and to determine structures, mechanisms, sequences, which are producing this phenomenon in a complex networks perspective (Chen & He, 2014; Gilbert, Ahrweiler, & Pyka, 2014; Wang & Sun, 2016). The research process started with the creation of a conceptual model through the phenomenon re-description. This stage uses existing theoretical approaches and is validated with some interviews with relevant system actors, as well as, its theorization as a complex network with multilevel clusters of knowledge (Carayannis & Campbell, 2011, 2012). On one hand, the model constructed is compared with data of five periods taken from information systems of the National Education Ministry and the Science and Technology Observatory of Colombia to analyze the contributions of human capital graduated of different knowledge areas (engineering, math and natural sciences, social sciences, economy, health sciences, education, and arts) from 287 universities and the STI projects implemented in the regions. On the second hand, the partial results characterize the KT phenomenon as an innovation multilayer network, which has a structure of preferential attachment, but also it has links between actors of each layer with non-trivial interactions, besides some nodes have attributes that affect the dynamic and the structure of the other level (Guan, Zhang, & Yan, 2015; Lazega & Snijders, 2016; Wang & Sun, 2016; Zhang et al., 2017). The results will be used to identify the attributes of the most influential actors, as well as to find the relationship between the two analyzed KT University-Region channels and the regional systems performance. Furthermore, the envisaged effects could help to define what factors, attributes and links should be foster to improve the RIS performance.

P45 Visibility Graph analysis for catalogs of synthetic seismicity.

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Experimental models have been used to understand fundaments features in several natural phenomena. It is well known that seismicity has been one of the most important studied phenomena due to the hazard impact in the society and economic aspects for instance. Our interest is to study the seismic phenomena since an experimental point of view. In this work we introduce an experimental device based in the interaction between surfaces with asperities trying emulating the tectonic plates interaction. We have calculated catalogues of synthetic seismicity. The sequences of synthetic seismicity can be mapped in a graph. With this visibility graph algorithm have characterized the synthetic catalogs obtained by using several degrees of roughness between both interacting surfaces.

P46 Using multilayered networks to investigate procurement contracts: the case of Mexico

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In order to better detect corruption in public procurement contracts, it is important to understand how social networks reduce the costs of collusion. In this paper, we reconstruct the historical work relations graph between government officials and supplying firms within public procurement processes. We exploit this information with two different approaches: first, we construct and compute several metrics for suspicious behaviour, both for government officials and firms, and evaluate the joint distribution between these metrics and corruption-related events. Second, we implement feature and community-based anomaly detection models. Both approaches are taken with the same goal: to motivate a technical framework for authorities to better allocate resources into contracts.

P47 Is it complex to be a hub?

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In this line of research, we try to know if there is any relationship between the topological position a node occupies in a complex network and its dynamical state. Furthermore, it would be interesting to determine whether it is possible to infer a node's topological place from its dynamics. We work with the Morris-Lecar (M-L) model, which is a tool for modeling the electrical potential of a neuron's membrane, and start studying the behavior of an isolated neuron, to firstly gain some intuition about the complexity measure we will be using. After having some experience at the single neuron level, we will be dealing with various types of networks (while maintaining the M-L model in each node) and we will see if we can distinguish any topological property of the net from just dynamical measurements.

Multi-scale organisation of core-periphery structure in networks P48

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Core-periphery structure of networks consists in at least one core group of nodes and one periphery group of nodes that are paired with each other. If we are based on the density of edges to characterise core-periphery structure, a core is a group of nodes that are densely interconnected with each other, and a periphery is a different group of nodes that are adjacent mainly to the core nodes and not to other peripheral nodes. For example, in social networks, core and peripheral nodes often correspond to leaders and followers in social relationships, respectively. Here, we study multi-scale organisation of core-periphery structure using the concept of Markov stability, which is derived from random walks on networks. Initial studies of core-periphery structure considered such structure on a global scale in the sense that one core group and one peripheral group constitute an entire network. Some recent studies have focused on multiple, and therefore smaller, core-periphery pairs embedded in a network. These studies have focused on core-periphery structure on a particular scale. However, as is the case for communities in networks, core-periphery structure with different scales may simultaneously exist in a network. We examine multi-scale organisation of core-periphery pairs using the Markov stability, which has been used for detecting communities on different scales. Discrete-time random walkers in a core-periphery pair tend to move to the core in one time step because, by definition, core nodes are adjacent to both core and peripheral nodes, and peripheral nodes are adjacent mainly to core nodes. In a small core-periphery pair, a random walker may move to the core in a small number of moves, whereas a walker may need a large number of moves to reach the core in a large core-periphery pair. By using the characteristic time scale as a resolution parameter, we uncover core-periphery pairs across different scales. We reveal the hierarchy of core-periphery structure in several empirical networks using the proposed methods. We argue that core-periphery structure is present on a small scale but not on a large scale.

Order, preferences and dynamics of illegal trade networks of reptiles in colombia: design elements of strategies to control and sustainability P49

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Reptiles are one of the most endangered groups worldwide. In Colombia this group is particularly threatened because of its cultural and economic importance for indigenous communities. Some uses of these species are considered as illegal due to the risk of species extinction and threats to the sustainability of ecosystems. Traffic often involves Illegal networks embedded in social structures that operate at the local, regional national and international levels. Understanding spatial patterns of traffic is important in order to design strategies to tackle this illegal activity. Here we characterize the spatial dynamics of the illegal trade of reptiles in Colombia to study the emergence of ordered practice in the harvesting of the species as well as the delivery. Results indicate the existence of preferences about specific places and species trafficked, that allow stablishing strategies to control illegal trade considering the effort that authorities have to do and the social and economic impact in human communities. A threshold for quotas is proposed in order to preserve cultural traditions, conserve endangered species and ecosystems, and to promote efficient ways to control traffic.

P50 Synchronization Transitions Induced by Topology and Dynamics

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An information theory approach is used to construct functional equivalent networks by optimizing the microscopic configuration subject to generalised mean-field constraints. In this framework, we derive a methodology to transform the topology of complex networks while keeping the collective behaviour invariant in a general dynamical process. In our work, we use this new methodology to study the collective dynamics of coupled phase oscillators in the Kumamoto Model, unveiling the relation between synchronization transitions induced by changes in the topology and in the dynamics of the system. In this context, we provide new tools to analyze and predict the behaviour of real coupled systems when dealing with uncertainty in the measurements.

P51 Electron transport in tight-binding networks with dislocations

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It is well known that electronic technologies have the objective to optimize circuits to make devices more efficient, portable and faster. In the last decades, this has been done by the recurrent reduction of existing devices. However, this reduction has reached mesoscopic scales where quantum phenomena, originated from the wave-behavior of electrons, become very important. Particularly, quantum coherence of wavefunctions avoids a classical solution of the system by determining properties of small sections separately, since the effect of each section is strongly altered by other sections due to complex interference phenomena [1]. Within the context of quantum mechanics, electron transport properties of a material can be theoretically addressed using the Landauer theory [2], by determining the transmission function of a system. This quantity can be directly calculated by means of the S-matrix, that relates amplitude of incoming and outgoing wavefunctions, where systems can be modeled in terms of tight-binding networks. For crystalline (periodical) materials, calculation of S-matrices can be done efficiently by using the reciprocal space and obtaining the so-called Bloch functions. However, the presence of defects and impurities broke crystalline periodicity, and in consequence calculations should be perform in real space. In fact, the presence of defects and impurities may allow to design materials per desired specifications, but also implies computational calculation of S-matrices restricted to small systems. In this work, a new efficient method to calculate the S-matrix of tight-binding systems in terms of the S-matrices of its components is presented [3], which permits calculations in macroscopic-length systems. This method is used to determine the effects on the electron transport caused by dislocations in periodic nanowires. Dislocations are defects in crystalline materials were some atoms are out of position or missed. Cases with periodic and aperiodic occurrence of dislocations are discussed. Finally, conductance behavior is determined as function of the number of dislocations. This work has been supported by UNAM-DGAPA-PAPIIT IA106617. Computations were performed at Miztli under project LANCAD-UNAM-DGTIC-329.

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Analysis of Mexico's drug-cartels network **P52**

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Violence linked to drug traffic in México has increased the last ten years, the reasons of this spread are difficult to quantify. However, a relevant feature to take into account is the large number of drug cartels and the disruption of them into small violent cells.
Many strategies have been proposed to dismantle the operation networks of these criminal groups, being the capture attempt of the cartel leaders the most usual one. This strategy has not have a significant positive outcome decreasing the influence of these groups neither the violence around the country. In this sense, the complex network theory approach emerges as an alternative to understand the dynamics underlying this no-trivial phenomenon. In this approach, a network is composed by nodes such as people, places, cities, etc., and links represent any kind of relashionship between said nodes.
In this work, by means of a semi-automated text mining tool we construct a network of the characters of the Anabel Hernandez's book "Los señores del narco" in order to analyze it's topological and dynamical properties. By performig directed attacks to the most relevant nodes of the network using different centralities, we measure the robustness of this network in terms of the size of the giant component i.e. optimal percolation. We also analyze the resulting network communities after these attacks and observe the exact amount of removed characters needed to dismantle this giant component.
With this approach it is possible not only to propose a minimal quantity of characters to be removed from the network to desmantle it but also if there are differences between the most socially influential nodes and those who are important to the network topology. These kind of approaches could aquire relevance in terms of developing strategies to disable complex criminal structures.

P53 Modularity Detection in Biological Networks

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Currently, biological networks constitute the most common model to represent the behavior of complex living systems. Network modeling and analysis have thus become essential to understand the large scale structure of molecular biosystems.
It is currently believed that biological functionality is organized in a modular structure within the biological network and then methods to discover this non-trivial community structure have been developed.
Several discoveries have been made by analyzing this modularity in biomolecular networks, however most of these results have been produced by ad-hoc methods of limited applicability to general cases. On the other hand, the mathematical problem of graph modularity has also been the object of much attention in complex networks groups. Many approaches and computational algorithms have been developed. For diverse reasons these two research areas are, in our view, less connected than they should, quite specially in relation to the community structure problem.
A central goal of this work is to draw them closer by discussing a number of applications to some problems of relevance in contemporary biology and then presenting the general methods of graph theory and network modularity.

Whole genome transcription factor analysis reveals long range-functional interactions in breast cancer gen regulatory networks P54

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Transcription factors corresponding to the MEF2 family possess diverse roles in cell development of various systems such as muscle, cardiac, skeletal neural, immune among others. Therefore, this family of transcription factors has effects on cell differentiation, proliferation, apoptosis, metabolism and migration which indicates that MEF2 activity plays a role in different human diseases including several cancer types. The transcription regulation process by members of the MEF2 family is modulated by a diversity of elements including upstream regulators and co-regulatory proteins. The endeavor of mapping MEF2 regulatory networks in the contexts in which they act represents both a challenge and an opportunity to understand various diseases including cancer. One of the most important members of the MEF2 family: MEF2C, has been suggested as being one of the master regulators involved in the pathogenesis of primary breast cancer. Consequently, in this work we decided to map the transcriptional regulatory activity of the elements targeted by MEF2C and MEF2C itself to evaluate how such activity leads to events related to carcinogenesis, apoptosis and gene deregulation. By means of an integrative approach, we found evidence of long range interactions based on the analysis of a database of 880 whole genome gene expression experiments (819 primary breast cancer and 61 normal tissue samples) supplemented with a list of downstream targets of MEF2C transcription factors obtained from Transcription Factor Binding Site predictions (TFBS). Differential expression analysis was performed for a total of 14,500 transcripts that correspond to well annotated genes from the gene expression experiments. Additionally, the inferred network from TFBS data consisting of 4,543 nodes and 12,422 interactions was used to identify a set of highly connected nodes. The status of these hubs was then examined through their differential expression values and the associated biological function and biochemical pathways were studied. The results support the role of MEF2C as a master regulator gene, both in general biological processes and in relation to primary breast cancer.

P55 Prioritizing individuals for identification purposes in base of inferred network

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This is a collaborative work with the Argentine Forensic Anthropology Team (EAAF), who have used a multidisciplinary approach to investigate human rights violations in different parts of the world. In Argentina, for instance, they have tried to learn about the final destination of the people who were disappeared during the last military dictatorship in the country. The underlying idea in our work is that people whose kidnappings were closely related may have been kept captive and killed in the same location, a fact which would link the findings of their remains. In a previous work, we studied data from the province of Tucumán, in the north of Argentina. Based on different rules, we formalized a network whose nodes represent the people who were kidnapped and established their connections applying the information known up to the moment when the kidnappings occurred (using variables of the geographical and temporal type, among others). We detected the best rules which could generate results consistent with other known information available in the problem [1]. In this work, we construct priority scores among people who might have shared the same destination from the emergent structures of that network: groups or clusters of individuals. In this case, the same destination means the same place of burial, as "Pozo de Vargas" in Tucumán, where more than 100 people have already been identified, though there are still remains to be identified. In order to qualify clusters, we define magnitudes using information about variables not used to define connections (occupation, studies, etc.) from the pointwise mutual information of a cluster, and compare them with the results that would be obtained if that structure was randomly generated. Using acceptable clusters, we define priorities among individuals, considering the geodesic on the network between unidentified people and solved cases from "Pozo de Vargas". Prioritizing helps in the preliminary investigation work carried out by the EAAF in the process of identifying the people buried in Tucumán.

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Time-reversibility analysis of earthquake magnitude sequences and interevent times series. P56

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The visibility graph is a method that converts time series into networks according to some specific geometric rules (Luque et al., 2009; Lacasa et al., 2008), so that properties of time series can be accordingly mapped in properties of networks (Lacasa et al., 2009). The horizontal visibility graph (HVG), firstly proposed in (Luque et al., 2009), is one type of visibility graph, which will be used in the present work to investigate the time-reversibility of earthquake magnitude and interevent times series associated with the seismicity of five seismic areas of the subduction zone into the Southwest Pacific Mexican coast. Applying the Kullback-Leiber divergence D, we distinguish between reversible and irreversible stationary seismic sequences, and our findings suggest that among the five seismic areas, Jalisco-Colima is characterized by the largest D value for both magnitude and interevent time series. Our results are consistent with the peculiar seismo-tectonic characteristics of Jalisco-Colima, which is the closest to the Middle American Trench and belongs to the Mexican volcanic arc.

P57 Using network science to evaluate cognitive reserve and the interplay between network topology and dynamics in functional brain networks.

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We investigate how the organization of functional brain networks was related to cognitive reserve (CR) during a memory task in healthy aging. We obtain the magnetoencephalographic functional networks of 21 elders with a high or low CR level to analyze the differences at network features. We report a negative correlation between synchronization of the whole network and CR, and observed differences both at the node and at the network level in: the average shortest path and the network outreach. Individuals with high CR require functional networks with lower links to successfully carry out the memory task. These results may indicate that those individuals with low CR level exhibited a dual pattern of compensation and network impairment, since their functioning was more random and energetically more costly to perform the task as the high CR group. Additionally, we evaluate how the dynamical properties of the different brain regions are correlated to the network parameters obtaining that entropy was negatively correlated with the strength and clustering coefficient, while complexity behaved conversely. Consequently, highly connected nodes of the functional networks show a more stochastic and less complex signal. We consider that network approach may be a relevant tool to better understand brain functioning in aging.

Using Ordinal Synchronization to evaluate coordination between dynamical systems. P58

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In 2002, Bandt and Pompe proposed the use of ordinal patterns to evaluate the entropy and complexity of time series. Their methodology consists on binning a given time series (each bin with length *D*), and ranking the values inside each bin, which leads to a series of vectors of length *D*. Next, the evaluation of entropy and complexity is based on the probability distribution of the obtained vectors, each one corresponding to an ordinal pattern. Here, we propose a generalization of this idea, with the aim of quantifying the coordination between two (or more) dynamical systems through the analysis of their corresponding time series. We call this new measure, the *Ordinal Synchronization* (OS). As Bandt and Pompe, we obtain a series of ordinal patterns of length D from the binning of the times series of two dynamical systems. Next, the inner product of each vector against its correspondent one from the other time series is computed. The result is averaged and normalized to get a value between -1 and 1 for each pair of time series. A value near -1 indicates opposite or anti-synchronization (as vectors in each time series tend to be, on average, antiparallel), a value near 0 indicates no synchronization (orthogonal vectors), and a value near 1, high synchronization (parallel vectors).We analyzed several simulated and real time series, for different number of dynamical systems and coupling between them, and compared the results with classical synchronization measures, namely mutual information (MI), coherence (C) and phase locking value (PLV). Our results show how OS captures subtle differences not accounted by classical measures. Both amplitude and phase determine the rank of each value in every bin, so this new measure offers a trade-off between phase and amplitude synchronization. It shows several advantages when compared to other synchronization measures: computation time is extremely decreased; it doesn't make any assumption on the time series distributions; it is robust to noise; as a general measure for synchronization, it is applicable in many contexts; and, further more, it captures anti-phase synchronization, a very realistic process in natural and artificial systems, many times neglected by a diversity of synchronization measures.

