Modeling and Control of Complex Systems in Life and Physical Sciences (MC2S-LPS)

Dschang, 24-28 novembre 2025 (Cameroun)
https://mc2s-lps.sciencesconf.org/

List of presentations during the parallel sessions

1 Monday 24th November 2025

1.1 Session on Nonlinear dynamics in Physics

15h50-16h10 : Brice Arthur Azangue – Coherent and Incoherent Control in Neuronal Network based on two Sub-networks and Biological implication

Chimera states are fascinating phenomena nowadays and are largely discussed in neuroscience in the aim to describe the coexistence between coherent and incoherent states observed in complex neuronal networks. The case of brain is a typical example, where depending on the problem observed for instance neurodegenerative diseases, some regions on the cerebral cortex can show coherent or incoherent dynamics. Coherent dynamics is associated to the synchronization of different nodes of network constituted while incoherent dynamics are linked to the desynchronization. In this work, we analyze the emergence of chimera states in a network designed by two subnetworks interacting with electrical and chemical synapses. We observe that with the help of a controller on a group of nodes, it is possible to significantly achieve coherence or incoherence of cluster oscillators in a network. The control strategy consists to consider both sub-networks with different types of inter-layer connections (electrical and chemical) between links. In addition, a possibility to find a global synchronization in the network and an issue to explain the behavior of brain in case of some neurodegenerative diseases is given. We observe that for a controlled domain, when one sub-network is coherent (Resp. incoherent) this involves automatically a coherent (Resp. incoherent) behavior of the other sub-network.

16h10-16h30 : Chenceline Fouedji – Dynamical analysis of the Hindmarsh-Rose neuron under electromagnetic induction with time delays

The study of neuron system is of great importance. It helps to understand deeper how some processes such as memory occurs. Moreover, it allows to have a better understanding about some pathological diseases such as Parkinson, Epileptic seizure, Dementias [1]. However, control techniques have been utilized to make neuron exhibit a specific type of behavior regardless its usual movement [2]. In this work, we studied the effect of time-delayed feedback control on Hindmarsh Rose Neuron model under electromagnetic induction. The first part of our studies is

focus on establishing the condition for which there is Hopf bifurcation. The second part is about the numerical simulation with Julia. Results showed that, with a certain type of condition on model's parameters, the neuron exhibit amplitude death; Mostly when the time delay increase. Furthermore, during numerical simulation, we realized that the external current increases the number of bifurcation points when its value increases.

Keywords: Hindmarsh-Rose, Delay, Hopf Bifurcation

References:
[1] C. S. Von Bartheld, J. Bahney, S. Herculano-Houzel, the search for true numbers of neurons and glial cells in the human brain: A review of 150 years of cell counting, Journal of Comparative Neurology 524 (2016) 3865–3895.
[2] Tsuji, T. Ueta, H. Kawakami, H. Fujii, K. Aihara, Bifurcations in two-dimensional hindmarsh–rose type model, International Journal of Bifurcation and Chaos 17 (2007) 985–99

16h30-16h50 : Imelda Clairette Feudjio : Etude et caracterisation des dynamiques collectives dans un reseau de pendule d'Huygens : Apport de l'analyse de recurrence

L'étude des dynamiques collectives dans les réseaux d'oscillateurs constitue un enjeu majeur pour la compréhension des phénomènes complexes en physique, biologie et ingénierie. Dans ce travail, nous nous intéressons à un réseau composé de 150 pendules de Huygens identiques, de masse m et longueur l, suspendus à un banc mobile de masse M, lui-même relié à un support extérieur par un ressort et un amortisseur. Chaque pendule est auto-entretenu par un amortissement de type Van der Pol et couplé localement à ses voisins par des ressorts de raideur k.

L'objectif principal est d'étudier les dynamiques collectives pouvant émerger dans notre système ,en particulier les phénomènes de synchronisation, de désynchronisation, le pendule solitaire et l'émergence d'états collectifs complexes tels que les états chimères et chimères en cluster et d'utiliser l'analyse de récurrence, un puissant outil mathématique base sur les répétitions dans la trajectoire d'une série temporelle, pour les caractériser. Pour ce faire, nous avons adopté une approche combinant modélisation lagrangienne et simulations numériques.

