

## SIDIM 2026 Schedule of activities

### Friday (February 27)

2:30-4:00	Registration (Lobby Natural Sciences Bldg.)			
	<b>C-202</b>	<b>C-204</b>	<b>A-227</b>	<b>A-229</b>
	<b>Thematic sessions and contributed talks (Natural Sciences Bldg.)</b>			
3:00-5:30	A. Ouslan	Anasofia Colon	J. Romero	J. Wilson
	D. Torres	A. Ramos	B. Rivera	J. Ruiz
		C. Bolanos	C. R. Vazquez	L. Fontan
	F. Betancourt	D. Rodriguez	J. Perez	L. Meyers
	J. Vargas	F. Lebron	J. Calderon	M. D. Gonzalez
5:30-6:00	Coffee Break (Anf. #1 General Studies Bldg.)			
6:00-6:50	<b>Plenary talk – Victor Moll (Anf. #1 General Studies Bldg.)</b>			
7:00-9:00	Dinner (Mezzanine General Studies Bldg)			

**A-142**

L. Medina  
J. Calderon  
R. Leon  
C. Feria

**A-233**

A. Alvarado  
H. Cortez  
E. Guerrero  
L. Esquivel  
P. Negron

**A-231**

S. Samidha  
S. Rodriguez  
S. Castro  
S. Huanca  
V. Pineda

**A-225**

A. Hernandez  
A. Zabel  
A. Ortiz  
D. Quintana  
F. Pinero

### Saturday (February 28)

7:00-8:30	Continental breakfast (Lobby Natural Sciences Bldg.)			
8:00-9:30	Registration (Lobby Natural Sciences Bldg.)			
8:30-10:00	<b>Thematic sessions and contributed talks (Natural Sciences Bldg.)</b>			
	<b>C-202</b>	<b>C-204</b>	<b>C-206</b>	<b>A-227</b>
	J. Morales	M. Amaya	M. Aguilera	M. Leon
	M. Eglee	M. Motino	O. Castrillon	J. Osorio
	L. Pericchi	I. Rubio	O. Medina	N. Martinez
			L. Caban	L. Caban
10:00-11:00	<b>Poster Session and Coffee Break (Anf. #1 General Studies Bldg.)</b>			
11:00-11:50	<b>Plenary talk – Lisa Fauci (Anf. #1 General Studies Bldg.)</b>			
12:00-1:30	Lunch (Mezzanine General Studies Bldg)			
1:30-2:20	<b>Plenary talk – Xavier Ros-Oton (Anf. #1 General Studies Bldg.)</b>			
2:30-3:00	Coffee Break (Lobby Natural Sciences Bldg.)			
3:00-5:00	<b>Thematic sessions and contributed talks (Natural Sciences Bldg.)</b>			
	<b>C-202</b>	<b>C-204</b>	<b>C-206</b>	<b>A-227</b>
	M. Marazzi	E. Morales	R. Martinez	E. Ramos
	A. Bustos	G. Farfan	R. Sanchez	F. Bello
		J. Lebron	Y. Colon	N. Ramirez
		A. Coronel	Y. Choque	P. Torres
5:00-5:30	<b>Administrative Session (A-227)</b>			

**A-142**

J. Agosto  
L. Aparicio  
L. Alvarado  
A. Rodriguez

**A-233**

A. Cruet  
S. Estrada  
R. Arce  
J. Ortega

**A-231**

C. A. Vazquez  
C. Peluffo  
L. Caban

**A-142**

R. Ortiz  
D. Vasquez  
B. Patino  
C. Pena

**A-233**

M. Gonzalez  
M. Delgado  
O. Rodriguez  
E. Montes

**A-231**

L. Cardoso  
M. Cruz  
N. Moreira

### Notes:

A yellow background indicates a Thematic Session.

The thematic session on Saturday morning runs from 8:15-10:15.

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Department of Computer Science, University of Puerto Rico at Rio Piedras

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# 1 Charlas Plenarias / Plenary Talks

## Flexible filaments and swimming cups: just go with the flow

Lisa J Fauci, Tulane University.

The motion of waving or rotating filaments in a fluid environment is a common element in many biological and engineered systems. Examples at the microscale include chains of diatoms moving in the ocean, flagella of individual cells comprising multicellular colonies, as well as engineered nanorobots designed to deliver drugs to tumors. In this talk we will present mathematical and computational insights into these flows at the microscale. Our modeling approaches will vary from detailed models that capture flagellar material properties and wave geometry to minimal force-dipole models that represent a flagellum by a single point. We will investigate a few intriguing systems, including the journey of extremely long insect sperm flagella through tortuous female reproductive tracts, and the hydrodynamic performance of shape-shifting *Choanoeca flexa* colonies.