Horizontal visibility networks procedure to bridge Mexico City pollution data in meteorological time series and chaotic intermittent dynamics P59

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In this paper, we study the connection between meteorological/pollution time series of Mexico City and intermittency in low-dimensional non-linear dynamical systems. The implemented methodology consists of transforming the real data time series into complex networks using the horizontal visibility algorithm. In this generated complex networks the degree distribution as well as its associated entropy are determined. In parallel, the same procedure is performed for time series generated close to the intermittency route out of chaos, as in a tangent bifurcation. For convenience and without loss of generality we use attractors of the logistic map close to tangent bifurcations. In this way, we study the statistics of chaotic attractor laminar periods and the relationship with the probability of duration of quiescent events in real time series. The goal is to understand pollution contingencies in Mexico City. Finantial funding for this work was supplied by UNAM under grant DGAPA-PAPIIT-IV100116 and CONACYT under grant 2016-01-2277.

P60 Entropy Measure as a Key to Determine the Dynamics of a Real Social Network

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The information theory proposed in Claude Shannon has been used to model the dynamics of social networks. The entropy plays a fundamental role in the theory since it provides conclusions about the dynamics of the social network as it is the mobility of an actor (node) in the network. In this work we take a study done by a psychologist to a social network made up of the health personnel of the Oncology Medical Unit of the state of Zacatecas. The actors were under a psychological intervention and the social network was modeled before and after this intervention. We calculated the entropy of the social network before and after finding that the quantitative value fell after the psychological intervention. With this, it is possible to propose a parameter that measures the dynamics of the network. In the future it is intended to extend to complex networks and include more variables for the purpose of having a theory of social behavior in a complex network.

PT7: Plenary Talk

The Scale Invariance of Crime Concentration in Cities

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Crime is a major risk to society's well-being, particularly in cities, and yet the scientific literature lacks a comprehensive statistical characterization of crime that could uncover some of the mechanisms behind such pervasive social phenomenon. Evidence of nonlinear scaling of urban indicators in cities, such as wages and serious crime, has motivated the understanding of cities as complex systems—a perspective that offers insights into resources limits and sustainability, but usually without examining the details of indicators. Notably, since the nineteenth century, criminal activities have been known not to occur uniformly within a city. Crime concentrates in such way that most of the offenses take place in few regions of the city. However, though this concentration is confirmed by different studies, the absence of broad examinations of the characteristics of crime concentration hinders not only the comprehension of crime dynamics but also the proposal of sounding counter-measures. Here, we developed a framework to characterize crime concentration which splits cities into regions with the same population size. We used disaggregated criminal data from 25 locations in the U.S. and the U.K. which include offenses in places spanning from 2 to 15 years of data. Our results confirmed that crime concentrates regardless of city and revealed that the level of concentration does not scale with city size. We found that distribution of crime in a city can be approximated by a power-law distribution with exponent α that depends on the type of crime. In particular, our results showed that thefts tend to concentrate more than robberies, and robberies more than burglaries. Though criminal activities present regularities of concentration, we found that criminal ranks have the tendency to change continuously over time. Such features support the perspective of *crime as a complex system* which demands analyses and evolving urban policies covering the city as a whole.

MS3: "Explosive Transitions in Networks""

Synchronization is a very well studied phase transition in complexnetworks which classically occurs in a continuous andreversible way. However, explosive synchronization has been recentlyreported in complex networks developing as a sudden increase (discontinuous and irreversible) in thecoherence of the networks' dynamics, capturing the attention in many relevant fields (social dynamics, braindynamics, power grids, ...). So far, several important contributions and progresses(including experimental verifications) have been made, which have provided insights on what structural anddynamical properties are needed for inducing such abruptchange in the collective dynamics of the network, as well as have greatly enhanced ourunderstanding of phase transitions in networked systems. Our Minisymposium has the intention of providing an overview on the main existing results together with presenting the latest contributions describing noveldynamical phenomena emerging at the onset of explosiveness inadaptively evolving networks and multiplex networks, with attractive and repulsive interactionsin the presence of noise as well as the coexistence of the explosive phase with the standard phase of the Kuramoto oscillators.

Organizers: *Irene Sendiña-Nadal and Juan A. Almendral*

Emergent explosive synchronization in adaptive complex networks

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One of the most significant challenges of present-day research is bringing to light the processes underlying the spontaneous organization of networked dynamical units. Discontinuous transitions to synchronized states of networked phase oscillators were initially reported in a Kuramoto model for a particular frequency distribution and network topology [1]. The same finding was also described for both periodic [2] and chaotic [3] phase oscillators in the yet particular condition of a heterogeneous degree-distribution with positive correlations between the node degree and the corresponding oscillator's natural frequency. Later on, it was proposed a more general framework [4] where this explosive synchronization is obtained in weighted networks, if the weights are adequately selected. More recently, it has been shown that explosive synchronization can be obtained for any given frequency distribution, provided the connection network is constructed following a rule of *frequency disassortativity* [5, 6]. These studies so far have concentrated on proposing topologies for which the transition is explosive, given a specific frequency distribution on the dynamical units, or vice versa, proposing a frequency distribution on the oscillators, given a specific connectivity structure. However, no models have yet succeeded in generating dynamically the conditions for a transition to be explosive. We show here that these conditions may spontaneously emerge in an adaptive network of interacting oscillators, as the result of a delicate interplay between synchronization processes and co-evolution of the connectivity structure. When the connectivity dynamics is such that links coupling the nodes with non-synchronous (synchronous) dynamics are promoted (weakened), we prove that an initially unstructured clique configuration evolves in time toward an emerging structured network whose transition is explosive. We also study the parameter space of this model to demarcate the region in which this happens.

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Abrupt transitions in networks of noisy oscillators with asymmetric attractive-repulsive interactions

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We study two intertwined coupled networks of noisy Kuramoto phase oscillators that have the same natural frequency, but differ in their perception of the mean-field and their contribution to it. Such a give-and-take mechanism is given by asymmetric in- and out-coupling strengths which can be both positive and negative. We uncover in this minimal network of networks intriguing patterns of discordance, where the ensemble splits into two clusters separated by a constant phase lag. If it differs from π, then traveling wave solutions emerge. Despite its simplicity, the model exhibits a rich dynamical behavior which includes a new route to traveling waves via one-cluster configurations, and bistable regions between all accessible states. This bistability is shown to give rise to abrupt transitions not only between incoherent and partially synchronized states – as in classical scenarios where “explosive synchronization” is found –, but also between π- and traveling waves states. These findings provide evidences that different mechanisms other than large frequency mismatches are able to induce such transitions in networks. Analytical results and bifurcation diagrams are derived with a reduced system. In addition, networks of Rössler oscillators under asymmetric attractive-repulsive couplings are explored. Traveling waves are also observed when the phase dynamics coexists with chaotic amplitudes; however, in this case, we show that phase waves are possible even in the absence of global coherence and cluster separation.

MS4: "Southamerican Network Science"

It is known from network science that when a new research topic emerges, at the beginning, few individuals work in relative isolation and the co-authorship network is sparse. However, when the emerging field reaches a certain maturity, the individuals conform a truly collaborative community and dense network. This structural changes usually take place abruptly and coincide with the occurrence of specialized conferences, workshops and project developments. The 1st LANET conference conforms then a perfect environment in order to strengthen research, work dissemination, and outreach, for scientists related to Network Science in South America and foster collaborations among them and across other continents. Consequently, we are proposing a mini-symposium within LANET, the “South American Network Science” (SAmNetS), to provide them with such a forum and keep the scientific community updated with the new developments and tendencies in Network Science in South America.

Organizers: *Arturo C. Martí and Nicolás Rubido*

Detecting amplitude and frequency synchronization in global surface air temperature data

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Network based techniques have been widely applied to characterize the output signals of complex systems and in particular, the network approach has given useful insights into the complex dynamics of our climate. Here I will show that, by applying the Hilbert transform to observed atmospheric data (time series of daily air temperature in a regular grid over the Earth surface, covering a period of more than three decades), large-scale spatial patterns of synchronized amplitude and frequency oscillations are unveiled, whose temporal evolution can be related to the well-known phenomena of El Niño or La Niña.

Information-based immunization strategies on complex networks

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When unexpected infectious disease outbreaks occur, public health agencies activate different immunization strategies to try hamper their spreading into a large scale epidemics. However, the question of the efficiency of a given strategy when availability of resources is complete, depends also on the individual’s compromise to follow the strategies at hand. We propose a simple model to evaluate the performance of three strategies of immunization, assuming complete availability of resources on a population-network that has an exponential degree distribution. The strategies are based on the information (number or fraction of infected) that an individual collects and processes from two sources, local (neighborhood) and global (whole system). We show that even when all strategies reduce considerably the fraction of infected individuals, the most efficient strategy - that maximizes the herd immunity in the system - is achieved when individuals keep record of their infected neighbors. Additionally, when evaluating on different underlying topologies, the performance of the strategies would depend on the infectiousness of the disease as well as in the degree of heterogeneity of the population.

Electronically-implemented networks and what can we say about them

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The analysis of complex systems is a scientific trending topic. However, such analysis is usually constrained to synthetic models and numerical experiments. Here, we tackle this problem by developing a network of coupled electronic circuits, which are simple to implement, have low-cost components, are easy-to-handle, and have a broad range parameter-versatility. Our experimental findings show that this implementation has a remarkable agreement with the numerical simulations, and behavioural aspects of the coupled system are well-characterized with high resolution. Consequently, and as we show with our results, we can tackle the bottom-up (i.e., predict the system's behaviour from its network's topology) and top-down (i.e., infer its network topology from its behaviour) approaches to study complex systems in a controlled experimental fashion.

PT9: Plenary Talk

Long-range influences and dynamics on networks

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I will start with a motivation for the necessity of including long-range influences on the study of dynamical processes on networks. I will provide some experimental evidences supporting the existence of long-range hops in the diffusion of atoms and molecules adsorbed on metallic surfaces. Then, I will generalise the Laplacian operator of a network to account for long-range hops in graphs. I will define this operator on a Hilbert space and prove that it is bounded and self-adjoint. At this point I will make a generalisation of the diffusion equation by using Laplace and Mellin transformations of the d-path Laplacian operators. I will prove analytically that this generalised diffusion equation produces super-diffusive processes when certain parameters in the Mellin transform are used. Finally, I will illustrate the generalisation of other well-known equations for networks, which includes the Kuramoto model, the epidemic spreading models and the replicator-mutator equation. In the last case I will show how the long-range influences among agents increases the "cultural" diversity of the system but makes the attitudes more homogeneous among them. In other words "Cultural globalization increases diversity but make attitudes more homogeneous

PT10: Plenary Talk

Identifying and characterizing regime transitions with network-based data analysis tools

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Complex systems can undergo gradual or sudden transitions between different dynamical regimes. While some transitions can be safe (e.g., the sleep-awake brain transition), others can be catastrophic (e.g., desertification, population extinction, arrhythmia, etc.). It these situations it is important to identify appropriated early-warning signals, and a lot of efforts are nowadays focused on developing reliable diagnostic tools that can be directly applied to observed data. In this presentation I will discuss how various network-based data analysis tools (correlation networks, symbolic networks, horizontal visibility) allow identifying early-warnings and characterizing dynamical transitions in various complex systems.

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C3: Synchronization and Brain

Module detection on functional brain networks using resting-state fMRI

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In this project we studied the modular changes of the human functional brain network in the first decades of life. For this purpose, we used fMRI in resting state to obtain data of 84 subjects between 6 and 18 years old. We considered the regions of the brain and the statistical correlation between their activity to construct and average network for each group: the children's group (6 to 11 years old) and the adolescents' group (12 to 18 years old). Using a Newman's module detection algorithm, we identify the regions grouped in modules according to their activity and compared them between both networks, in order to understand the changes on integration and segregation of regions from childhood to adolescence in resting state over a normal development. The module detection algorithm used has the advantage to detect communities of regions in the brain without an a priori knowledge of the number of groups in which the network must be divided, this because this algorithm optimize a quality function that measures modularity. The results obtained yield a greater integration of regions in more adult stages of life, observing less modules with higher density connection on adolescence. Some of the modules remain equal between childhood and adolescence suggesting an early development of the human abilities related with those parts of the brain, such as the vision areas. Using the algorithm mentioned, we also observed the default mode network.

Inter-layer synchronization in non-identical multiplex networks

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Inter-layer synchronization is a dynamical state occurring in multi-layer networks composed of identical nodes. The state corresponds to have all layers synchronized, with nodes in each layer which do not necessarily evolve in unison. So far, the study of such a solution has been restricted to the case in which all layers had an identical connectivity structure. When layers are not identical, the inter- layer synchronous state is no longer a stable solution of the system. Nevertheless, when layers differ in just a few links, an approximate treatment is still feasible, and allows one to gather information on whether and how the system may wander around an inter-layer synchronous configuration. In this Minisyposium, we will report the details of an approximate analytical treatment for a two-layer multiplex, which results in the introduction of an extra inertial term accounting for structural differences. Numerical validation of the predictions highlights the usefulness of our approach, especially for small or moderate topological differences in the intra-layer coupling. Moreover, we identify a non-trivial relationship between the betweenness centrality of the missing links and the intra-layer coupling strength. Finally, by the use of two multiplexed identical layers of electronic circuits in a chaotic regime, we study the loss of inter-layer synchronization as a function of the betweenness centrality of the removed links.

C4: Interdisciplinary Applications

The dynamics of collaboration and its implications - from careers to Europe

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Collaboration in science is intrinsically interpersonal, and as a result, the networks of (in)formal relations are characteristically dynamic. In this talk I will discuss recent work on how these dynamics impact career paths, with implications as far-reaching as the evolution of entire national research systems. In the first part I will focus on the remarkably wide variation of collaborative strengths within research careers. In order to demonstrate the added value of long-term interpersonal partnership on career outcomes, I will present the results of a within-career (i.e. Researcher fixed-effects) regression model showing that publications authored by a given scientist that include her strongest collaborators have higher citation impact relative to those publications that do not. These results point to the advantage of "super" social ties characterized by trust, conviction, and commitment. In the second part I will discuss the aggregate implications of collaboration dynamics at the level of the European Research Area (ERA) - a longstanding vision of the European Union to develop a competitive and integrated innovation system through directed cross-country policies. In order to measure the EU's progress towards the establishment of the ERA, we analyzed the rate of international publication for 32 European countries using data extracted from millions of academic publications from 1996 to 2012. We then used the EU 2004/2007 enlargement, a large policy intervention representing a multi-country and multi-stage "quasi-experiment", to provide causal insights into the interaction between two types of cross-border activity: human mobility and international collaboration. Our results reveal a counterintuitive result - that the twelve 2004/2007 entrant EU countries would have had higher rates of cross-border collaboration had they not joined the EU - thereby identifying an unintended consequence of labor market integration in Europe. Together, these results identify East-to-West European brain drain as a mechanism underlying the stalled integration of the ERA.