Afin de caractériser finement ces dynamiques, nous avons mobilisé l'analyse de récurrence (Récurrence Quantification Analysis, RQA) et ses extensions. Cette méthode non linéaire permet de détecter et de quantifier les structures cachées dans les trajectoires temporelles, d'évaluer la stabilité des régimes et de mesurer le degré de synchronisation entre oscillateurs.

Les résultats obtenus révèlent non seulement la richesse du système à travers la coexistence de régimes synchrones et incohérents, l'apparition de structures en cluster, , l'apparition des structures mixte dite cluster-chiméra avec des oscillations atypiques de type carré, ainsi que la formations des pendules solitaires Mais également ,ils ont permis de mettre en valeur l'analyse de récurrence ,de par sa caractérisation fine de ses dynamiques .Ces observations confirment la richesse dynamique du réseau et mettent en évidence l'intérêt de l'analyse de récurrence comme outil complémentaire à l'étude et la caractérisation des systèmes complexes.
Mots-clés : Pendules de Huygens, Synchronisation, États chimères, Dynamique non linéaire, Analyse de récurrence.

16h50-17h10 : Cedric Noufozo Talonang – Complex Dynamics in Memristive Micro/Nano Beam Resonators Incorporating Josephson Junctions

This work focuses on the emergence of chaos in a nonlinear memristive NEMS (Nano ElectroMechanical System) actuated by two-sided electrodes based on a Josephson junction (JJ). Nanoelec-

tromechanical systems (NEMS) are devices that integrate electrical and mechanical functions at the nanoscale. These components enable the conversion of one form of energy into another, allowing for rapid and precise measurements. A comprehensive dynamical analysis is conducted using standard indicators, such as bifurcation diagrams, to highlight critical transitions and the nature of electrical neuronal activities. Relevant tools are employed to assess the system's stability, providing detailed insights into its operation and the overall behavior of the coupling. Additionally, complex and diverse routes to chaos have been identified. Local Lyapunov exponents with strongly interwoven attractors further confirm the presence of multistability. The PSpice implementation is carried out to demonstrate the feasibility of NEMS in real-world applications. This study makes a significant contribution to understanding the behavior of MEMS by proposing a framework for designing a nano-mechanical system with tunable frequency and nonlinear properties.

1.2 Session on Applied Mathematics

15h30-16h15 : Jean-Marc Mandeng – Highlighting the impact of Pollen Flows in Maize Yield Losses: Mathematical modelling approaches

We develop and analyze three complementary compartmental models to investigatet he dynamics of pollen flow and their impact on maize yield losses. First, we present ap atch model describing pollen exchanges between neighboring fields follows by a reaction-diffusion system (PDE) capturing large-scale diffusion of pollen driven by wind, and wec onclude with an impulsive model incorporating seasonal agricultural practices. Analytical results establish positivity, boundedness, and equilibria of the proposed models, while numerical simulations highlight yield losses arising from cross-pollination and environmental heterogeneity. The findings shows the importance of understanding pollen migration in optimizing maize production, particularly in sub-Saharan Africa. These modeling approachesp provide theoretical insights and decision support tools for improving resilience and sustainable management of maize production systems.

16h15-16h40 : Lessina Ladouce Magong Kenounouh – Mathematical Modeling and Analysis of the Interaction Between Plants and Phytopathogenic Fungi : Impact of Resistance and Species Mixture

Fungi are among the main agents responsible for plant diseases, threatening agricultural productivity and reducing crop yields. Understanding fungus-plant interactions remains a major challenge for growers. In this work, we develop a deterministic mathematical framework, based on an analogy similar to that of predator-prey relationships, which accounts for the dynamics of a phytopathogenic fungus in plantations composed of several plant species with different levels of resistance. The model describes the joint evolution of plant biomass, the fungal load of each plant species, and spore density in the environment. We perform a rigorous analysis of the model and highlight the impact of plant diversity and resistance on the epidemiological dynamics of the pathogen. The results show that there are significant thresholds that depend on the ability of all infected species to produce new spores, beyond which the disease will disappear or persist in the plantation. Finally, all results are supported by numerical simulations.

