**Mini-workshop on Recent Trends in Pure and Applied Mathematics**

Institute for Basic Science, Daejeon, South Korea

Biomedical Mathematics Group

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**Effective time step analysis of numerical schemes for gradient flows**

**Seunggyu Lee (Korea University)**

A gradient flow has an important role in PDEs and it has a variety of applications including biological fields. In this talk, we briefly introduce the unconditionally stable numerical schemes for type of gradient flows and analyze them by comparing the real and its rescaled time steps, which has been a critical issue in this field. Some numerical simulations are performed to confirm our result.

**Optimization and Approximation in Time-Frequency Analysis and other areas**

**Angelo Gino M. Velasco (UP Diliman)**

We shall first describe some recent works on optimization and approximation in the Institute of Mathematics, University of the Philippines Diliman. Then we focus more specifically on some aspects of optimization and approximation in time-frequency analysis. In particular, we consider systems of functions in $L^2(\mathbb{R})$ which are optimally concentrated or 'localized' on compact regions of the time frequency plane $\mathbb{R}^2$. Such systems can be useful in the analysis of signals where one needs to restrict  certain portions of a signal's time-frequency content. Reconstruction of the signal from its analysis coefficients is possible via some dual system of functions. In practice, however, these dual systems may be cumbersome to construct, and approximate dual systems may be used instead. We investigate their approximation properties and illustrate the results with numerical examples.

**Inferring delays in partially observed gene regulatory networks**

**Hyukpyo Hong (IBS)**

Cell function is regulated by gene regulatory networks (GRNs) defined by protein-mediated interaction between constituent genes. Despite advances in experimental techniques, we can still measure only a fraction of the processes that govern GRN dynamics. To infer the properties of GRNs using partial observation, unobserved sequential processes can be replaced with distributed time delays, yielding non- Markovian models. Inference methods based on the resulting model suffer from the curse of dimensionality. In this talk, I will introduce a simulation-based Bayesian MCMC method for the efficient and accurate inference of GRN parameters when only some of their products are observed. We illustrate our approach using a two-step activation model: An activation signal leads to the accumulation of an unobserved regulatory protein, which triggers the expression of observed fluorescent proteins. With prior information about observed fluorescent protein synthesis, this method successfully infers the dynamics of the unobserved regulatory protein. The present method can estimate the delay and kinetic parameters characterizing target regulation including transcription, translation, and target searching of an unobserved protein from experimental measurements of the products of its target gene. This method is scalable and can be used to analyze non-Markovian models with hidden components.

**The Groups, Geometry and Representations Academic Group**

**Jose Maria P. Balmaceda (UP Diliman)**

Groups arise naturally as symmetries of geometric, combinatorial and analytic structures and can be used to understand geometry and topology. Representation theory deals with how these symmetries give rise to families of operators on vector spaces. Conversely, one can study abstract groups, other algebraic structures, and their representations by using geometric techniques and ultimately by treating the structures themselves as geometric objects. These complementary perspectives typify the spirit and nature of the work of the Groups, Geometry and Representations Academic Group that will be introduced in this presentation. Our members do research on various problems in algebra, geometry and representation theory and are motivated by the interconnections between these fields.

**General ODE-based causal inference overcomes the curse of synchrony and indirect effect**

**Seho Park (IBS)**

To identify causation, model-free inference methods, such as Granger Causality, have been widely used due to their flexibility. However, they have difficulty distinguishing synchrony and indirect effects from direct causation, leading to false predictions. To overcome this, model-based inference methods were developed that test the reproducibility of data with a specific mechanistic model to infer causality. However, they can only be applied to systems described by a specific model, greatly limiting their applicability. Here, we address this limitation by deriving an easily-testable condition for a general ODE model to reproduce time-series data. We built a user-friendly computational package, GOBI (General ODE-Based Inference), which is applicable to nearly any system described by ODE. GOBI successfully inferred positive and negative regulations in various networks at both molecular and population levels, unlike existing model-free methods. Thus, this accurate and broadly-applicable inference method is a powerful tool for understanding complex dynamical systems.