Hunter-gatherer networks and cumulative culture

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Social networks in modern societies are highly structured, usually involving frequent contact with a small number of unrelated friends. However, contact network structures in traditional small-scale societies, especially hunter-gatherers, are poorly characterized. We developed a portable wireless sensing technology (motes) to study within-camp and inter-camp proximity networks among Agta and BaYaka hunter-gatherers in fine detail. We show that hunter-gatherer social networks exhibit signs of increased efficiency for potential information exchange. In particular, to estimate global network efficiency [1], we first built weighted social networks using our motes proximity data from Agta and BaYaka camps, and subdivided the networks into three decreasing levels of relatedness: close kin, extended family and non-kin. We estimated the contribution of each relatedness level to global network efficiency by comparing our hunter-gatherer network structures with randomly permuted networks. Our analyses show that randomization of interactions among either close kin or extended family (including affinal kin) does not affect the global efficiency of hunter-gatherer networks. In contrast, randomization of non-kin relationships (friends) greatly reduces global network efficiency. Therefore, increased global efficiency in our networks results from investing in a few strong close friends in addition to an extended net of social acquaintances, or a combination of strong and weak ties [2]. In agreement with classic studies of small-world networks [3], our results show that only a few shortcuts (friendships) connecting closely knit clusters (households consisting mostly of close kin) suffice to significantly reduce the average path length or distance between any two points across the whole network, thus reducing redundancy and the cost of maintaining strong links with a large number of unrelated individuals. Since unrelated individuals often live in different households, they provide a small number of reliable shortcuts between households. Both the Agta and BaYaka had between one and four unrelated close friends with whom they interact as frequently as with close kin. This number is consistent across ages and camps, and with the finding that people in western societies are in close contact with an average of four friends[4]. We also show that interactions with non-kin appear in childhood, creating opportunities for collaboration and cultural exchange beyond family at early ages. We also show that strong friendships are more important than family ties in predicting levels of shared knowledge among individuals. We hypothesize that efficient transmission of cumulative culture [5, 6, 7, 8] may have shaped human social networks and contributed to our tendency to extend networks beyond kin and form strong non-kin ties.

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Networks of melody: The complex use of tonal consonance in music

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Music is an abstract process rooted in human nature that conveys sensations and sophisticated emotions. Graph theory has been used to recognize and characterize the constitutive elements in music as well as relational patterns in problems as the determination of the meaning of complex diagrams. Networks theory has been applied to explore dynamical properties of sets of musical pieces, through the topology of graphs, as well as to produce pieces with properties that resemble musical genres or styles. Here we study musical pieces departing from the tonal consonance properties of musical intervals in terms of physical parameters. This model relates physical properties as pitch and tonal consonance with musical concepts as the size of musical intervals and their position in the register. We construct a dual representation of melodic lines as graphs where pitches are nodes and melodic intervals ties, and vice versa. From the topological properties of networks we find conserved quantities with musical meaning, described in terms of physical parameters, with information about the use of tonal consonance in some baroque and classical musical pieces, including levels of consonance and asymmetry properties associated to the selection of ascending and descending intervals. Finally, an interpretation of the work carried on by composers is given in terms of the tonal consonance structure of musical scales and the extremalization of entropy.

MS5: "Colombian Networks"

The promising field of network sciences have percolated different disciplines in Colombia. Our scientists have started to commune with the idea of inter/trans-disciplinary studies to better understand global and local problematics from diverse viewpoints. The main view of inspiring this forum is to present how Colombian scientists have tackled some problems by means of network science. We will show the relevance of a multiplex approach of illegal trade networks of reptiles in Colombia, a multipartite perspective aiming at explain a voter model based on specific culture features, a driven-data mapping of a social cohesion process in Colombian policies, and an innovative method to establish thresholds in Gene co- expression networks. In this vein, we aim to promote novel ways to directly strike important issues in Colombia that also could shed lights on Latin American similar topics.
All in all, our proposal is inherently cross-disciplinary, calling upon expertise from fields as diverse as Ecology, Political Science, Mobility, and Systems Biology.

Organizers: *Johann H. Martínez*

Multiplexity and robustness of wildlife traffic networks

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The use of wildlife is an important part of human economy and culture in many places. However, the overexploitation of this resource can lead to species extinction and serious ecosystem disturbances. Social structures are associated to the dynamics of wildlife trading and social networks expedite both legal and illegal operations. The illegal context of wildlife traffic is embedded in social networks characterized by secrecy and authorities usually lack of information about the social actors and their patterns of interactions. As a consequence, these criminal structures, defined as dark networks, are difficult to trace and hence to be controlled. We propose that trafficking several taxa simultaneously reflects aspects about the actions developed in dark networks and social dynamics. Here, we use the Multiplex Network Analysis to study the network function, through the topology of the spatial representation of traffic. Structural properties for a real network, the traffic of reptiles in Colombia, a null model corresponding to Erdös-Renyi random graphs that conserve density, and a null model that conserves the degree sequence are found. These results show that the network of reptile traffic in Colombia outperforms null models. This network is darker, less cohesive but more overlapped, with larger paths. This network is robust to random nodal removal, and to removal by participation and PageRank centrality, however it is vulnerable to nodal removal according to betweenness and, mostly, degree centrality. This results and the fact that large degree centrality is due to the In-degree centrality, indicate that spatial robustness of the network depends of hiper-connected nodes, that usually are associated to places where demand is present. Then, strategies that address consumers are recommended for controlling the traffic.

Data driven network analysis confirms U.S. Culture as the main long-term factor to support results of last presidential elections

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According to studies based on 2016 polls, Trumps's U.S. presidential victory has been attributed to the vote of the white working class, and specifically due to fears about American culture and identity. However, this was not a contingent or short terms result. By using one hundred samples of about 30,000 registries of the 2013 version of the American Community Survey, we reconstructed a probabilistic network of variables representing nineteen factors of objective well-being of the U.S. population. The network nodes corresponded to variables and links to statistical controlled weighted associations among variables, that mapped the complex interdependency of factors inside individual and household scales, below social networks and above molecular 'omic' networks. Analysis of the multipartite network allowed addressing factor relevance and role in the whole systems of well-being. factor relevance relied on parametric and non-parametric statistical tests between distributions of the adjusted averages of link weights and network customary indices within and between nodes of each factor. To identify the role of factors in the whole system of well-being, we used hierarchical clustering and permutation of the network's adjacency matrix that located closer factors in four branches and seven levels. By their dense connectivity, factors of culture (as a sense of belonging by including variables of race, ethnicity, nativity and permanence in the U.S.) and Household economic characteristics occupied the root level supporting and influencing the remaining factors and providing consistency to the whole system. In this way, taking account of the more sensitive and core issues and concern related to the U.S. population well-being is central to mobilize people's decisions. Our network analyses results found those core issues to anticipate results of the winning discourse, but also showing that the core factors of sense of belonging and household economy are more than short term objective concerns of the U.S. population.

MS6: "Nonlinear Dynamical Systems and Complex Networks"

The concepts and techniques developed by mathematicians, physicists, and engineers to characterize and predict the behavior of nonlinear dynamical systems have been increasing during the last decades. We can find a multitude of examples of nonlinear dynamical systems in nature which have been subjects of study, and we have also been working on carrying out the design of these systems by the use of laboratory prototypes which have allowed us to compare the behavior generated by these systems with natural phenomena. Between the great variety of nonlinear dynamical systems we can mention some applications of these systems as elements in a multiscroll system that can be used for security in communications or for image encryption, and also for pattern selection in networks as part of its the collective behavior. Nonlinear dynamical systems also are used as nodes in complex networks as an important element of the system in order to reproduce an infinity of emergent phenomenon depending of the structure and proposed characteristics for the networks.

Organizers: *Guillermo Huerta-Cuellar*

On the generalized synchronization of networks with nonidentical nodes

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Synchronization emerge between two or more dynamical systems when their solution become correlated in time. Therefore, complete identical synchronization occurs when their solutions evolve at unison. In this sense, the emergence of generalized synchronization (GS) occurs when a functional relationship exists between their states. To extend this notion to the case of dynamical systems coupled in networks two basic approaches have been proposed: (i) the auxiliary system and (2) the controlled synchronization approaches. On the first, GS is inferred between two systems from the identical synchronization of the slave system and an auxiliary copy under the same driving force from the master system. On the latter, a functional relationship between the systems can be explicitly imposed by controller design. In this contribution, we take the latter approach to impose an specific functional relation on a linearly and diffusively coupled network, where the nodes are different dynamical systems. Unlike previous results, our proposed approach is not restricted to fully triangularizable node dynamics. Further, only mild differentiability conditions are require to impose GS in the network. We illustrate our proposed approach with numerical simulations.

Dynamics of piecewise contractions: Dominant Vertices, Complexity & Network Reduction

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Inspired by models of biological networks, we have introduced a class of piecewise contracting dynamical systems. They consist of a network of units, whose states are quantified by a continuous real variable. The state of each of these units evolving according to a contractive transformation chosen from a finite collection. The particular transformation chosen at each time step depends on the state of the neighboring units. In this way we obtain a network of coupled contractions. In this talk I will present some of our theoretical results concerning the existence of and effect of dominant vertices in the system. Indeed, the contracting and interdependent nature of the dynamics allows a size reduction. We will show that the knowledge of a trajectory on well-chosen sub-collections of vertices allows to determine the asymptotic dynamics of the whole network. We call the nodes in these distinguished sub-collections, dominant vertices, and we completely characterize them from combinatorial grounds. We also propose a heuristic algorithm to compute those sub-collections of nodes, which we call dominant sets. We show how a set of dominant vertices defines a smaller network supporting a dynamical system equivalent to the original one. In this way we obtain a network reduction on dynamical grounds. Some applications will be discussed as well.

Sincronización en redes de sistemas complejos por acoplamiento a modelos

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En este trabajo se presenta la sincronización de redes de osciladores caóticos usando acoplamiento a modelos. En particular, en este trabajo se limita el tipo de redes topología estrella. Acoplamiento a modelos es una técnica tomada de la teoría de control no lineal y es adaptada para sincronizar no solo parejas de sistemas complejos, sino redes en topología estrella. Los nodos de las redes de sistemas complejos están propuestos como sistemas caóticos, lo que permite tener sistemas verdaderamente complejos y la propuesta aporta a la problemática de sincronización de redes aplicada a las comunicaciones seguras.

Preserving scrolls via generalized synchronization

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The objective of this study is to show chaotic multi-scroll systems interconnected in master-slave configuration as they perform in references [1, 2]. An interesting phenomenon is found when the master system presents different numbers of threads that the slave system and achieve the preservation of the number of scrolls in the slave. In particular, it presents the so-called generalized synchronization of multistability and the preservation of scrolls, which means that there is a functional relationship between the master and slave systems in synchronization [3].
Dynamic switching systems called unstable dissipative systems (UDS) in R^3 are synchronized based on Campos et. All (2010) [4]. The system displays multi-scrolls that can be increased in number due to the unstable hyperbolic saddle balance ie a negative real eigenvalue and a pair of complex conjugate eigenvalues with a positive real part. These systems are constructed using a discrete control mode that changes the break-even point with respect to the location of their states. Scrolls are generated when the stable and unstable eigenvalues of each adjacent equilibrium point generate the stretching and folding mechanisms to generate chaos [3, 4].
Following the same idea of chaotic synchronization, we observe the master system that behaves as an autonomous system and the slave system is a forced system that under certain conditions or signals could behave as a non-autonomous system, where this dynamics is completely determined by the Master system, ie the slave system acts as a function of the master system. Therefore, the slave system can be seen as a system driven by an external signal that forces it, and that this can be studied as a filter where the input signal comes from a master system or any coupled signal [5].
In this way, my contribution is to show as the phenomenon of synchronization that is contained within an interconnected nonlinear structure. When synchronizing UDS systems with different number of scrolls we have two cases. 1) When the master system has fewer scrolls than the slave system, the multistability phenomenon is generated, changing the initial conditions of the master system. 2) When the master system has more number of scrolls than the slave system, it generates the phenomenon of scrolls preservation.
The scrolling behavior of scrolls can be called preserving scrolls. By coupling the systems with the x_1 state of the master to the x_1 system of the slave system. The scrolls appear along a specific axis, where we can see the phenomenon of multiestabilid, only when the master system is smaller in number of scrolls to the slave system. In the opposite case of number of scrolls, a displacement between the axes is observed, completing the space of the scrolls. Taking into consideration the mathematical expressions of the coupled systems, there is a preservation of scrolls.

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PT11: Plenary Talk

Synchronization in populations of moving oscillators

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Here we will show results obtained in our group concerning synchronization of populations of moving oscillators. On the one hand, populations of identical Kuramoto oscillators that move randomly on a plane, without considering excluded volume effects, enables to obtain analytical results for the time needed to synchronize [1]; later on, we hace extended this framework to locally interacting self-propelled particles for which synchronization generically proceeds through coarsening verifying the dynamic scaling hypothesis, with the same scaling laws as the the 2d XY model following a quench [2]. Our results shed light into the generic nature of synchronization in time- dependent networks, providing an efficient way to understand more specific situations involving interacting mobile agents. Alternatively, we have also investigated synchronization in populations of integrate and fire oscillators, showing that under restrictive conditions of connectivity, the time needed for the population to synchronize is not a monotonous function of velocity [3].

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C5: Structure

Complex networks, Google matrix and quantum chaos

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The Google matrix G of a directed network is a stochastic square matrix with nonnegative matrix elements and the sum of elements in each column being equal to unity. This matrix describes a Markov chain of transitions of a random surfer performing jumps on a network of nodes connected by directed links. This matrix is the fundamental part of the origin of the crawler. In this talk I will show some spectral properties of this matrix for real matrices coming from different fields as computer science and economics or built from models of chaotic systems. We will use tools coming from the field of quantum chaos to study this networks [1, 2, 3]. We will analyze the eigenvectors of the matrix which can be related with network communities. Other interesting result will be that the number of long lived eigenvalues of the matrix is associated with the fractal dimension of the network. Also a two dimensional ranking of the networks will be defined using the time inversion of PageRank, and using phase-space properties developed in dynamical systems. The relationship between this two different fields as "complex networks" and "quantum and classical chaos" would be clarified in this talk with different examples of real networks.

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Long Walks and Holes in Networks

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We have developed new matrix functions to study and reveal new properties within networks. We begin by studying the flow of information around a network. We do this by studying walks, with the idea that information lost is directly correlated with the length of the walk. Previously, the factorial function has been used to scale walks, scaling walks of length k, by $k!$. We propose to use the double factorial scaling instead, hypothesizing that longer walks may also carry key information in a network, which the single factorial function may penalize too much. We develop a new centrality measure, noticing that it correlates poorly with the single factorial scaling when applied to networks which contain holes. Holes within a network are defined as cycles, with the extra condition that any two non-adjacent nodes in the cycle must not be connected. We explore this lack of correlation, developing new methods to detect when a network contains holes and making deductions on where they are likely to be.

Centrality measures in simplicial complexes

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Simplicial complexes represent an alternative representation of complex systems in which groups of nodes instead of individual ones interact with each other. A simplicial complex consists of the same set of nodes as a network but allows the set of simplices to have a size greater than two. Simplicial complexes are closed under the operation of taking subsets. A k-simplex is a subset of the nodes of size $k-1$, while a face of a k-simplex is a $(k-1)$-simplex which is a subset of the original k-simplex. In this work we define a notion of adjacency at each level of the simplicial complex [1]. Namely, for $k \geq 1$ we have that two k-simplices are considered adjacent if they both share a common face and are not faces of the same common $(k+1)$-simplex. Using this definition we introduced a matrix representation for the adjacency between simplices in a simplicial complex. This allows us to generalise network centrality measures to simplicial complexes. We define the simplicial degree, betweenness, Katz index, eigenvector, and subgraph centrality. We prove the existence of a spectral scaling between the simplicial subgraph centrality and the simplicial eigenvector centrality. This method allows us to classify simplicial complexes into four universal topological classes. We apply this method to predict the invasion rate of species into a group of ecosystems represented by their food webs. An ecological system with a higher invasion rate is more susceptible to invasive species. The model implies that holes in the food web can be filled by invasive species which can then fill a niche in the network and be successful.