Keywords: Polycyclic phytopathogenic fungus, plant biomass, fungal load, species mixture, mathematical modeling.

16h40-17h05 : Alex Darius Mba – Mathematical modeling for the sustainability and resilience of an agroforestry system in Cameroon

Agroforestry systems combine trees, crops, or livestock to promote the sustainability and resilience of farming systems; It play a crucial role in sustainable land management, especially in tropical regions such as Cameroon. They provide ecological benefits (e.g., carbon sequestration, biodiversity conservation) and socio-economic advantages (e.g., support for smallholder farmers), yet face two major paradoxes: Ecological: tree facilitation turns into competition at high densities, reducing crop yields, and Socio-economic: short-term income needs undermine long-term sustainability. This thesis proposes an integrated bioeconomic modelling framework applied to cocoa-based agroforestry systems in Cameroon. A coupled tree–crop dynamic model is developed, incorporating ecological interactions (facilitation/compe tition), optimal harvesting strategies (MSY/MEY), and probabilistic climate scenarios. Viability theory is used to define critical thresholds: minimum tree density (avoiding collapse), viable agricultural output (food security), and economic profitability (financial sustainability). Resilience is assessed through the 3R framework: Robustness, Resistance, and Recovery. The results map critical zones (ecological thresholds, competition limits) and define adaptive strategies (climate-responsive harvesting). This framework provides a decision-support tool for designing resilient agroforestry systems, aligned with SDGs 2, 13, and 15. Policy recommendations include targeted subsidies and climate insurance linked to 3R metrics. By formalizing the trade-offs between ecology and economics, this study offers an operational toolbox for the sustainable and resilient management of agroforestry systems under global climate and demographic change.

17h05-17h30 : Wilson Christ Likeufack – Mathematical Modeling of Tsetse Fly Dynamics and the Sterile Insect Technique. Analysis and Simulation

Tsetse flies (Glossina spp.) are hematophagous insects that serve as the main vectors of Human African Trypanosomiasis (HAT, or sleeping sickness) and Animal African Trypanosomiasis (AAT, or nagana), both of which represent major health and economic burdens in sub-Saharan Africa. Traditional control methods, such as insecticides, traps, or livestock treatments, have achieved only partial and often unsustainable results due to ecological adaptability, insecticide resistance, and environmental concerns. The Sterile Insect Technique (SIT), which relies on the mass release of sterilized males to suppress wild populations, has emerged as an environmentally friendly and species-specific alternative. However, its integration into mathematical models for the optimization of release strategies remains limited.

This thesis develops and analyzes deterministic models of tsetse population dynamics that explicitly incorporate SIT under both constant and periodic impulsive release regimes. Starting from a biologically realistic delay-differential model without control, conditions for persistence and extinction of populations were established. SIT was then introduced into the framework, and the equilibria and their stability were studied theoretically. Numerical simulations were conducted to evaluate and compare the effectiveness of different release schedules. The results show that both constant and periodic releases are capable of driving the population to extinction, but with important differences. Periodic impulsive release achieves elimination more quickly and, despite requiring a larger total number of sterile males, is logistically simpler and more cost-effective in practice. By contrast, constant release may theoretically involve fewer sterile males overall, but its requirement for continuous daily operations makes it economically and operationally less feasible. These findings highlight the need to balance biological effectiveness with practical constraints when

designing SIT programs.