**Graphs and Tilings**

**Manuel Joseph C. Loquias (UP Diliman)**

In the first half of the talk, we introduce some of the work done involving graphs and tilings by members of the Discrete Geometry and Combinatorics Academic Group of the Institute of Mathematics, University of the Philippines Diliman. The second half of the talk will be devoted to coordination sequences of 2-uniform tilings and perfect precise colorings of semiregular tilings.

Given a tiling T, we may view it as a graph whose vertex and edge sets are respectively the sets of vertices and edges of the tiling. The coordination sequence for the tiling with respect to a vertex P is the sequence (a\_n) where a\_n is the number of vertices Q of the tiling such that n is the length of the shortest path in the graph from P to Q.

A colored tiling is said to be perfect if every symmetry of the uncolored tiling effects a permutation of colors. A coloring of a tiling is called precise if each tile surrounding a vertex is assigned a different color.

**A simple and efficient method for characterizing daily physiology form wearable data**

**Daewook Kim (University of Michigan)**

Non-invasive data collection in real-world settings with wearables provides a new opportunity for characterizing daily physiology. However, accurate and efficient characterization remains an open problem because the complex autoregressive noise of the data makes it challenging to use simple and efficient methods for inference of clock proxies (e.g., least squares method). In this talk, we will introduce a simple approximation that alters the noise structure and thus enables one to use the least squares method. We will show its usefulness for personalized inference of circadian phase of heart rate rhythms by testing the simple method on over 100,000 days of real-world data.

**On the number of minimal vectors in linear codes**

**Romar B. dela Cruz (UP Diliman)**

A nonzero codeword in a linear code is minimal if its support does not properly contain the support of another nonzero codeword.  Minimal codewords have found applications in decoding and cryptography. We present recent results on the maximum and minimum number of minimal codewords given the length and dimension.

**Optimal intervention strategies for tuberculosis**

**Soyoung Kim (NIMS)**

[Tuberculosis (TB)](https://www.cdc.gov/tb/publications/factsheets/general/tb.htm), which is a respiratory disease caused by Mycobacterium tuberculosis bacteria, is one of the top 10 causes of death. Millions of people fall ill with TB disease annually. Although significant progress has been made in the detection and cure of TB for past decades, eradication of TB diseases is still a burdensome task. In this talk, the risk of TB spread in the Philippines and top three TB burden countries (India, China, and Indonesia) are analyzed using mathematical model. Based on the annual population and TB incidence data reported by World Health Organization, demographic and epidemiological parameters are estimated. Applying the optimal control theory, the effective intervention strategy for each country is suggested to minimize the TB patients.

**UPD IMath research activities in the actuarial science and mathematical finance**

**Jose Maria L. Escaner IV (UP Diliman)**

In this talk, I will briefly introduce the MFAS Academic Group, its aims and some of the  member’s recent research activities.  I will also discuss the Institute’s Actuarial Science program that is currently undergoing revisions.

**Detecting causality between circadian rhythm and affective state of mood disorders**

**Aurelio A. de los Reyes V (IBS)**

A circadian rhythm is a natural, endogenous process that regulates the 24-hour daily human physiological activities such as the sleep/wake cycle, body temperature and hormone secretion. It also plays a critical role in regulating mental, emotional, and behavioral functions. Evidences suggest that mood disorders are associated with circadian misalignment. However, causative relationship between circadian rhythm disruption and mental health disorders remains to be ambiguous. In this study, a potential direction of causality between circadian rhythm and mood of major depressive and bipolar disorders is quantified.

**Collaboration and partnership: Keys to relevant problem-solving**

**Carlene P.C. Pilar-Arceo (UP Diliman)**

This talk will present sample research collaborations – a dopamine synthesis model, a review of Filipino contributions to the study of chemical reaction networks, and contributions of the Modeling and Applications Group to the study of COVID-19 pandemic in the Philippine setting. Inherent in the presentation of the researches is the message that (multi-)partnership is core to achieving significant and relevant results to problems.