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C6: Network Dynamics

Coherent and incoherent strategists: Evolutionary dynamics on multiplex networks

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Cooperation is a very common, yet not fully-understood phenomenon in natural and human systems. The introduction of a network structure within the population is known to affect the outcome of cooperative dynamics, as described by the Game Theory paradigm, allowing for the survival of cooperation in adverse scenarios. Recently, the introduction of multiplex networks, where individuals can adopt different strategies in different layers, has yet again modified the expectations for the outcome of the Prisoner's Dilemma (PD) game, compared to the single-layer (monoplex) case: for example, it is known that the average level of cooperation is slightly lower in the multiplex scenario for very low values of temptation, but also, cooperation is able to resist until higher values of the temptation. These phenomena, however, are not well understood at a microscopic level, and much remains to be studied regarding the rest of the social dilemmas in the T-S plane (PD, Stag-Hunt, Snow Drift and Harmony) on multiplex. We explore here the microscopic organization of the strategies across layers, and find some remarkable and previously unknown phenomena, that are at the root of the differences between monoplex and multiplex. Specifically, we find that in the stationary state and for any given time step, there are individuals that play the same strategy in all layers ("coherent"), and others that don't ("incoherent"). We find that this group of incoherent players is responsible for the surprising fact of a non-full-cooperation in the Harmony Game on multiplex (values of around 90$\%$), which has never been observed before, as well as a higher-than-expected survival of cooperation in some regions of the other three social dilemmas. Moreover, we are able to prove mathematically the existence of defectors in the case of the harmony game on multiplex networks, also calculating the probability of the necessary topological configuration happening for uncorrelated Erdös–Rényi layers. To summarize, the introduction of a multiplex structure in the population not only allows for more sophisticated and realistic behaviors for the individuals (that can now display different strategies in different layers), but also helps promote cooperation in regions of the parameter space in which it cannot survive in the monoplex scenario, at the expense of a moderate decrease of cooperation in those where traditionally it was very high. These phenomena can only be understood by the existence of incoherent players.

Coevolution of Synchronization and Cooperation in Costly Networked Interactions

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The synchronization of coupled oscillating systems is a phenomenon that has received considerable attention from the scientific community given the wide range of domains spanning from biology to social and applied science. More specifically, the pattern of interaction among the oscillators has been proven to play a crucial role in promoting the conditions for the emergence of a synchronized state. Such interaction pattern may be encoded as a graph and several studies investigating the emergence of synchronization have been performed in groups of oscillators on complex networks. Despite the amount of studies made so far, all the approaches were based on the hypothesis that the variation of the state for an oscillator, which is a fundamental requirement to attain synchronization, is costless. Yet, it seems reasonable to assume that when an oscillator alters its state this frequency variation involves an adjustment cost that, in turns, impacts on the dynamics. The introduction of such adjustment cost leads to the formulation of a dichotomous scenario. In this framework, an oscillator may decide to pay the cost necessary to alter its state and make it more similar to that of the others or, alternatively, keep it unaltered hoping that the others adjust their states to its own. The former behavior can be considered as an act of cooperation while the latter as a defection one; both of them constitute the basic action profiles of a Prisoner's Dilemma game. Hence, the emergence of synchronization may be seen as the outcome of an evolutionary game in which the oscillators can strategically decide which behavior they will adopt according to the payoff they received in the previous synchronization stage. Complex networks play a key role in the emergence of cooperation and, in particular, the presence of hubs in scale-free networks fosters even more such phenomenon. Thus, it is worth to study the underlying mechanisms responsible for the onset of synchronization in systems where the single oscillators are placed on the nodes of a network and can decide to cooperate, by synchronizing their state with that of their neighbors, or not. This leads to a coevolutionary approach where the synchronization dynamics and the evolution of cooperation influence each other. Coevolutionary approaches represent the natural extension of the actual models in order to achieve a better description of complex systems. More specifically, we consider a system of Kuramoto oscillators that are able to decide which strategy between cooperation and defection they will adopt upon the evaluation of their payoff. We consider that an oscillator assumes a cost that is tuned by a model parameter alpha and it is proportional to the absolute value of the difference between the previous and the current frequency of the oscillator. On the other hand, the positive payoff, i.e. the benefit, is given by the synchronization achieved within the oscillator neighborhood. The emergence of both cooperation and synchronization is studied for three different topologies, namely: Erdös-Rényi random graphs, Random Geometric Graphs and Barabási-Albert scale-free networks.

Neworks underlying the minority game reflects different behavior of the model

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The Minority Game (MG) was introduced in 1997 by Challet and Zhang in an attempt to catch essential characteristics of a population competing for limited resources. As in the case of a traffic problem in which people have to decide between two routes, in the MG an individual achieves the best result when she manages to be in the minority group. In the model, there are N agents, who at each step of the game must choose one of two sides, 0 or 1. The only information available for the agents is the system state, which stores the best side choices for the last m steps and which is updated after each step of the game. The parameter m defines the information-processing capacity of the agents. Agents take decisions based on strategies. Although there is no explicit interaction among MG agents, it is known that they interact through the global magnitudes of the model and through their strategies. We have formalized the implicit interactions among MG agents as if they were links on a complex network. We have defined the link between two agents by quantifying the similarity between them, in terms of their strategies. We have analyzed the structure of the resulting network for different MG parameters, such as the number of agents (N) and the agents capacity to process information (m). In the region of crowd-effects of the model, the resulting network structure is a small world network, whereas in the region where the behavior of the MG is the same as in a game of random decisions, MG networks become a random network of Erdös-Renyi. Finally, we have studied the resulting static networks for the Full Strategy Minority Game Model, a maximal instance of the Minority Game in which all possible agents take part in the game [1]. We have explicitly calculated the degree distribution of the Full Strategy Minority Game network and, on the basis of this analytical result, we have estimated the degree distribution of the minority game network, which is in accordance with computational results [2].

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C7: Epidemics

General Markov Chain Approach for Disease and Rumor Spreading in Complex Networks

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Spreading processes are ubiquitous in natural and artificial systems. They can be studied via a plethora of models, depending on the specific details of the phenomena under study. Disease contagion and rumor spreading are among the most important of these processes due to their practical relevance. However, despite the similarities between them, current models address both spreading dynamics separately. In this work, we propose a general information spreading model that is based on discrete time Markov chains. The model includes all the transitions that are plausible for both a disease contagion process and rumor propagation. We show that our model not only covers the traditional spreading schemes, but that it also contains some features relevant in social dynamics, such as apathy, forgetting, and lost/recovering of interest. The model is evaluated analytically to obtain the spreading thresholds and the early time dynamical behavior for the contact and reactive processes in several scenarios. Comparison with Monte Carlo simulations shows that the Markov chain formalism is highly accurate while it excels in computational efficiency. We round off our work by showing how the proposed framework can be applied to the study of spreading processes occurring on social networks.

Quarantine efficiency in epidemic spreading control on scale-free networks with different power-law exponents

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Infectious diseases are by far one of the leading causes of death throughout the world. In this sense, one of the most effective mechanisms to contain the spread of an infectious disease in a population is the implementation of quarantine policies. The heterogeneous structure of society is best represent by a scale-free distribution of connections. In order to investigate the influence of heterogeneity in the quarantine efficiency in the spread of infectious diseases, in this work an alternative SIQRS epidemic model on scale-free networks is presented. In particular, we investigate the effect of the power-law exponent ν of the degree distribution ($P(k) \sim k^{-\nu}$) in the density of infected individuals in steady state. Our results show that the exponent ν determines the effectiveness of the quarantine policy on the spreading process. More precisely, we show that for ν exponent below the three value associated with the conventional scale-free network model the quarantine mechanism loses effectiveness. In other words, the density of infected individuals in steady state increases.

Disease surveillance on social complex networks

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As infectious disease surveillance systems expand to include digital, crowd-sourced, and social network data, public health agencies are gaining unprecedented access to high-resolution data and have an opportunity to selectively monitor informative individuals. Contact networks, which are the webs of interaction through which diseases spread, determine whether and when individuals become infected, and thus who might serve as early and accurate surveillance sensors. Here, we evaluate three strategies for selecting sensors—sampling the most connected, random, and friends of random individuals—in three complex social networks—a simple scale-free network, an empirical Venezuelan college student network, and an empirical Montreal wireless hotspot usage network. Across five different surveillance goals—early and accurate detection of epidemic emergence and peak, and general situational awareness—we find that the optimal choice of sensors depends on the public health goal, the underlying network and the reproduction number of the disease (R0). For diseases with a low R0, the most connected individuals provide the earliest and most accurate information about both the onset and peak of an outbreak. However, identifying network hubs is often impractical, and they can be misleading if monitored for general situational awareness, if the underlying network has significant community structure, or if R0 is high or unknown. Taking a theoretical approach, we also derive the optimal surveillance system for early outbreak detection but find that real-world identification of such sensors would be nearly impossible. By contrast, the friends-of-random strategy offers a more practical and robust alternative. It can be readily implemented without prior knowledge of the network, and by identifying sensors with higher than average, but not the highest, epidemiological risk, it provides reasonably early and accurate information.

C8: Spanish Session

Distinguiendo ruido de caos: un criterio objetivo versus subjetivo basado en Grafo de Visibilidad Horizontal

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La recientemente metodología propuesta denominada "Gráfico de Visibilidad Horizontal" (HVG) [Luque et al., Phys. Rev. E., 80, 046103 (2009)], la cual constituye una simplificación geométrica del conocido algoritmo "Visibility Graph" [Lacasa et al., Proc. Natl. Sci. ESTADOS UNIDOS. 105, 4972 (2008)], se ha utilizado para estudiar la distinción entre componentes determinísticos y estocásticos en series temporales Que constituye una simplificación geométrica del conocido algoritmo Visibility Graph [Lacasa et al., Proc. Natl. Sci. Estados Unidos 105, 4972 (2008)], se ha utilizado para estudiar la distinción entre comportamiento de origen determinístico y estocástico en series temporales [L Lacasa y R. Toral, Phys. Rev. E., 82, 036120 (2010)]. Específicamente, los autores proponen que la distribución del grado de nodos del grafo asociado a dichas series temporales de estos procesos es descripta por una funcional exponencial de la forma $P(\kappa)\ sim\ exp(-\lambda \cdot \kappa)$, en el que κes el grado del nodo y λ es un parámetro positivo capaz de distinguir entre un comportamiento determinista (caótico) y uno estocástico (ruido no-correlacionado y ruido correlacionado). En este trabajo, investigamos las características de las distribuciones de grado de nodo del grafo asociado construido utilizando HVG, para seri s temporales correspondientes a 28 mapas caóticos, 2 caóticos y 3 procesos estocásticos diferentes. Estudiamos en profundidad la metodología propuesta por Lacasa y Toral encontrando varios casos para los cuales su hipótesis no es válida. Se propone una metodología que utiliza metodologia HVG junto con cuantificadores de la Teoría de la Información. Un análisis exhaustivo y cuidadoso de las distribuciones del grado de nodos obtenidas mediante la aplicación de HVG nos permiten concluir que el plano de información de Fisher-Shannon es una notable herramienta capaz de representar gráficamente la naturaleza diferente, determinista o estocástica, de los sistemas bajo estudio. Se presentaran algunas aplicaciones a series experimentales y su correspondiente análisis.

Dinámicas de Opinión y Enfermedad en Redes Múltiples Interactuantes: Transición de Fase Discontinua y Tiempo de Consenso No Monótono (Interacting opinion and disease dynamics in multiplex networks: Discontinuous phase transition and nonmonotonic consensus times)

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La formación de opiniones y la propagación de enfermedades se encuentran entre los procesos dinámicos más estudiados en Redes Complejas. En sociedades reales, se espera que estos dos procesos dependan y se afecten entre sí. Sin embargo, poco se sabe sobre los efectos de la dinámica de la opinión sobre la dinámica de la enfermedad y viceversa, ya que la mayoría de los estudios los tratan por separado. En este trabajo se estudia la dinámica del Modelo del Votante para la formación de opiniones entrelazada con la del Proceso de Contacto para la propagación de enfermedades, en una población de agentes que interactúan a través de dos tipos de conexiones: sociales y de contacto. Estas dos dinámicas interactuantes tienen lugar en una red múltiple compuesta por dos capas acopladas a través de una fracción q de enlaces presentes en ambas redes. La probabilidad de que un agente modifique su opinión dependerá del estado de enfermedad del agente con el que interactúa y del suyo. En forma equivalente, la probabilidad de que un agente sea infectado por un vecino dependerá de los estados de opinión de ambos agentes. Encontramos que la dinámica de la opinión tiene un profundo efecto sobre las propiedades estadísticas de la propagación de la enfermedad. El más importante es que la transición suave (continua) de una fase sana a una endémica observada en el Proceso de Contacto, a medida que la probabilidad de infección aumenta más allá de un umbral, se vuelve abrupta (discontinua) en el sistema de dos capas. Por lo tanto, no tener en cuenta los efectos de la dinámica social sobre la propagación de las epidemias puede conducir a una desestimación de la magnitud real de la propagación. También, una transición discontinua endémica-sana se encuentra cuando el acoplamiento q supera un valor umbral. Además, se demuestra que la dinámica de enfermedad retrasa el consenso de opinión, lo que lleva a un tiempo de consenso que varía de forma no monótona con q en una amplia gama de parámetros del modelo.

C9: Epidemics

Human Mobility and the spread of Vector-Borne Diseases

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In the transmission of vector-borne diseases, such as Dengue, Chikungunya or Zika, the use of the network approach has to overcome the impossibility of capturing the contact patterns between people and mosquitoes. However, it is possible to combine network theory and metapopulation modeling so to incorporate the structure of the individual flows between different areas and the contact between humans and vectors within them. In our case, the nodes of our network denote urban areas and the connections between them describe the flow of people between the corresponding areas of a city. In this way, infections have a "wellmixed" character inside each of the areas (dynamics within nodes) whereas the flows of people between nodes are responsible of promoting the epidemic spread to distant areas (by causing the infection of the vectors placed there). The available data on the flow of people and the incidence of the disease in different areas allowus to examine the robustness of the control strategies that consider the spatial differences, beyond the limits of classical models of control.

The spread of multipartite viruses

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Commonly studied pathogenic viruses are monopartite: Their viral particles contain the complete genome, and one particle infecting a cell is potentially enough to start replication. This is, however, not the only organization of the genetic material found in nature. Multipartite viruses have their genome divided into two or more segments, and these segments are each packaged into separate virus particles. Replication inside a host cell is possible only when the whole genome is present, thus requiring co-infection of the same host by several variants. This should represent an evolutionary disadvantage with respect to monopartite viruses, and indeed multipartite viruses infecting animals are quite rare. However, around 40% of viruses infecting plants are multipartite (Hull, Plant virology, 2014). From this observation, two questions arise. What are the evolutionary mechanisms that lead multipartite viral forms to fixation, despite their apparent disadvantage? Why are they so common among plant viruses infecting plants, and so rare among animal ones? Experimental works and modeling frameworks have so far tried to answer these questions adopting a within-host (sometimes within-cell) perspective. Knowledge of the spreading dynamics of multipartite viruses at the population level has been lacking. Using both analytical approaches and stochastic simulations, we characterize the conditions that lead to the evolutionary fixation at the population scale of the monopartite and/or multipartite variants. We analytically derive the critical values discriminating among the different scenarios, gauging the impact of homogeneous vs heterogeneous contact topologies, and single populations vs metapopulation structures. We find that simple, experimentally known, microscopic features of insect-borne transmission, when coupled to different population structures, lead to a rich phenomenology, which contributes to shed light on the origin of this puzzling genetic organization. In addition to the specific biological interest, we believe that the analytical framework developed in this work can be further generalized to study the critical behavior of pathogen interaction in other contexts.

Human mobility network and persistence of multi-strain diseases

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Rapidly mutating pathogens may be able to persist in the population and reach an endemic equilibrium by escaping acquired immunity of hosts. For such diseases, multiple biological, environmental and population level mechanisms determine epidemic dynamics, including pathogen's epidemiological traits, seasonality, interaction with other circulating strains and spatial fragmentation of hosts and their mixing. In previous studies we focused on the impact of the heterogeneities characterizing population distribution and mobility network. In this work we go one step further and study the impact of these heterogeneities with multiple competing strains. We consider a susceptible-infected-recovered-susceptible model on a metapopulation system where individuals are distributed in subpopulations connected with a network of mobility flows. We simulate disease spreading by means of a mechanistic stochastic model and we systematically explore different levels of spatial disaggregation, probability of traveling among subpopulations and strain competition/cooperation, reconstructing the phase space of pathogens persistence and the dynamics out of the equilibrium. Results depict a rich dynamical behavior. The increase in the average duration of immunity reduces the chance of persistence until extinction is certain above a threshold value. Such critical parameter, however, is crucially affected by the traveling probability, being larger for intermediate levels of mobility coupling, and the competition of the different strains. The dynamical regimes observed are very diversified and present oscillations and metastable states. Topological heterogeneities leave their signature on the spatial dynamics, where subpopulation connectivity affects recurrence of epidemic waves, spreading velocity and chance to be infected. The present work uncovers the crucial role of hosts' space structure on the ecological dynamics of rapidly mutating pathogens, opening the path for further studies on disease ecology in presence of a complex and heterogeneous environment.