2 Wednesday 26th November 2025

2.1 Session on Nonlinear dynamics in Physics

15h10-15h30 : Baroki Munphano Emery – Robust Trajectory Tracking Control for a Two-Wheeled Mobile Robot in the Presence of Uncertainties and Obstacles Using Machine Learning

With the growing need for autonomous navigation, effective trajectory tracking control for two-wheeled mobile robots has become essential, especially in the face of uncertainties and obstacles. This research presents an innovative method that combines machine learning techniques with a non-linear discrete cost function controller, optimized through metaheuristic approaches. The proposed strategy improves control performance by adapting to dynamic environmental conditions, ensuring accurate trajectory adherence while reducing oscillations and response times. Experimental findings demonstrate notable enhancements in robustness and efficiency when compared to traditional control methods, underscoring the critical role of optimization in machine learning-based control systems for autonomous robotics.

Keywords: Trajectory Tracking Control, Machine Learning, Non-linear Discrete Cost Function, Metaheuristic Optimization, Two-Wheeled Mobile Robot.

15h30-15h50 : Hilary O'maiva Nogning Fopa : Using Non-local and Ephaptic coupling to study the dynamics of beta pancreatic cells in relation with the control of blood sugar

Pancreatic beta cells play a crucial role in maintaining glucose homeostasis through the secretion of insulin. Located within the islets of Langerhans in the pancreas, these cells are responsible for detecting blood glucose levels and responding accordingly. When blood sugar rises, beta cells release insulin, facilitating the uptake of glucose by tissues, thereby lowering blood sugar levels. In biophysics, the study of beta cells encompasses their electrical properties, signaling pathways, and the biophysical mechanisms underlying insulin secretion. The membrane potential of beta cells is a key factor in their function; changes in glucose concentration cause alterations in ion channel activity, leading to depolarization and subsequent calcium influx. This calcium signaling is vital for the exocytosis of insulin containing vesicles. Research into the dynamics of beta cells includes exploring their heterogeneity, responsiveness to metabolic changes, and the effects of stressors such as high glucose levels or inflammation. Understanding these dynamics is essential, especially in the context of diabetes, where beta cell dysfunction or loss is a central issue. Recent advances in techniques such as imaging and mathematical modeling have provided deeper insights into the behavior of beta cells under various conditions. By integrating biophysical principles with molecular biology, researchers aim to uncover novel therapeutic approaches to enhance beta cell function and viability, ultimately contributing to more effective treatments for diabetes and related metabolic disorders.

15h50-16h10 : Armand Anthelme Nanha Djanan – Vibration Control two coupled portal frame nonideal excited with MRD

We propose a MRD device to cope with large vibration observed in two nonlinearly coupled portal frames excited by a non ideal excitation. The vibrating system studied consists of two portal frames type shear buildings coupled, carrying at the top an unbalanced DC motor. The engine is supposed to rotate in the same direction and act on each as external excitation. The dynamics investigations are done with analytical and numerical methods to achieve this purpose. The solutions are derived and their stability conditions are also explored using the averaging method. The results of this analytical investigation are confirmed later by numerical simulations. The effects of some physical parameters on the portal frames vibrations are presented. The impact of the nonlinear coupling between the floors on the DC motors dynamics is also explored. The Sommerfeld effect appearing in the system is reduced by taking into account the damping coming from the environment and the coupling between the portal frame.

16h10-16h30 : Zidane Choffo Yemeli – Recurrence analysis for the characterization of traveling chimera

Traveling chimera states are the behavior of certain dynamic systems on a network where both a coherent zone and a incoherent zone coexist, moving on successive elements of the network. The behavior studied here results from the communication between neurons in the brain, where we have described each neuron by the HIND MARSH-ROSE system of dimension 3 and the communication between neurons is translated on the one hand by local coupling (through the gap junction) and on the other hand by non-local coupling translating the synaptic chemical transmissions between neurons in the brain. Recurrence analysis is a method for studying complex systems that has its origins in information theory and is interested in the behavior that occurs in the dynamics of a system over time. The latter uses tools such as recurrence plot and parameters such as determinism, laminarity, ie... The recurrence analysis allowed us to identify the recurrence structures specific to the coherent zone and the incoherent zone over time. In addition, for a given element, it allows us to know the number of times it has passed through the incoherent zone. In addition, the parameters of recurrence analysis in a reduced time interval allowed us to differentiate the elements present in the coherent zone from those in the incoherent zone at the edge of separation of these two zones. The recurrence analysis here shows that the elements, whether in the same area or not, have a signature specific to each of them, and the measurement of times allows us to distinguish the elements sharing the same dynamics. This new approach opens interesting perspectives for understanding the mechanisms underlying the formation of traveling chimera states in various fields such as neuroscience for understanding neurological disorders or modeling brain rhythms.