## Integration can be reduced to solving small linear systems (thanks to Ramanujan)

Victor H. Moll, Tulane University.

I will present a collection of examples illustrating a method of integration (developed jointly with Ivan Gonzalez, Physics Department, Universidad de Valparaiso, Chile) in the context of integrals coming from Feynman diagrams. The method consists of a small number of rules, the first one being Ramanujan's Master Theorem.

## Regularity theory for PDE and free boundary problems

Xavier Ros Oton, Universitat de Barcelona.

One of the most basic and important questions in PDE is that of regularity: to decide whether all solutions to a given PDE are smooth or not. A classical example is Hilbert's 19th problem, solved in 1956 by De Giorgi and Nash. The regularity theory for elliptic and parabolic PDE experienced a huge development during the second half of the 20th century, and nowadays there are still several problems of crucial importance that remain open. The aim of this talk is to give an overview of this topic and present some recent results in this direction.

## 2 Sesiones Temáticas/ Thematic Sessions

### 2.1 Estadística y Ciencia de Datos en Investigación STEM: Proyecto Bee Hunting de Arecibo C3

**Organizer:** Jairo A. Ayala Godoy, Instituto de Estadística y Sistemas Computarizados de Información, UPR-RP.

El proyecto Bee Hunting de Arecibo C3 constituye una iniciativa interdisciplinaria orientada al monitoreo de las poblaciones y la salud de las abejas de miel, *Apis mellifera*, organismos fundamentales para la estabilidad de los ecosistemas y la productividad agrícola debido a su rol polinizador. En un contexto donde las poblaciones de abejas enfrentan amenazas significativas asociadas a la pérdida de hábitat, el uso de pesticidas, las enfermedades, los desastres naturales y el cambio climático, el análisis riguroso de los datos recolectados resulta clave para comprender mejor sus patrones biológicos y conductuales, así como para apoyar esfuerzos de conservación basados en evidencia. Esta sesión temática se centra en el uso de métodos estadísticos y herramientas de ciencia de datos aplicados a la información generada por el proyecto Bee Hunting, destacando el papel de la estadística a lo largo del flujo de trabajo, desde la recolección de datos en campo hasta su análisis, visualización e integración para la toma de decisiones. Se abordarán enfoques actuales de investigación en el análisis de datos ecológicos, incluyendo el uso de aplicaciones computacionales para la captura de información, técnicas de limpieza y visualización de datos, y métodos de triangulación estadística para estimar la localización de colmenas de abejas silvestres, enfatizando los retos asociados al manejo de datos recolectados en entornos reales y a la construcción progresiva de estrategias analíticas en un contexto interdisciplinario. Finalmente, el alcance de la sesión temática enfatiza el valor de la investigación convergente que integra estadística, computación, biología y educación, en consonancia con la misión del proyecto Arecibo C3. La sesión busca no solo presentar resultados y metodologías, sino también fomentar el diálogo entre investigadores y educadores interesados en el uso de datos reales como vehículo para la investigación aplicada y la innovación educativa en múltiples niveles académicos. Apoyo: Esta sesión temática cuenta con el apoyo de la National Science Foundation (NSF), con las subvenciones 2321760, 2321759, 2321761 y 2318597.

**Apoyo:** Esta sesión temática cuenta con el apoyo de la National Science Foundation (NSF), con las subvenciones 2321760, 2321759, 2321761 y 2318597.

## Perspectiva Estadística del Proyecto Bee Hunting de Arecibo C3

*José Agosto Rivera, Departamento de Biología, University of Puerto Rico at Río Piedras.*  
*Jairo A. Ayala Godoy, Instituto de Estadística y Sistemas Computarizados de Información, University of Puerto Rico at Río Piedras.*