C10: Spanish Session

La intermediación como estrategia en el análisis de la propagación de un rumor en una red basada en el modelo de Barbell

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Considerando una red de individuos los cuales pertenecen a un salón de clase, algunos de ellos están divididos en dos grupos β y α con distintas afinidades. Utilizando como motivación el grafo de Barbell el cual consiste en dos grafos completos idénticos con grado *K* conectados por una ruta *P* de *m* saltos. Los individuos que integran los grupos β y α comparten al menos una ruta con *m* individuos intermediarios λ que les permite comunicarse. El comportamiento de la distribución de un rumor debe de emerger de acuerdo a las relaciones entre los individuos. Teniendo como referencia que la sociedad humana crea lazos de amistad a través de encuentros aleatorios y decisiones conscientes, un rumor puede esparcirse de acuerdo al grado de agrupamiento que tienen los individuos y su ubicación en la red. Para analizar la difusión de un rumor se deben clasificar las relaciones que tienen los individuos en su vecindario de acuerdo a la información de la estructura de la red. El atributo que permite determinar la ubicación del individuo en la red es su medida de *intermediación*. Este concepto fue introducido en 1948 por Bavelas, el cual sugiere que una persona en particular dentro de un grupo se encuentra estratégicamente ubicado en una posición central, siendo la ruta más corta para conectar a otros individuos del grupo. En redes como Internet los mensajes pueden ser clasificados en tres tipos unidifusión, multidifusión y difusión. Trasladando ésta clasificación a un salón de clase un rumor inicia desde un individuo a otro cualquiera dentro del grupo β lo que correspondería a un mensaje tipo unidifusión. El dispersar un rumor a todos los integrantes del grupo β por parte de un sólo sujeto es un mensaje multidifusión, en éste caso el grupo α ignora el rumor. Mientras que el esparcir el rumor a todos los que pertenecen al salón se identifica como mensaje tipo difusión. La medida de intermediación de los individuos λ los cuales pertenecen al salón de clase, pero no pertenecen a los grupos β y α son críticas para identificar el patrón de comportamiento que emergerá en la distribución del rumor. Omando en cuenta que el salón de clase está constituido como un grafo de Barbell con *m=5* saltos y grado *k=6* para los grupos β y α. Si el individuo tipo λ con mayor índice de intermediación entrega un mensaje unidifusión para esparcir un rumor, éste impactará únicamente a uno de sus dos vecinos. En cambio, si el mensaje para transmitir el rumor es de tipo multidifusión entonces llegará a ambos vecinos del intermediario, lo cual abrirá un canal para que el rumor se esparza hacia alguno de los grupos β o α, siempre y cuando alguno de sus vecinos transmita el mensaje a un compañero que pertenezca algún grupo.Finalmente, el individuo λ con el grado de intermediación más alto es una pieza relevante para que un rumor se transmita de un grupo a otro. En conclusión, los nodos intermediarios en una red social con menor grado de agrupamiento no deben descartarse en el análisis de la difusión de un rumor de una región de la red a otra.

Estructura Dinámica de las Redes Complejas Temporales como Herramienta de Evaluación para la Gestión de Proyectos

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Gran parte del pensamiento que domina la gestión de proyectos, tal como se practica y se enseña hoy en día, aún se basa en teorías de control que se desarrollaron en los primeros tiempos de la era moderna para abordar la industrialización de los siglos XIX y XX. Sin embargo, múltiples problemas acontecen cuando estas ideas se aplican unilateralmente a todos los tipos de proyectos, en todos los contextos. En entornos complejos, los problemas de gestión surgen de la suposición de que los resultados, anticipados al inicio del proyecto, pueden ser suficientemente determinados y luego entregados como estaba previsto. Este enfoque de la gestión de proyectos sólo funciona para un número limitado de proyectos. Estos proyectos tienden a ser bastante pequeños en escala y de corta duración. Sin embargo, una vez que un proyecto alcanza un tamaño crítico, un calendario, un nivel de ambigüedad e interconexión, los enfoques basados en control no funcionan enteramente.
La teoría de la complejidad también tiene un alcance considerable para proporcionar una visión de la naturaleza sistémica de los proyectos. La mayoría de los proyectos se pueden describir más fácilmente como sistemas complejos adaptativos que como sistemas simples, porque consisten en múltiples componentes dinámicos interdependientes, implican múltiples procesos de retroalimentación, implican relaciones no lineales e implican tanto datos hard (dinámica de procesos) como datos soft (dinámica del equipo de gestión y operativo).
Así, se propone una perspectiva evolutiva, pasando de la perspectiva tradicional basada en el estándar internacional PMBOK a la visión de la complejidad, utilizando herramientas de las ciencias de la complejidad. La estructura del proceso/subproceso dinámico del PMBOK se simula a través de una red compleja, lo que permitirá evaluar la gestión de proyectos mediante la observación de las conexiones entre procesos/subprocesos y medidas de la red. La dinámica de la red compleja será dada por el flujo de información que directa o indirectamente activará las conexiones entre nodos, a través de rutas redundantes encontradas por procesos de inferencia.
Estas herramientas de hibridación complejas permiten un acercamiento a la realidad de la ejecución de proyectos, obteniendo un mejor desempeño al lograr un mayor porcentaje de éxito. En este trabajo, mostramos algunas simulaciones numéricas que conducen a una herramienta de decisión clara para clasificar qué procesos de gestión son críticos para el éxito.

Agentes persistentes en un modelo de dinámica de opinión considerando indices de difusión e influencia.

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El éxito de muchas de las sociedades modernas está directamente relacionado con el hecho de que la opinión de la mayoría de los individuos permita la toma de decisiones que generen acciones directas sobre el bienestar social. De esta manera, se entiende que las dinámicas de opinión pueden ser útiles y poderosas herramientas para diseñar mecanismos para la realización de acciones colectivas[1]. El propósito de este artículo es caracterizar la dinámica de opinión de un conjunto de agentes dividido en dos grupos. El primero, de agente persistentes, los cuales típicamente no cambian su opinión a pesar de las interacciones sociales, además estos agentes difunden su opinión de manera pública. Por otra parte, se establece un grupo de agentes regulares los cuales están dispuestos a cambiar sus opiniones y la comparten de manera semi-privada con un número específico de agentes. El modelo usado como referencia es una variación del modelo de Friedkin-Jhonsens [2]. Se evalúan los efectos que los agentes persistentes tienen sobre el comportamiento del modelo de dinámica de opinión representado a través de grafos dirigidos. El modelo propuesto considera la actualización de las opiniones como una combinación convexa de la opinión actual de los vecinos y la opinión inicial del agente, además la disposición convexa de las variables es usada para introducir el peso de la difusión de las opiniones del grupo de los agentes persistentes y el valor de la información privada, más específicamente el mecanismo para la actualización de las opiniones afirma que el peso individual de las propias opiniones varia, los pesos relativos que se asignan a otros individuos y a otras hacen que la red cambie[3].El modelo propuesto es validado por medio de simulación, donde se analizan algunos índices de convergencia y la influencia de los agentes persistentes sobre los agentes regulares [4].

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PT12: Plenary Talk

Spatio temporal analysis of Language use.

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The advent of large scale online social services coupled with the dissemination of affordable GPS enabled smartphones resulted in the accumulation of massive amounts of data documenting our individual and social behavior. Using large data sets from source such as Twitter, Wikipedia, Google Books and others we will present several recent results on how languages are used across both time and space. In particular, we will analyze the role of multilinguals in Social Networks and how language dialects can be defined empirically based on the way a language is used in the real world. Finally, we will also analyze how Chinese and English usage changes from place to place and over time and how languages can be used to identify communities within the urban environment.

PT13: Plenary Talk

Brain networks: is complexity jumping the shark?

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As with other complex real-world systems, studying the complexity of brain dynamics has had profound implications in the comprehension of phenomena like the emergence of coherent behavior and cognition, or the capability to functionally reorganize after brain lesions (i.e., brain plasticity). Since the chaos theory in the late 80s and early 90s, the theory on nonlinear synchronizations in early 2000 to the last framework based on complex networks, the area of complex systems has led to different paradigm shifts in the neuroscience community. Hence, despite the increasing popularity of practical methods (e.g. synchrony measures, connectivity indices, etc) to analyze brain dynamics, our understanding of brain organization is still in its infancy. This is in part due to the fast and wide methodological development of new analytical tools and the inevitably slower rate of absorption by the neuroscience community, which needs to validate their physiological relevance and practical reliability. Nevertheless, researchers developing methods (e.g. mathematicians, physicists, engineers) and neuroscientists (e.g. neurologists, psychologists, psychiatrists) often belong to different scientific domains with radically different assumptions about the observed data. Although this interdisciplinary integration is fascinating, and may eventually lead to fundamental advances in the comprehension of the brain functioning, there is a number issues that should be considered to optimize collaborative efforts. In my talk, I'll review and illustrate some of the main pitfalls in the integration of some concepts of complex systems, including complex networks, in neuroscientific studies. In an attempt to appeal to dwindling audiences (i.e. some neuroscience communities, some media or scientific journals, etc) researchers often forget the core assumptions of the theoretical concepts. I'm fully convinced that neuroscience community does not jump the shark because it runs out of ideas, but we do it because we're pressure to be scientifically greedy.

C11: Synchronization

Enhancement of early warning properties in the Kuramoto Model and in an Atrial Fibrillation Model due to an external perturbation of the system

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This contribution deals with the impact of external noise added to the system on the so-called Early Warning signals (EWs). Our goal is to understand the importance of the amplitude and complexity of the noise, in order to achieve such goal, we analyze EWs of two computational models related to biology: 1) the Kuramoto model, which is a paradigm of synchronization for biological systems, and 2) a cellular automaton model of cardiac dynamics which has been used as model for atrial fibrillation. For each model we first characterize the EWs. Then, we introduce external noise of varying intensity and nature to observe what effect this has on the EWs. In both cases we find that the introduction of noise amplify the EWs, in particular, those with more complex noise have a greater effect. This offers a way to improve the chance of detection of EWs in real systems and suggests that natural variability in the real world does not have a detrimental effect on EWs, but the opposite.

Synchronization in interacting signaling networks

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We study synchronization and temporal correlations in a two-layer interacting signaling model. The interacting network consists in units/oscillators located in two small-world networks, where each network displays different fractal temporal correlations and avalanche activity. We use the global lability of synchronization method, which is based on the rate of change of the total number of synchronized oscillators to estimate the level of synchronized behavior between networks. Particularly, we evaluate the change in the temporal correlation and synchronization dynamics displayed by the system in terms of the coupling parameter between layers. Our results show that for intermediate and large interconectivity, $1/f$ signals are present for any combination of interacting systems. Moreover the cross-correlation between system's synchrony events closely follow a power-law scaling when networks are coupled, indicating that there exist a high correlation over long time scales due to information transmission.

Hybrid Model of Pulse-Coupled Oscillators in Dynamic Networks

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The analysis and control of pulse-coupled oscillators is a currently active field of engineering research. Existing models had been used to study the behavior of cells, neurons, and other biological systems. One such behavior is desynchronization, a more severe problem and the inverse problem of synchronization. For pulse coupled oscillators, desynchronization is the action in which the phase difference between all of the oscillators is equal. This phenomenon has many important applications in communications, electronic converters, mental diseases, and control. Most of the existing results are constrained to a completely interconnected network [1, 2], or fixed topologies [3]. Also, in concern to the case of time-dependent networks some works in the literature describe analysis for synchronized state [4, 5, 6]; however, the extent of the modeling and analysis of desynchronization state over dynamical networks does not exist in the state-of-art. This work proposes a Hybrid systems model of pulse-coupled oscillators over dynamic changing networks of interaction on the framework proposed in [7]. We analyze the emergence of desynchronization state and its dependency on network dynamics by recasting the problems as a set stabilization problem in the hybrid systems framework. Moreover, some perturbations are applied to show properties of the desynchronization state. We also illustrate the dynamics via simulations. The main contributions of this work are the study of the convergence of the desynchronized state for changing network topology, and the use of hybrid systems tools, which capture the continuous and impulsive behavior of oscillators and the sudden changes in network topology. Also, it gives us a proper framework for the analytical study of its stability and robustness properties.

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Reconstructing networks of pulse-coupled oscillators from non-invasive observations

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Reconstruction of a network structure from observations is an important problem relevant for many different areas such as neuroscience, physiology, climatology, genetics, ecology, etc. A group of established reconstruction techniques relies on analysis of the system response to a specially designed perturbation, i.e., on invasive measurements. However, often invasive measurement is not an option, e.g., in problems related to climatology, physiological studies, and medical diagnosis. In such cases one is restricted to analysis of observations of the free-running system. In this work we develop a method of reconstruction relying only on observation of the free-running system. We address the case when the signals are spiky, namely, that the measurements between the spiking events are dominated by noise and only determination of the times of spikes is reliable. Hence, the data we analyze are spike trains and estimation of time-continuous phase is not feasible. The reconstruction routine is of iterative nature. First, since we do not have any knowledge of the system yet, we evaluate the phase response curve (PRC) in the mean-field approximation, i.e., all-to-all equal coupling. Next, using the PRC estimate, we obtain an approximation of the network, which is then in turn used to obtain a better approximation of the PRC, and so on, continuing this procedure until the error of the reconstruction falls bellow a chosen value. Assuming that the outputs of all nodes are known and that the coupling between the elements is sufficiently weak to justify the phase dynamics description, we recover the connectivity of the network and properties of all its nodes. We perform thorough statistical analysis to quantify the robustness of our method. Finally, we test our method on a network of 20 Morris-Lecar oscillators, to see how it behaves for a realistic neuronal model.

C12: Social Dynamics

Data driven network analysis confirms U.S. Culture as the main long-term factor to support results of last presidential elections

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According to studies based on 2016 polls, Trumps's U.S. presindetial vistory has been attributed to the vote of the white working class, and specifically due to fears about American culture and identity. However, this was not a contingent or short tems result. By using one hundred samples of about 30,000 registries of the 2013 version of the Aemerican Community Survey, we reconstructed a probabilistic network of variables representing nineteen factors of objective well-beong of the U.S. population. The network nodes corresponded to variables and links to statistical controled weigted associations among variables, that mapped the complex interdependency of factors inside individual and household scales, below social networks and above molecular 'omic' networks. Analysis of the multipartite network alloed addressing factor relevance and role in the whole systems of well-being. factor relevance relied on parametric and non-parametric statistical tests between distributions of the adjusted averages of link weights and network customary indices within and between nodes of each factor. To identify the role of factors in the whole system of well-being, we used hierarchical clustering and permutation of the network's adjacency matrix that located closer factors in four branches and seven levels. By their dense connectivity, factors of culture (as a sense of belonging by including variables of race, ethnicity, nativity and permanence in the U.S.) and Household economic characteristics occupied the root level supporting and influencing the remaining factors and providing consistency to the whole system. In this way, taking account of the more sensitive and core issues and concern related to the U.S. population well-being is central to mobilize people's decisions. Our network analyses results found those core issues to anticipate results of the winning discourse, but also showing that the core factors of sense of belonging and household economy are more than short term objective concerns of the U.S. population.

Dissecting structural systemic properties of mammalian tissue-specific transcription factor networks

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Real world complex networks are known to be robust against sporadic errors occurring randomly across the system components, yet fragile against directed attacks. This 'robust yet fragile' behavior is grounded on the scale-free degree distribution associated with complex networks. Although biological networks are known to approximate a theoretical scale-free degree distribution, the actual implementation of the regulatory circuitry acting within the different tissues is likely to presents high structural heterogeneity and deviations from the theoretical models. With the hypothesis that the specific patterns of heterogeneity could provide insights into the systems-level mechanisms underlying cell behavior, here we analyze the structure and behavior against structural perturbations of tissue-specific networks in human and mouse. The state of the cell/tissue is structurally represented by condition specific transcription factor networks generated using chromatin accessibility data. By extensive profiling and quantification of the global systems behavior of a broad sample of different tissues against damage, and by measuring their degree of deviation from theoretical expectations, we uncovered a novel systemic structural property underlying embryonic stem cells: their regulatory heterogeneity endows them with high robustness against both errors and attacks. Further inspection of network structure, revealed that embryonic stem cell networks display a higher degree of similarity to the expectations of analogous random exponential network models than the other tissues, explaining their increased structural robustness.