16h30-16h50 : Nfor Oma Nkeh – Periodic pressure waves and transmembrane wavefronts in an electromechanical nerve model

We show that axoplasmic pressure waves governed by the improved Heimburg–Jackson hydrodynamic equation evolve as periodic soliton pulses, in which the membrane capacitance effectively ensures the coupling between transmembrane voltage (modeled by the modified Hodgkin–Huxley cable equation) and the pressure waves. Time independent wavefronts that serve as steady state solutions of the transmembrane voltage are analytically obtained, with it threshold values vital in determining wavefronts propagation in the entire nerve fiber. An increase in numerical value of the membrane coupling coefficient generally decrease the amplitude and speed of the propagating

electromechanical wavefronts, thereby leading to the effective control of neuronal information and other mechanosensory processes. This work finds application in the field of anesthetics because the amplitude and speed of propagating wavefronts which transmit pain, can be controlled by varying the parameters of the system.

2.2 16h50-17h10 : Arthur Yonti Tchouala – Conception d'une commande libre par mode glissant terminale basée sur un observateur de perturbation non linéaire pour des systèmes non linéaire incertain

De nos jours, le développement technologique a conduit à la réalisation de systèmes de plus en plus complexes et hautement non linéaires. Au cour des dernières décennies, l'analyse et la commande des systèmes mécaniques non linéaires ont attiré beaucoup d'attention, en particulier dans les domaines de la robotique, de l'automatisation et la commande. Ces dynamiques sont généralement soumises à l'effet des perturbations et d'incertitudes qui sont souvent imprévisibles, ce qui peut entrainer des défaillances dans les performances du système. La nécessité de développer des techniques de contrôle capables de résoudre ces problèmes est devenue Un sujet de recherche important. La technique de contrôle robuste adaptative par mode glissant de second ordre et la technique de contrôle robuste dynamique par mode glissant base sur un observateur de perturbation non linéaire sont largement utilisées pour leurs capacités à garantir la stabilité et la robustesse du système. Cependant, ces techniques peuvent encore rencontrer des problèmes de précision en présence de perturbations ou d'incertitudes importantes.

2.3 Session on Applied Mathematics

15h10-15h35 : Aurelien Fouetio Dongmeza – Homogenization of deterministic tidal dynamics equation in 2D

This work deals with the homogenization of Deterministic Tidal Equations in 2D. We study the asymptotic behavior of the solution by combining some compactness arguments with the sigma-convergence method. We prove that the sequence of solutions of the original problem converges in suitable topologies to the solution of a homogenized deterministic problem with constant coefficients.

15h35-16h00 : Ange Wilfried Dongmo – Modeling and optimization of strategies for combatting Human Papillomavirus infections and cervical cancer

Human papillomavirus (HPV) is the primary cause of cervical cancer, a major public health concern in Central Africa. We propose a compartmental mathematical model capturing HPV transmission dynamics and the progression to precancerous and cancerous stages. Using optimal control theory and numerical simulations in Python and MATLAB, we evaluate combined interventions such as vaccination, screening, and treatment. Our results identify cost-effective strategies that minimize both infection prevalence and intervention costs. This work provides actionable insights for policymakers to enhance cervical cancer prevention programs in resource-limited settings.