Esta ponencia presenta la perspectiva estadística que guía el análisis de los datos recolectados en el proyecto Bee Hunting de Arecibo C3, una iniciativa interdisciplinaria orientada al estudio y monitoreo de abejas polinizadoras en entornos reales. Se describe el contexto general del proyecto y los tipos de datos generados a partir de actividades de observación en campo, así como las principales preguntas analíticas que surgen al trabajar con información ecológica recolectada fuera de entornos controlados. La charla discute los retos estadísticos asociados a este tipo de datos, incluyendo la heterogeneidad de las observaciones, la presencia de inconsistencias, la variabilidad espacial y temporal, y las limitaciones inherentes a los procesos de recolección. A partir de estos retos, se presentan enfoques estadísticos exploratorios que permiten evaluar la estructura de los datos, identificar patrones preliminares y apoyar la formulación de estrategias analíticas progresivas. Asimismo, se enfatiza el papel de la estadística como eje integrador entre la computación, la visualización y la triangulación de información, estableciendo un marco conceptual que articula las distintas ponencias de la sesión temática. La charla busca ofrecer una visión general del estado actual del trabajo estadístico en el proyecto, resaltando oportunidades de investigación y colaboración interdisciplinaria en el análisis de datos ecológicos y ambientales.

**Palabras clave:** estadística aplicada, Bee Hunting, interdisciplinariedad, computación, visualización, triangulación.

## Aplicaciones Computacionales para la Recolección de Datos en el Proyecto Bee Hunting de Arecibo C3

*Luis Fernando Aparicio Mestra, Department of Computer Science, University of Puerto Rico at Río Piedras.*

En esta ponencia se describe el desarrollo y uso de aplicaciones computacionales diseñadas para la recolección de datos en el proyecto Bee Hunting de Arecibo C3. Se presentan las principales decisiones técnicas adoptadas para la captura de información en campo, así como el filtrado de datos generados a partir de estas herramientas. La charla discute los retos asociados al diseño de aplicaciones para entornos reales, incluyendo la variabilidad en las condiciones de recolección, la consistencia de los registros y las limitaciones tecnológicas. Desde una perspectiva aplicada, se destaca cómo estas soluciones computacionales constituyen el primer eslabón del flujo de trabajo estadístico del proyecto y condicionan las etapas posteriores de análisis y visualización de datos.

**Palabras clave:** desarrollo de aplicaciones, captura de datos, datos de campo, filtrado de datos.

## **Limpieza y Visualización Interactiva de Datos en el Proyecto Bee Hunting de Arecibo C3**

Lizbeth Alvarado Vargas, Facultad de Educación, University of Puerto Rico at Río Piedras.

En esta ponencia se presenta el desarrollo de una aplicación interactiva diseñada para realizar la limpieza inicial y visualización de los datos recolectados en el proyecto Bee Hunting de Arecibo C3. La herramienta permite explorar los ángulos de vuelo de cada abeja registrados en múltiples localizaciones del alimentador, mediante representaciones circulares, facilitando la identificación visual de patrones y posibles inconsistencias en los datos. Se llevan a cabo procedimientos para la detección de valores atípicos, a través del uso de estadísticas circulares, las cuales se consideran esenciales para el análisis de datos angulares. La presentación destaca la importancia de la visualización interactiva como un componente clave en las etapas iniciales del análisis estadístico, particularmente en contextos donde los datos provienen de entornos reales y presentan alta variabilidad.

**Palabras clave:** limpieza de datos, análisis exploratorio, visualización interactiva, estadística circular.

## **Triangulación de Datos para la Inspección de la Localización de Colmenas en el Proyecto Bee Hunting de Arecibo C3**

Ariana Rodríguez Flores, Facultad de Educación, University of Puerto Rico at Río Piedras.

En esta ponencia se presenta una investigación STEM que integra la estadística y la geometría para analizar el comportamiento direccional de las abejas y estimar áreas probables donde podrían ubicarse colmenas silvestres. El trabajo se enfoca en el uso de datos obtenidos desde tres puntos de observación. En esta ponencia se resalta la importancia de la limpieza de datos como parte esencial del análisis estadístico y de la toma de decisiones basada en información confiable. El análisis se apoya en la estadística circular y en la triangulación como estrategia para combinar la información proveniente de múltiples observaciones y representar los resultados en el plano. Este proceso combina elementos de la geometría con el análisis estadístico, permitiendo reducir el área de búsqueda para encontrar las colmenas silvestres. Esta experiencia evidencia el valor de la estadística como herramienta dentro de investigaciones STEM y su potencial para promover el razonamiento matemático y el pensamiento interdisciplinario.

**Palabras clave:** triangulación de datos, estadística circular, comportamiento direccional de las abejas

## 2.2 On the theory of $\tau$ -factorization and $\tau$ -graphs

**Organizer:** Reyes M Ortiz-Albino, University of Puerto Rico-Mayagüez Campus, Department of Mathematical Sciences.

In 2011, Anderson and Frazier introduced the notion of generalized factorizations, also known as  $\tau$ -factorizations. This framework can be viewed as the study of an integral domain in which the multiplicative operation is restricted by a symmetric relation  $\tau$  on the set of nonzero, nonunit elements. In this setting, multiplication is only permitted between elements that are  $\tau$ -related. Anderson and Frazier characterized several classes of relations that preserve properties analogous to the basic axioms of multiplication, such as the ability to multiply by associates or factors, or to combine factors in a way that reduces the length of a product.