A networked voting rule for democratic representation

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We introduce a general framework for exploring the problem of selecting a committee of representatives with the aim of studying a networked voting rule based on a decentralized large scale platform, which can assure a strong accountability of the elected. The results of our simulations suggest that this algorithm-based approach is able to obtain a high representativeness for relatively small committees, performing even better than a classical voting rule based on a closed list of candidates. We show that a general relation between committee size and representatives exists in the form of an inverse square root law and that the normalized committee size approximately scales with the inverse of the community size, allowing the scalability to very large populations. These findings are not strongly influenced by the different networks used to describe the individuals interactions, except for the presence of few individuals with very high connectivity which can have a marginal negative effect in the committee selection process.

Control-Oriented Modeling of Large-Scale Networked Systems: A Dynamic Mode Decomposition Approach

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Modern control strategies for large-scale networked systems should achieve safe, robust, and efficient operation. Two main constraints arise when we desire to control large scale network systems. First, communication complexity due to a large number of sensor and actuators. Second, overly computational burden due to size and complexity in the system. To deal with these control challenges in a large-scale networked system, decentralized and distributed control are the primary approach. To achieve an efficient operation, it is required control in real-time. A decentralized or distributed control can guarantee real-time operation, but in both strategies is necessary a control-oriented model due to computational capacity. In most large-scale systems, it is hard to have a model of the system, then to identify systems is an alternative. Classical techniques for modeling dynamical nonlinear system rep- resent the systems in a monolithic model. This model captures the main characteristic of its elements as well as their basic relationships but ignoring any structural topological effects. With an overall model, there is an additional complex task, which is partitioning the systems for the implementation of a control strategy. We use Dynamic Mode Decomposition (DMD) for capture the dynamic of each subsystem and infer strong coupling functions between them. DMD is an equation-free algorithm that represents a complex system in several spatiotem- poral structures, which are useful for predicting states or control design. This method uses only a buffer of measurements, and then through a regression, we can obtain a linear model. Additionally, we will use the connection between DMD and spectral analysis of Koopman operator. This operator captures the evolving of the observables of any nonlinear dynami- cal system. Then using their spectral properties, we can capture nonlinear dynamics in the systems from an infinite dimensional linear operator. In this work, we show how to use the DMD for obtaining control-oriented models able to capture features of system interest and to obtain nonlinear couplings of interconnection while the partitioning problem is avoided, and additionally the model may be used for improving global performance using the same control strategy. These results are tested in simulations through of a large-scale networked system, showing the effectiveness of the proposed method.

MS7: "Dynamics of Networks: observability, modeling and synchronization"

Assessing the dynamics of complex networks is still an open challenge, mostly due to the large number of variables spanning the state space. Due to this high-dimensionality, there are some related problems that can be stated in form of questions as follows:

- Do we need to measure all variables from the network or could we choose an optimal reduced set of them?
- Is the concept of dynamical « observability » useful to address the first problem?
- Is it possible to obtain a global model that reproduces the collective dynamics of the network for any possible synchronization state ?
- Can hub-node dynamics be approximated by a low-dimensional system?

The connotation of "observability" may vary according to the area of application. Here it seems that the distinction between "structural observability", "symbolic observability" and "dynamical observability" is beneficial. In the first two talks of this session, the concepts of dynamical and symbolic observability will be reviewed and new developments will be reported. Particular emphasis will be given to the use and interpretation of observability in the context of networks. The two last talks are more focused on how to represent and characterize the collective dynamics in networks. All talks will discus examples and possible applications.

Organizers: *Luis A. Aguirre* & *Christophe Letellier*

Dynamical and structural observability of networks

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Network analysis is currently a very exciting research area. Some rather recent examples of networks include the Internet, sensor networks and formation of robots, to mention a few. However, networked systems have existed for a longer time as for instance: the power grid, social epidemic networks and the brain, but the analysis of such high-dimensional systems is clearly part of a more recent trend. The development of conceptual and numerical tools has made it possible to start aiming at the analysis and monitoring of such systems. One of the many concepts used to analyze networks is observability. The genesis of this can be traced back to mid 20th century. It is interesting to see that depending on the research area observability has been painted with different colors. In control theory, the cradle of this concept, observability is related to the ability of reconstructing the state of the system from a limited set of measured variables. A somewhat relaxed version of this definition of observability and which is applicable to networks is mainly concerned with the topology of the network and is known as structural observability. These concepts have a main aspect in common: both classify the network as either observable or unobservable and might be useful to choose which and how many nodes should be measure in order to render the network observable. There is a different concept, which evolved from the traditional approach to observability, that has a different aim. Even if a system is observable, it might be advantageous, especially from a numerical point of view, to measure specific variables of the sensor nodes. Instead of a binary classification in terms of observability, this concept permits distinguishing between more and less observable scenarios. We shall refer to this as dynamical observability. Hence, in the context of dynamical networks, it is assumed that there is an n-dimensional dynamical system in each node and instead of measuring the n variables, it is desired to choose the one that provides the best dynamical view of the node dynamics. To move from node dynamics to network dynamics the other views of observability are also relevant. In this talk various aspects of observability will be reviewed. The aim is to make a clear distinction between concepts and to understand what does each one contribute to the analysis and monitoring of networks. A dynamical network will be considered. Different choices of variables and nodes will be used in trying to detect phase synchronization regimes as a way to illustrate the main ideas.

Assessing the observability of complex networks: a nonlinear theory

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With the emergence of chaotic systems and, more recently, of complex networks, the problem of observing and synchronizing (network of) coupled oscillators became widely studied due to the important applications it has not only in life and environmental sciences but also in power grids or social networks. Indeed, when a network is considered, the problem of the number of variables to measure required for its study is crucial because it is very often not possible to measure all of them. How to choose them is an important challenge which may depend on the task. In order to hand complex networks, it is not possible to use analytic computations and we introduced symbolic computations – based on a weighted adjacency matrix describing the network - to assess the observability of network dynamics as required for instance for getting a reliable and robust model and/or characterizing of its dynamics. A very challenging 13-dimensional rational dynamical network will be explicitly treated with an analytical validation of our results.

Detection and formulation of causal couplings: an alternative approach based on global modelling

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Biophysical, societal and environmental systems are governed by complex nonlinear couplings that are often essential to the behavior. One direct consequence of such couplings is that the dynamical processes involved in the observed behavior cannot be separated from the other processes. To understand such systems, it may be necessary to consider the dynamic as a global behavior. The global modeling technique was designed in the early 1990s to obtain ordinary differential equations from single observational time series [1]. Thanks to algorithms increasingly powerful [2], the approach was proven to be applicable to real world behaviors [3, 4]. To apply such an approach to investigate the couplings in a set of observed variables under real conditions is a difficult problem. In the present work, an algorithm dedicated to multiple time series is presented. Its ability is first tested on a case study of two chaotic oscillators. Its application to real world systems is then presented: Applied to the Bombay plague (1896-1911), the approach allows, not only to detect the couplings between the epizootics in brown and black rats and the epidemic, but also to get an algebraic formulation of these couplings for which interpretation can be proposed for all the terms [5]. Applied to the West African epidemic of Ebola virus disease (2003-2016), a four-dimensional chaotic model of the coupling between the numbers of infections and deaths is obtained [6]. This model exhibits a very complex behavior. The topological analysis of the resulting attractor shows that the dynamics can be reduced to a four-branch skeleton.

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Global modelling of optimally coupled dynamical systems

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The Ansatz library was initially constructed to obtain a global model working in a space spanned by variables which might be equal to those spanning the original state space (and not derivative or delay coordinates as commonly used). The Ansatz library is a list of coordinate transformations $\Phi : \mathbb{R}^m(\vec{x}) \mapsto \mathbb{R}^m(\vec{X})$ between the original state space $\mathbb{R}^m(\vec{x})$ and a differential embedding induced from a measured variable: to belong to the library, transformation Φ must be invertible. Once a global model is obtained in the differential embedding $\mathbb{R}^m(\vec{X})$ — as in the standard global modelling procedure — the inverted coordinate transformation Φ^{-1} is used to express it in the "original" state space $\mathbb{R}^m(\vec{x})$. To each map $\Phi : \mathbb{R}^m(\vec{x}) \mapsto \mathbb{R}^m(\vec{X})$ corresponds a transformation $\varphi : \mathbb{R}^p(\vec{a}) \mapsto \mathbb{R}^{p'}(\vec{A})$ between the p parameters of the original system and the p' ones from the global model. It is possible that different "original systems" can share the same global model and, consequently, two different original systems can produce the same time series (one of their variable is exactly the same). presenting a time series Invariant sets in the parameter space — defined by some relationships between some parameters which leave invariant the system dynamics — can be identified. It is thus possible to use the terms related to these invariant sets to couple dynamical systems and for which the dynamics is only weakly affected when the coupled systems are not synchronized: such a feature lead to the concept of "optimal coupling". Our target is here then to investigate whether or not such optimally coupled systems can be captured by a global model from a limited set of measurements.

MS8: "Network Biology Approaches to Understand Complex Diseases"

Understanding the mechanisms behind the origins, development, evolution and resilience of diseases is one of the most important challenges in Contemporary Science. To do so, Medicine and the Biomedical Sciences are supported by hysics, Mathematics and Computational Sciences in an emergent field known as Systems Biology. Here, living systems and its constituents at different levels of description can be seen as nodes interacting into a network.
Network approaches are able to integrate, in a relatively easy and visually appealing fashion, a considerable amount of information of diverse classes coming from a large range of sources. Global properties of the networks, often provide information that can shed light upon the underlying emergent processes of living systems, and thus help to complement information obtained by biomedical research.
Network Biology has contributed to the discovery of a myriad of different processes and mechanisms of biological systems at the molecular, cellular and physiological level, demonstrating that biologicallyinspired network inference and analysis is a useful tool to direct basic and applied experimental research. In this sense, one of the main objectives in network biology is that network structure and dynamics can be modified to switch from a disease to a nondisease phenotype.
Goals To provide state of theart network research applied to understand the origins and development of several

Organizers: *Enrique Hernández Lemus*

Transitions between Dynamic Phases in Fertilization Regulatory Networks

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Fertilization is one of the fundamental processes of living systems. In this work we look into global systemic properties of biochemical signaling networks that regulate the motility of external marine spermatozoa in their search of the egg. In previous work, based on experimental evidence, we have shown that sea urchin sperms swim towards the ovum guided by flagellum internal [Ca2+] concentration fluctuations triggered by the binding of chemicals from the oocyte surroundings. For a better understanding of this process, we have constructed a family of logical regulatory networks for the [Ca2+] signaling pathway [1,2,3,4]. These discrete models reproduced electrophysiological behaviors previously observed and have provided predictions, some of which we have confirmed within our research group with new experiments. From our studies we have gained insight on the flagella structure and operation under the influence of drugs that modify the calcium fluctuation temporal behavior and hence control sperm navigation [2,3,4]. These findings, in conjunction with more recent work we have undertaken on mammals, may eventually contribute to the development of a male contraception treatment, which is an area of intense research. In this presentation we focus on systems biology issues of the [Ca2+] regulatory network dynamics such as: stability, redundancy, degeneracy and complexity. Within a formalism developed by Pomeau and Derrida [5] we look into the presence of two dynamical phases, a contracting regular phase and an expanding chaotic phase, which are separated by a critical dynamical regime, at which a transition between the dynamical phases takes place. Our findings show that our discrete network dynamics operates at a critical regime, where robustness and evolvablity coexist. We also show that under strong perturbations criticality is preserved. These findings are a matter for reflection and may be of evolutionary interest. Furthermore, by considering a generalization of the Derrida map, first introduced in [6] we are able to implement a node reduction method that leads to a network which coincides the one we obtained via an attractor landscape study. Finally, it is encouraging to find that the outcome of this network reduction process coincides with the result of an alternative, bottom, up step by step, continuous model approach.

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Network Community Structure in Breast Cancer Molecular Subtypes

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Breast cancer is a heterogeneous and complex disease, a clear manifestation of this is its classification into different molecular subtypes. On the other hand, gene transcriptional networks may exhibit different modular structures that can be related to known biological processes. Thus, community structures in transcriptional networks may be seen as manifestations of regulatory structures that tightly controls biological processes. In this work, we identify community structures on gene transcriptional networks statistically inferred from microarray data of molecular subtypes of breast cancer: luminal A, luminal B, basal, and HER2-enriched. We analyzed the communities (modules) found in each network to identify particular biological functions (described in the Gene Ontology database) associated to them. We further explored these modules and their associated functions to identify common and unique features that could allow a better level of description of breast cancer, particularly in the basal-like subtype, the most aggressive and poor prognosis manifestation. Our findings related to immune systems in basal subtype could help to understand it and design strategies for its treatment.

Structure-based control of complex networks with nonlinear dynamics

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What can we learn about controlling a system solely from its underlying network structure? Here we adapt a recently developed framework for control of networks governed by a broad class of nonlinear dynamics that includes the major dynamic models of biological, technological, and social processes. This feedback-based framework provides realizable node overrides that steer a system toward any of its natural long-term dynamic behaviors, regardless of the specific functional forms and system parameters. We use this framework on several real networks, identify the topological characteristics that underlie the predicted node overrides, and compare its predictions to those of structural controllability in control theory. Finally, we demonstrate this framework's applicability in dynamic models of gene regulatory networks and identify nodes whose override is necessary for control in the general case but not in specific model instances.

The use of a drug-gene perturbation network for the study of drug side effects: The case of drug-induced peripheral neuropathy

Guillermo de Anda-Juáregui[1], *Brett McGregor*[2], *Kai Guo*[3] *and Junguk Hur*[4]

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In the drug discovery process, the evaluation of both therapeutic efficacy and safety are considered equally important. Nonetheless, many available drugs in the market therefore are capable of causing undesirable side effects. The consequences of these can range from minor discomfort to therapeutic inefficacy, and all the way to serious complications. In many cases, it is difficult to identify a mechanism through which the drug may produce these effects. An example of this is drug-induced peripheral neuropathy, a loss of function in the axons of the peripheral nervous system.
Through literature mining of drug labels, we previously collected 234 U.S. FDA-approved drugs causing treatment-associated peripheral neuropathy (neuropathy-inducing drugs or NIDs). From Connectivity Map (CMap), a collection of gene expression signatures obtained from drug perturbation assays on cell lines, we collected transcriptional perturbation data for 98 NIDs and constructed a drug-gene perturbation network. A NID is linked to a gene, when it has either an up- or down-regulation effect in the gene's expression. As gene expression signatures take the form of ranked lists based on differential expression, we define an up- or down-regulated gene as one above or below a rank threshold. Therefore, each drug is connected to a defined number of genes in the network; however, each gene may be connected to any and up to the total number of drugs in the network.
With this model, we constructed a bipartite network consisting of 98 drug and 7,138 gene nodes with 19,600 interactions among them. This network was evaluated against a null model based on 5,000 networks of randomly ranked expression profiles, effectively reconnecting each drug to randomly selected genes. The structure of our NID network was significantly different from those of the randomly generated networks. We hypothesized that the most connected genes in this network (degree $\geq$ 10) were more likely to be involved in neuropathy driving mechanisms, and identified 64 such genes. To determine if these genes are highly connected only to NIDs, or whether they are generally susceptible to any drug perturbation, we generated 5,000 drug-gene perturbation networks derived from CMap profiles for randomly selected non-NIDs. Then, we constructed frequency distributions of degree for a given gene across the non-NID networks, and evaluated whether the degree observed in the NID perturbation network was expected. We found 27 out of the 64 highly connected genes were specifically associated with NIDs. These NID-specific genes are involved in cellular mechanisms such as cytoskeleton organization, mitochondrial function, solute transport, signaling, and transcriptional regulation, which can be linked to neurological damage and therefore neuropathy. We also discovered that these NIDs can affect wound healing and circadian function, whose role in a neuropathic setting remains to be studied.
In conclusion, we integrated literature and experimental data to study neuropathy as a drug side effect. Our network-based approach allowed us to identify candidate genes that may be involved in the development of drug induced neuropathy, as well as generate hypotheses regarding the molecular mechanisms behind this condition.