16h00-16h25 : Martin Luther Mann Manyombe – Optimizing multi-drug strategies to prevent antimicrobial quantitative resistance: A nested within- and between-host model

Antimicrobial resistance (AMR) is a critical global challenge driven by the evolution of bacterial populations that reduce the effectiveness of treatments. This study aims to design an optimal antimicrobial deployment strategy that minimizes both the epidemic size (epidemiological perspective) and the risk of therapeutic failure in the community (evolutionary perspective), particularly in multi-drug treatment settings. Key factors considered include compliance with recommended guidelines, infection duration, treatment initiation delay, and the effectiveness of different drugs. We evaluate the impact of introducing a new antimicrobial, conduct a sensitivity analysis of model parameters on the basic reproduction number and therapeutic failure probability, and explore outcomes of optimal treatment strategies. The approach employs a nested model that explicitly integrates within-host and between-host dynamics. At the within-host scale, the continuous character of AMR is introduced, referred to as quantitative antimicrobial resistance (qAMR). Most models addressing AMR focus on a limited number of resistant strains, often overlooking the potential continuum of resistance, especially as it develops through point mutations. The bacterial dynamics is described by an integro-differential equation, connecting this dynamics to epidemiological parameters such as individual infectiousness, disease-induced mortality, and treatment recovery rates. At the between-host scale, infected individuals are categorized into untreated, treated with compliance to treatment, and treated with non-compliance to treatment. Our results provide insights into AMR dynamics in multi-drug settings, offering a framework for optimizing treatment strategies that balance infection control and resistance prevention. This study contributes to a more effective approach for managing AMR at both individual and population levels.

16h25-16h50 : Sedrique Tiomela Tanefo – Analysis, simulation and applications of a delayed target limited cell model under the cumulative effects of vaccine and treatment

In this paper, we investigate mathematically and numerically a modified diffusive target cell limited model in one spatial dimension. The model considers the presence of delay transmission and virus production. Moreover, the model includes the effects from treatment either by mucosal vaccination or antiviral treatment. The cumulative effects are coupled by assuming a Beddington–DeAngelis-type incidence rate on the target cells. The mathematical model is studied analytically through a linear stability analysis. The disease-free and endemic equilibrium solutions are calculated, and the next generation matrix technique is employed to determine the basic reproduction number. Moreover, the stability properties of the equilibria are also derived. A traveling-wave analysis is performed next, and conditions for the existence of positive solutions are rigorously derived. From the numerical point of view, we perform also a traveling-wave analysis via a reliable implicit finite-difference scheme. Various physically relevant implications are derived from our simulations. Some of these consequences could have practical value in order to establish policies on the treatment of epidemic diseases. The proposed approach seems to be a good tool for preliminary test before experimentation in general and specifically may be an alternative to evaluate the within host dynamics in a low-income country where there is a crucial lack of logistics.

Keywords: Diffusive target cell limited model; delays in transmission and virus production; interaction mucosal vaccine; antiviral treatment.

16h50-17h15 : Sara Massob Tsakou – Modeling the combined effects of HPV disease, remission, and relapse on the occurrence of cervical cancer cases

A mathematical model for the dynamical transmission of HPV and the associated cervical cancer is considered with the aim to assess the impact of cancer remission and relapse on the occurrence of cervical cancer cases. The model incorporates the key epidemiological and biological features of HPV infection, such as the vaccine efficacy and the progression towards cervical cancer. We provide a theoretical study of the model. We compute the disease-free equilibrium and derive the reproduction number $\mathcal{R}_0$ that determines the extinction and the persistence of the disease. We compute equilibria and study their stability. More precisely, we show that there exists a threshold parameter ξ such that when $\mathcal{R}_0 < \xi < 1$, the DFE is globally asymptotically stable, while when $\xi < \mathcal{R}_0 < 1$, the model exhibits the phenomenon of backward bifurcation on a feasible region. We also investigate the impact of imperfect mass vaccination within a community. At the endemic level, we show that the number of females suffering from cervical cancer for the model with cancer remission is lower or greater than the corresponding number for the remission-free sub-model, depending on the occurrence of relapse due to the reactivation of dormant cancer cells. Therefore, it is natural to implement control strategies to reduce the severity of the disease by providing therapies that target residual dormant cancer cells in women in remission. Further, we perform numerical simulations to support the theory, and the model is fitted to real cervical cancer data released from Zambia.

Keywords : HPV; Cervical cancer; Remission; Stability; Bifurcation; Relapse.