Motivated by the theory of zero-divisor graphs, Coykendall and Maney introduced irreducible-divisor graphs in 2007. This idea was independently studied by Axtell and Stickles in 2008 and further developed by Axtell and Baeth in 2011. Motivated by the definition of Ortiz and Lucena of the  $\tau_n$ -graphs, in 2013, Mooney applied the theory of  $\tau$ -factorizations to extend irreducible-divisor graphs to  $\tau$ -irreducible  $\tau$ -divisor graphs for integral domains and commutative rings. Ortiz and his students have investigated several special cases and worked toward extending this framework to the theory of reduced factorizations.

These talks will survey the underlying theories, present illustrative examples, and highlight new directions in which this area is developing.

### A summary of the theory of $\tau_n$ -factorization

*Reyes M. Ortiz-Albino, Department of Mathematical Sciences, University of Puerto Rico at Mayagüez, University of Puerto Rico at Mayagüez.*

The theory of  $\tau$ -factorization or generalized factorization theory was defined by D.D. Anderson and A.M. Frazier in 2006. This theory was motivated by the co-maximal factorization of McAdams and Swan, as the study of a set with different operations or a way to study all factorizations at once. Of course, being born in the factorization setting was studied more mostly by algebraists in this area. They characterized types of relations that guarantee structural properties. This types basically determined what can be multiply or not. A brief summary of some results of Anderson's Ph.D. students until 2011.

On the other hand, we studied mostly the theory of  $\tau$ -factorization when the relation is an equivalence relation. One of the reasons, this relation is not as well behave in this

theory, as the ones classified as divisive or combinable by D.D. Anderson and J. Juett. As an example, we will present some approaches to try to characterized the behavior of the  $\tau$ -factorization, when  $\tau$  is the equivalence relation modulo  $n$ , some of the topics studied by Ortiz's students and opening the idea for upcoming talks in this setting.

**Keywords:**  $\tau_n$ -factorizations,  $\tau_n$ -primes, graphs

## The $\tau_n$ -prime counting function

Daniel R. Vásquez-Calderón, Department of Mathematical Sciences, University of Puerto Rico at Mayagüez.

The theory of  $\tau_n$ -factorizations is a topic in factorization theory over the integers that is still under exploration. It was introduced by Anderson and Frazier. In this framework, factors are related through a congruence modulo  $n$  over the nonzero nonunit integers. This generalization of factorizations in integral domains leads to the definition of  $\tau$ -prime numbers, which are those elements whose division of the  $\tau_r$ -product of two or more integers implies the division of at least one of the  $\tau_n$ -factors.

Despite recent progress on structural aspects of  $\tau_n$ -factorizations, the behavior of the associated  $\tau_n$ -prime counting function remains largely unexplored. In this work, we introduce and study an adaptation of the classical prime-counting function  $\pi(x)$ , in this context, verified for all  $x \geq n \max\{p : p|n\}$ . Additionally, we establish several properties of the function  $\pi_n(x)$  and provide a characterization in terms of the classical prime counting function  $\pi(x)$ . In particular, for some values of  $n$ , we determine a constant  $\alpha$  such that  $\pi_n(x) \approx \alpha\pi(x)$ . Graphical and analytical analyses are conducted to verify convergence using the logarithmic integral function,  $Li(x)$ .

Using programming tools, we provide results that illustrate how the usual prime-counting function relates to the  $\tau_n$ -primes generated up to the order of  $10*10$ . Furthermore, we analyze the effectiveness of adapting classical approximations via  $Li(x)$  and  $x/\log(x)$  as proposed by Gauss and de la Vallée Poussin, respectively, and compare the error.

**Keywords:**  $\tau_n$ -factorizations,  $\tau_n$ -primes, prime-counting functions, asymptotic analysis, computational methods.

## Sobre los grafos de $\tau_5$ -factores $\tau_5$ -irreducibles

Byron A Patiño de la Cruz, Department of Mathematical Sciences, University of Puerto Rico at Mayagüez.