PT14: Plenary Talk

Dynamics and Effective Connectivity in Neuronal Cultures: from Experiments to Medical Applications

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Neuronal cultures offer a unique platform to study collective phenomena in neuronal networks. The ability of experimentalists to modify the connectivity among neurons and their dynamics offer a unique scenario to investigate key open questions in neuroscience, including the emergence of spontaneous activity patterns, the importance of spatial embedding, network connectivity, and the resilience of the networks to damage. In In this talk I will present different experiments and theoretic-numerical resources to shed light on these questions. In particular, I will pinpoint on the potential of effective connectivity inference, as well as network measures such as hubness or assortativity, to characterize the behavior of neuronal networks affected by Sanfilippo, Alzheimer's and other diseases.

C13: Statistical Physics and Critical Phenomena

Inducing self-organized criticality in a network toy model by neighborhood assortativity

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Self-Organized Criticality (SOC) is a paradigm of complex system. Empirical examples that have been linked to SOC dynamics are earthquakes, solar flares, neuronal activity, or sand piles among others. Several models have been proposed to determine the physical properties of these dynamics on complex networks. In these models criticality is induced by a "fitness" parameter defined on the nodes or by a rewiring process. In this work we show a critical network toy model that is driven exclusively by the graph's topology. Starting from a single node, the network grows by the random addition of a new node (with a single link) at each time step. The criticality appears due to a topological stability condition: A node is stable, if and only if its degree is less than or equal to the average degree of its neighbors plus a global constant (hereafter buffering capacity constant). This local condition is related to an assortative mixing by the average degree of its adjacent nodes, i.e. the nodes tend to link to other nodes (its neighborhood) that show an average property similar to its own. When a node becomes unstable, one of its links is randomly removed and the smallest subnet is deleted. Then the stability condition of the node and its neighbors are checked iteratively until every node in the network is stable. When all the nodes are stable, a new time step starts. Here the set of removals performed until every node in the network is stable represents an avalanche. The size of the avalanche is defined as the total number of nodes removed from the network. The long-range correlations resulting from criticality have been characterized by means of fluctuation analysis and show an anticorrelation in the node's activity. The distribution plots of the size of avalanches and time intervals between two consecutive events for different values of the buffering capacity constant can be collapsed into universal curves. The probability density function for released energy fluctuations shows the lack of time scales in the correlations. Additionally, the simplicity of the model allows us to study it analytically in the simplest case of linear chains, by means of the Markov chains. This statistical approach and the numerical simulations are in complete agreement. Finally, we have characterized the assortative mixing by vertex degree and the neighborhood's assortativity. The assortative mixing by vertex degree is null for this model as for Erdös-Rényi (E-R) or the Barabási-Albert (B-A) models. However, assortative mixing by neighborhood's average degree is significantly positive, while it is null for E-R or B-A models. We have found that some real networks exhibit positive neigborhood assortativity and null degree assortativity.

Detecting the critical transition of the Ising model through timeseries-to-networks methods

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Phase transitions are one of the most interesting phenomena in nature, manifested as significant shifts in the dynamics of physical and complex systems (Solé et al. 1996). The identification of critical points where such transitions occur is of paramount importance, as measurable changes in the behavior of signals emanating from the system can provide early warnings of the nearing regime transition (Scheffer et al. 2009). The most studied laboratory for critical transitions is likely the Ising model of ferromagnetism, in which the behavior of a 2D lattice of two-state "spin sites" experiences a phase transition at a well-established critical temperature, resulting in a sudden and complete change of the material's magnetic properties (Ising 1925). The Ising model has traditionally been studied through timeseries analysis, which has revealed rich dynamical properties including early warnings and critical slowing down (Morales et al. 2015). While this path of investigation has proved successful, the Ising model's simplicity and seeming universality as a model of phase transitions have prompted the exploration of new ways to study its dynamics. At the same time, a number of techniques to map timeseries into complex networks have been proposed with the intent of applying the wide variety of network metrics and analysis tools to the study of timeseries, hoping to capture additional information about the underlying system or quantify its properties in new ways (Donner et al. 2011). While many authors have explored the effect of transporting Ising-like dynamics to networks of varying topologies (Dorogovtsev et al. 2002), little research has been done on the network properties of the Ising timeseries themselves obtained through timeseries-to-network maps. In this work we explore the phase transition of the Ising model through Campanharo's "QG algorithm" (Campanharo 2011), a recently proposed timeseries-to-network map that is built intuitively and that has interesting properties not commonly found in other maps of this type, such as being approximately invertible, allowing a network to be converted back into a timeseries. We study the properties of several network metrics obtained from Ising timeseries through this map at temperatures below, near and above the critical point, and analyze their usefulness as early warnings of the transition, comparing them to the results of more traditional timeseries analysis. We find that the usual network metrics yield very good indicators of the phase transition, and that they can be used as early warnings. We also compare our results to those obtained with a similar analysis through a well-known timeseries-to-network map, the visibility algorithm of Lacasa et al. (2008). Financial funding for this work was supplied by UNAM under grant DGAPA-PAPIIT-IV100116 and CONACYT under grant 2016-01-2277.

Phase Transition in the Communicability Clustering Structure of Graphs and Networks

Ernesto Estrada[1] *and Najlaa Sadeq Alalwan*[2]

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Communities represent important organizational structures in networks. Our research has mostly been concerned to study the community structure of complex networks with increase the temperature T. In every network there are groups of nodes that respond coordinately to external perturbations to nodes in the graph. Such coordinated responses are consequences of the high internal communicability among the nodes in the group. These communicability groups can be represented by hyperedges in a hypergraph constructed with the same set of vertices of the network.We have proved the existence of a universal phase transition in the connectivity of these communicability hypergraphs as a response to external stresses–described by means of an inverse temperature (β) – to which the network is submitted to. The inverse temperature $\beta = (k_B T)^{-1}$ could be regarded to account the strength of the interactions among the nodes in different temperatures T. Then the graph which has small critical value (β_c) of inverse temperature β by which the transition takes place, has stronger community structure than the graph which has large critical value. This result has a wide range of real world applications such as in electrical networks. Then the graph that has small critical value is the best kind to construct an electrical circuit, since it reflects the highest resistance to the raise of temperature T.We create a simple model based on windmill graphs which allows us to identify the main algebraic terms determining the value of the critical inverse temperature at which the transition takes place. We have generalized an upper bound for the critical value to the communicability cluster structure. This bound is mainly determined by the smallest eigenvalue of the adjacency matrix and the corresponding eigenvector. In addition, We show that this phase transition in graphs with ordered and random structures displays remarkable similarities with the melting of crystalline and amorphous solids. Finally, we study the phase transition in some real-world networks as a way to analyze the robustness on their communicability cluster structure. In conclusion, as has been shown, that there exist a transition in the communicability cluster structure of graphs and networks as a response to external stress. This transition is represented as a change in the connectivity in communicability hypergraphs–takes place in any graph. The robustness of a graph to this change in its communicability cluster structure is mainly determined by the smallest eigenvalue of the adjacency matrix and the corresponding eigenvector. This finding allows to regard β_c as the strength of the links of the networks. Finally, I would to mention that we have paper in progress.

Invariant properties of transport for interconnected linear reservoirs with Markovian inputs

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Consider a large number of interconnected linear reservoirs holding a time-dependent amount of some substance. Each reservoir discharges to its neighbors at a rate proportional to the amount of substance accumulated in it, and the whole system is forced randomly by a Markov process that deposits instantaneously random amounts of substance at random reservoirs. In this talk we will pose and solve the associated stochastic differential equations and characterize its solution as a piece-wise deterministic Markov process. Further, the invariant distribution of the substance throughout the network is computed. Special attention will be paid to the role played by the network topology on the shape of the solution and properties of the invariant distribution. In particular, the tail weight of the invariant distribution is shown to be equal, in some cases, to that of the random inputs. The results are applied to the case of river flow under random rainfall.

C14: Network Dynamics

Influence maximization in complex networks: the role of degree-degree correlation

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We propose a method based on community organization and network centrality to select the set of nodes that maximize the information propagation in networks. Communities are groups of nodes densely connected among them, but with few connections with other groups. In this way, nodes belonging to the same community are likely to be more similar to each other and share the same set of direct neighbors and influencers. Artificial networks presenting degree-degree correlation and eight real-world networks, including social and communication networks, are considered here. We vary the assortativity in artificial networks and the number of initial seeds, from two nodes to at least 10% of the network size. In contrast to what is expected, we observe that increasing the number of spreaders may not provide additional informed nodes at the end of the dynamics. In order to consider the topology of the network and improve the computational cost, we introduce a direct approach to maximize the information diffusion considering the community structure of the network. Our method selects as initial seeds the most central nodes inside each community. We also investigate the performance of two well-known methods: (i) the selection of the most central nodes and (ii) the hill-climbing Greedy optimization algorithm that is currently the state-of-the-art approach. We verify that the assortativity plays a significant role in the dynamics of the influence maximization problem. For instance, in disassortative networks, when the number of seeds is lower than 1% of network size, selecting the most central nodes as initial spreaders produces a higher peak of influence than for the Greedy method. In assortative networks, selecting the most central nodes by communities increases the information diffusion more intensely than selecting the most central individuals from the whole network. The simulation results show that our method has no statistical differences with the Greedy maximization, which retains the $(1 - 1/e)$ approximation guarantee ($\pm 63\%$ of optimal) for several classes of propagation models. Moreover, the proposed method has a computational cost of $\mathcal{O}(N \log N)$, which is faster than the Greedy algorithm that is very time-consuming (NP-hard). Thus, the influence maximization problem can be optimized by performing the identification of the best set of initial spreaders according to the community structure. Methods not taking into account the properties of the network might lead to suboptimal results.

Correlation analysis of random walks in complex networks

Rogelio Basurto Flores[1], *Israel Reyes-Ramírez*[2], *Ivan Yair Fernández Rosales*[3] *and Lev Guzmán Vargas*[4]

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Temporal correlation and dimensional analysis of complex networks is a topic of interest to characterize complex systems. Particularly, the duality between time series and complex networks is a relevant property recently explored by researchers from different perspectives. Recent studies based on random walks over a complex network have provided important topological features of these complex structures. Here, we perform different fractal analyses of random walks derived from random (Erdös–Rényi) and scale-free networks in order to characterize the temporal/spatial correlation properties of these networks. We find that scaling correlation exponents associated to sequences from random networks resemble uncorrelated dynamics, while exponents from scale-free configurations are representative of correlated behavior with long-range memory under particular conditions. Moreover, we verify our procedure by means of the visibility algorithm in order to compare the correlation properties of the original time series and its corresponding visibility network.

Emergent Polarization in Social Networks

Elisa Schmelkes[1], *Ana Leonor Rivera-Lopez*[2] *and Alejandro Frank*[3]

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[3]Centro de Ciencias de la Complejidad, Universidad Nacional Autónoma de México; Instituto de Ciencias Nucleares, Universidad Nacional Autónoma de México, Mexico City, México; frank@nucleares.unam.mx

This past year, the world has witnessed extreme political polarization in several places around the world. Referendums and elections have split countries apart, such as the UK, the United States and France. Here is shown that this polarization process is an emergent property of social networks, arising from phenomena such as virality and homophilia, and exacerbated by the structures of online social networks such as Facebook and Twitter. In order to study this phenomenon, we developed an agent-based model that simulates the dynamics of opinions spreading through an online social network. Each node in the network has an opinion ranging from red to blue. Each turn, a post is shared by a random node of the network. The post has a bias, which is somewhere on the red blue spectrum, not far from the emitter's opinion. It is also either negative or positive. The node's immediate neighbors are exposed to it. The opinion of the people exposed to the post will shift a little towards the bias of the post. If someone is exposed to a post that is too far from their opinion, they break the link between the two nodes. If the exposed node agrees with the post's bias, there is a probability that it will be shared. Negative posts are somewhat more likely to be shared than positive posts. After every turn, each node adjusts their opinion toward the average of their neighbors opinions. As opinions spread through the network, clusters of nodes with similar opinion begin to form. Soon, the network becomes polarized, and the histogram of opinions displays a bimodal distribution. Nodes form bubbles of similar opinions and rarely become exposed to opposing thoughts. Thus, a diverse network following simple rules for the spreading of opinions can quickly become polarized, and this is true for most controversial issues. These findings can help explain how the internet hastens polarization and restricts conversation by forming echo chambers in virtual social networks. This basic model also enables us to analyze the role of influencers, the impact of attacks on the network by bots or induced panics, the nuances of poll-taking and several other issues relevant to current socio-political dynamics. Financial funding for this work was provided by UNAM under grant DGAPA-PAPIIT-IV100116 and CONACYT under grant 2016-01-2277.

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GENERAL INFORMATION

GETTING TO PUEBLA CITY FROM MEXICO CITY INTERNATIONAL AIRPORT

From Mexico City International Airport (MEX) (https://www.aicm.com.mx/en/) to Puebla City there is a bus service by "Estrella Roja" (https://www.estrellaroja.com.mx/). Once at MEX follow the "Autobuses Foraneos" signs. The bus terminal in Terminal 1 is located near the fast food court. The bus terminal in Terminal 2 is located near gate D, between entrance 4 and the domestic arrivals exit point. You can buy bus tickets in kiosks located close to the bus departing place. They cost 300 pesos one way (17 USD or 14 EUR approx.). The ride takes bout 2.5 hours. Buses arrive to Puebla City at the bus station known as "Terminal 4 poniente". You can check schedules here (https://www.aicm.com.mx/en/passengers/transportation/buses) or here (https://www.estrellaroja.com.mx/).

GETTING TO PUEBLA CITY FROM PUEBLA INTERNATIONAL AIRPORT

Puebla International Airport (PBC) (http://flyto.mx/en/flyto/Aeropuerto_Internacional_de_Puebla) is located 25km from Puebla City. It is a small airport with a few arrival/departing flights mainly from/to:

- Cancun (CUN), Guadalajara (GDL), Tijuana (TIJ); operated by Volaris.
- Houston (IAH); operated by United Airlines.
- Dallas (DFW); operated by American Airlines.

There are shuttle buses and authorized taxis (called "Transportes terrestres") to get to Puebla City. Both, bus and taxi fares are about 300 pesos, one way (17 USD or 14 EUR approx.). Buses arrive at "Terminal 4 poniente" station.

HOW TO REACH PUEBLA CITY CENTER FROM "TERMINAL 4 PONIENTE"

In "Terminal 4 poniente" there is a service of "authorized taxis". Taxi tickets are sold in a desk that can be easily located. Rates are fixed. From "Terminal 4 poniente" to the city center the ticket cost is less than 100 pesos (6 USD or 5 EUR approx.).

THE CONFERENCE VENUE

The Conference will take place in "Centro de Seminarios" of **Complejo Cultural Universitario (CCU) BUAP** (http://www.complejocultural.buap.mx/), **with the exception of Monday 25th, when the Conference will take place at Edificio Carolino (see below the location of the School, also at the Edificio Carolino)**. CCU is 15 km from the center of Puebla. Address: Cúmulo de Virgo 34, Reserva Territorial Atlixcáyotl, 72810 Puebla. Tel: +52 (222) 229 5503

HOW TO REACH CCU

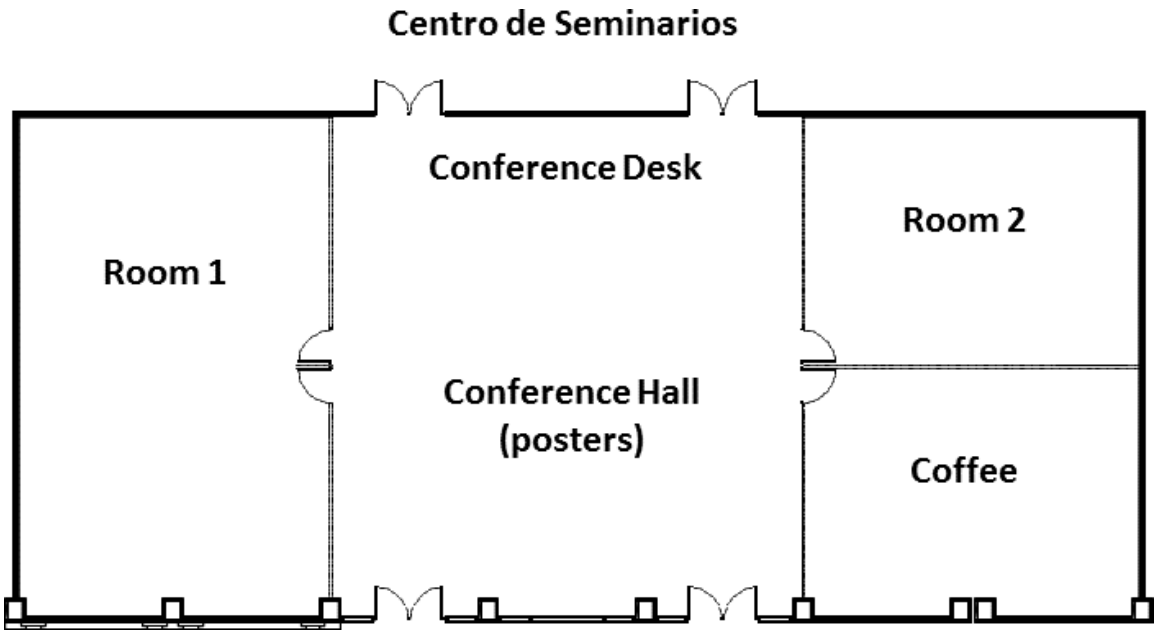
Conference Bus Service: A bus service will be available every day in the morning from the city center to the Conference venue, and back in the evening. The service is available for all the participants, not just for those staying at the recommended hotels. The meeting point for the buses will be timely announced. Consult the program timetable in the Book of Abstracts for the return time. **Using public transportation:** Public transportation in Puebla is not expensive. Nevertheless, the Conference Bus Service will be faster than any alternative. For those who wish to get to the conference by their own means, there is a public bus to the CCU departing from the city center. From Zócalo (Puebla City's main plaza) walk along 16 de Septiembre street up to 11 Oriente street. There take bus number 29 (Verde Atlixcayotl CIS Finanzas). Get off at Cúmulo de Virgo street. The CCU is on the opposite corner. Travel duration: Approx. 53 min. Fare $6.00 MXN one way.

LANET SCHOOL LOCATION

The LANET School on Fundamentals and Applications of Network Science will take place at the "Auditorio" in "Primer Patio" of Edificio Carolino BUAP (https://es.wikipedia.org/wiki/Edificio_Carolino). Address: 4 Sur 104. It is at walking distance from any of the recommended hotels, just in front of Hotel Colonial.

DURING THE CONFERENCE

On Monday, during the LANET School, there will be a Registration Desk at Edificio Carolino. Lunch (for students registered at the School) will be served in Hotel Colonial. The conference will officially begin at 18:00, and Conference Sessions and the Reception Cocktail will take place at Edificio Carolino.
From Tuesday to Friday Registration Desk, Conference Sessions, Poster Session, Coffee Breaks and Lunch Breaks will be located in Centro de Seminarios at Complejo Cultural Universitario (CCU) BUAP (see sketch below).



PREPARING YOUR CONTRIBUTION

The program is organized around thirteen invited plenary talks, six sessions of minisymposia, four contributed sessions and one poster session scheduled on Tuesday afternoon.
Oral Presentations. The lecture rooms will be equipped with a projector with standard VGA input and a Windows computer with Powerpoint software, although it is strongly recommended to bring the presentation converted to pdf to avoid font and formatting problems. Please, upload your presentation to the computer 30 minutes before the session begins. For those wishing to use their own computer, testing should also be done prior to the session. Remember that the duration of the talks are:

- Invited plenary talks 45 min including 5 min discussion.
- Minisymposia talks 30 min, including 5 min discussion.
- Contributed talks 15 min, including 5 min discussion.

For those who will present a poster: Posters will be on display throughout the entire event and can be affixed as early as Tuesday morning. Note that the Main **Poster Session** will be on **Tuesday afternoon**, from 18:15h to 20:30 h. Poster boards will be numbered. Please hang up your poster on the corresponding board with the number that matches the one assigned in the conference booklet. Tape will be provided at the Conference desk. Recommended poster size is **A0 (120 cm X 80 cm)** with portrait orientation.

VISIT TO CANTONA

On Wednesday afternoon we will visit the archaeological site called Cantona. It is located at about 100km from Puebla City. There will be a bus service from CCU to Cantona and from Cantona to Puebla City's center. **Please, bring a student/professor/researcher identification card in order to get a free ticket (you will have to pay 65 MXN otherwise).**The climate in Cantona region is semi-desertic so bring a hat, sunblock lotion, light clothes, and proper walking shoes. To have a taste of Cantona visit:

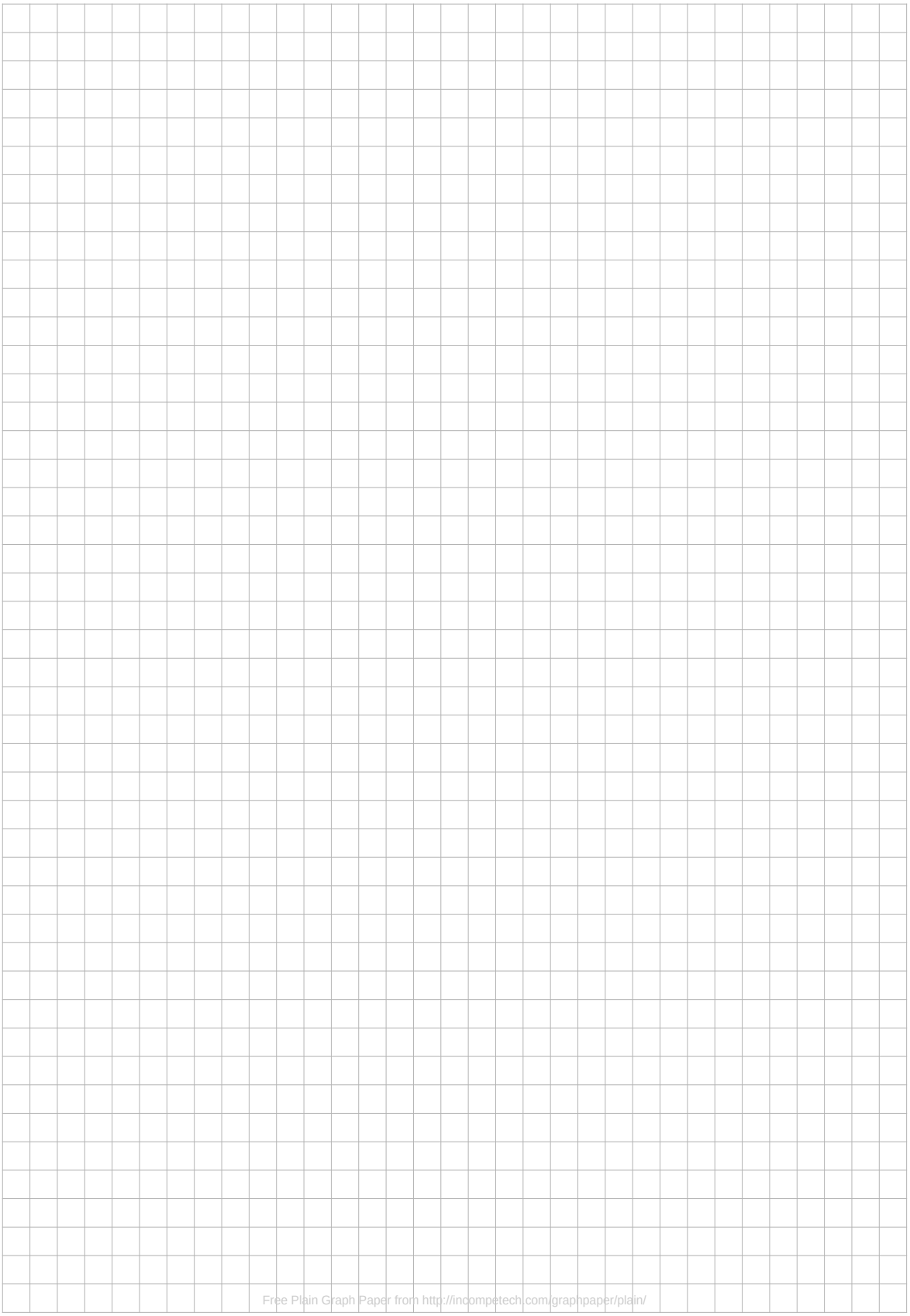
- https://es.wikipedia.org/wiki/Cantona
- http://www.tepeyahualcodehidalgo.puebla.gob.mx

Note that it is strictly forbidden the use of professional video cameras in all archeological sites in Mexico. Amateur video cameras, including cell phones, are charged a 5 MXN fee (about 30 USD cents).

TOURIST INFORMATION

Tourist and cultural information can be found at: Municipal Tourist Information Office. Address: Portal Hidalgo 14, Zócalo. State Tourist Information Office (has English-speaking staff). Address: 5 Oriente street 3, Centro Historico +52 (222) 777-1553. Also visit:

- http://puebla.travel/en/discover/puebla
- https://www.zonaturistica.com/en/tourist-attractions-in/401/puebla.html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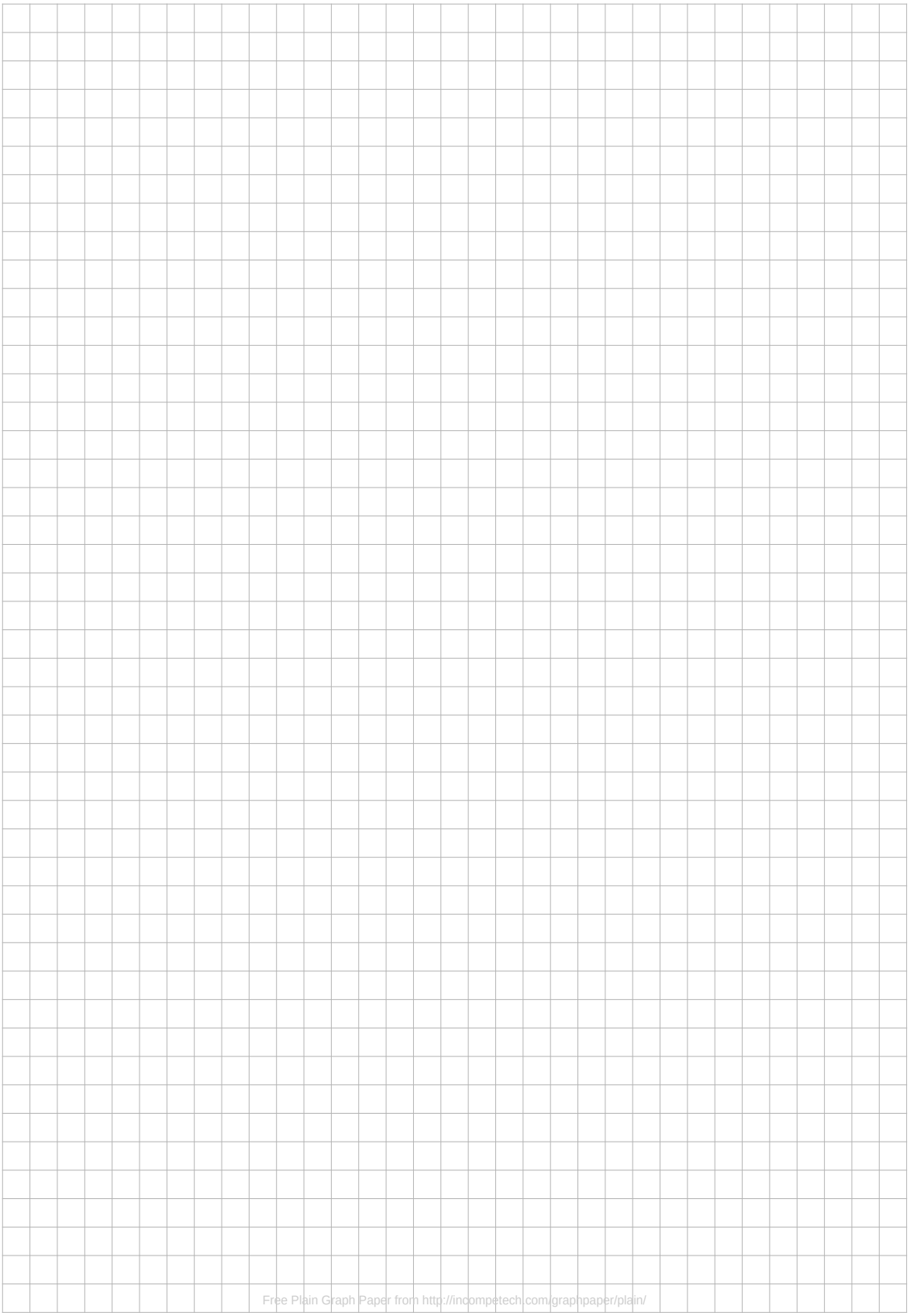
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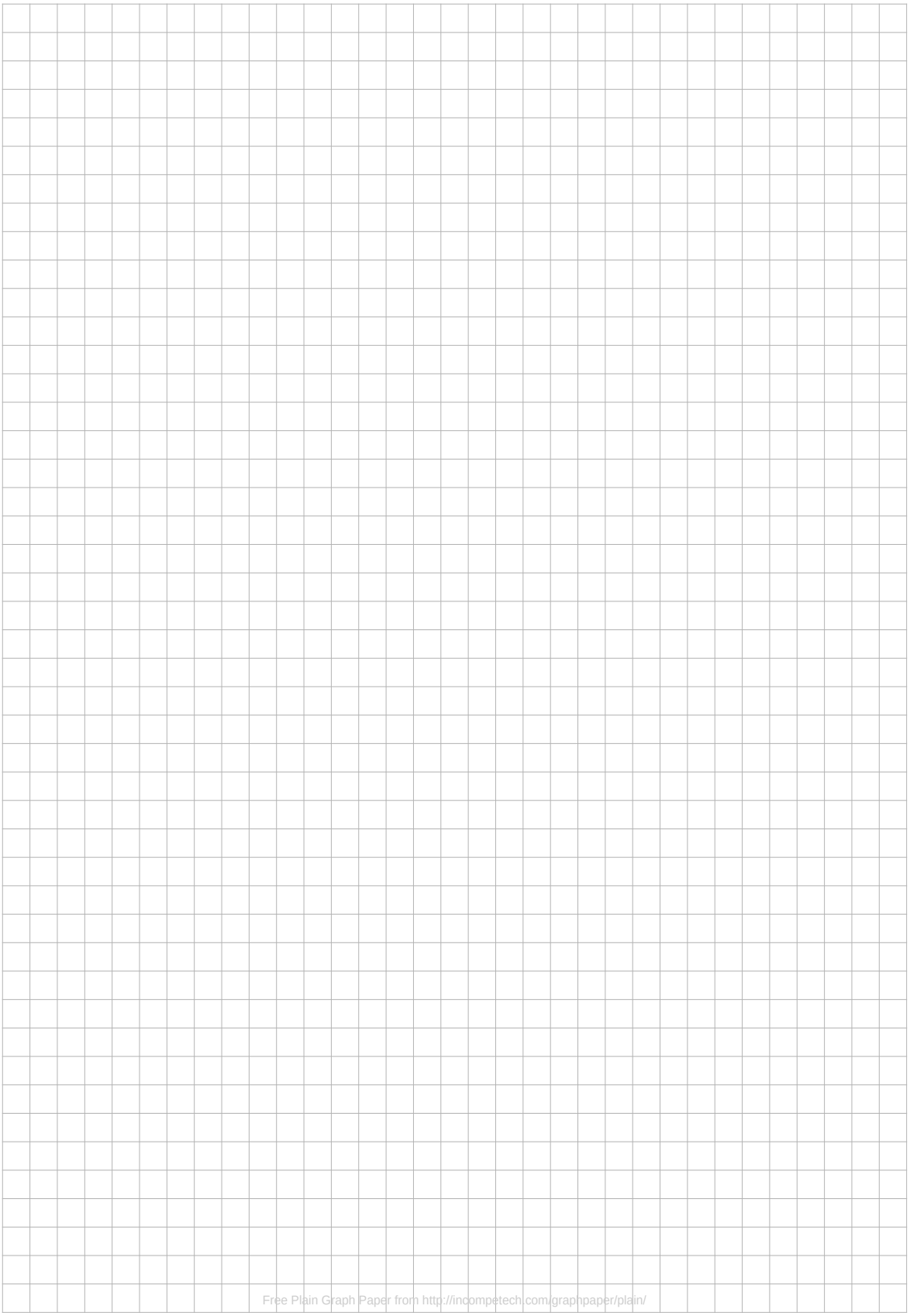
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