Desde 2010, Ortiz y sus estudiantes han estudiado los grafos  $\tau_r$ -divisores  $\tau_r$ -irreducibles para  $n = 0, 1, 2, \dots, 6$ . Mooney amplió en 2013 la teoría de los grafos  $\tau$ -divisores  $\tau_5$ -irreducibles, profundizando en sus propiedades estructurales.

En este trabajo se estudian los grafos  $\tau_5$ -divisores  $\tau_5$ -irreducibles, según la definición introducida por Ortiz. Dado un elemento  $x$  no nulo ni unidad, el  $\tau_5$ -grafo asociado a  $x$  es un grafo cuyos vértices corresponden a los  $\tau_5$ -factores  $\tau_5$ -irreducibles que aparecen en una  $\tau_5$ -factorización de  $x$ . Dos vértices están unidos por una arista si y solo si los  $\tau_5$ -átomos correspondientes son  $\tau_5$ -factores en una misma  $\tau_5$ -factorización. El objetivo principal es caracterizar estos grafos y analizar sus propiedades algebraicas y combinatorias, estableciendo relaciones entre la estructura del  $\tau_5$ -grafo y las  $\tau_5$ -factorizaciones del elemento. Note que el conocer las características del  $\tau_5$ -grafo es que nos provee un andamiaje para poder construir y caracterizar los  $\tau_8$ -grafos, los  $\tau_{10}$ -grafos y algunos  $\tau_{12}$ -grafos. Esta presentación proveerá la idea y ejemplos de la construcción y algunas características de estos grafos.

**Keywords:**  $\tau_n$ -factorizations,  $\tau_n$ -graphs

## On the reduced $\tau_r$ -divisor graph

Carmen E. Peña-Cueto, Department of Mathematical Sciences, University of Puerto Rico at Mayagüez, University of Puerto Rico at Mayagüez.

The theory of reduced  $\tau_n$ -factorizations was introduced by Anderson and Hamon, and further study by Ortiz and Florescu. A reduced  $\tau_n$ -factorization of a nonzero nonunit integer is an expression  $x = x_1x_2 \cdots x_k$  where for any  $i \neq j$ ,  $x_i\tau_n x_j$ . Notice that reduced factorization is an expression that do not carry a unit factor in front of the expression, meanwhile non-reduced factorization allows the unit factor in front. In this setting,  $x$  is known as a reduced  $\tau_r$ -product of the factors  $x_i$ , and each  $x_i$  is a reduced  $\tau_r$ -factor of  $x$ . A nonzero nonunit element is called a reduced  $\tau_r$ -atom (or reduced  $\tau_r$ -irreducible element) if its only reduced  $\tau_r$ -factorizations are trivial. The notion of  $\tau_r$ -irreducible  $\tau_r$ -factor graphs was first introduced by Ortiz in 2010. Later, in 2013, extended this notion for any symmetric relation  $\tau$  on integral domains and commutative rings with identity. For a nonzero nonunit integer  $x$ , the  $\tau_r$ -irreducible  $\tau_r$ -factor graph of  $x$  is defined as the graph whose vertices correspond to the  $\tau_n$ -irreducible  $\tau_r$ -factors of  $x$  up to associates. An edge between two vertices  $x_1$  and  $x_2$  indicates the existence of a  $\tau_n$ -factorization of  $x$  in which both  $\tau_n$ -irreducible factors appear. In 2020, López and Ortiz established general characteristics for constructing  $\tau_n$ -graphs of nonzero nonunit integers when  $n = 2, 3, \dots, 6$ . The reduced  $\tau_r$ -divisor graph is defined

analogously to the  $\tau_n$ -graph, with vertices corresponding to reduced  $\tau_r$ -irreducible  $\tau_r$ -factor of  $x$  and an edge between two vertices  $x_1$  and  $x_2$  indicates the existence of a reduced  $\tau_n$ -factorization of  $x$  in which both reduced  $\tau_n$ -irreducible factors appear. This work focuses on the study of reduced  $\tau_r$ -factorizations, reduced  $\tau_r$ -atoms, and reduced  $\tau_r$ -graphs. We present several properties that extend from  $\tau_r$ -graphs to reduced  $\tau_r$ -graphs, as well as new properties that contribute to the classification of  $\tau_r$ -graphs.

## 2.3 On the theory of $G$ -invariant Boolean functions

**Organizer:** José E. Calderón Gómez, University of Puerto Rico-Mayagüez Campus, Department of Mathematical Sciences.

Boolean functions lie at the intersection of combinatorics and number theory and play a central role in coding theory, cryptography, and information theory. Formally, an  $n$ -variable Boolean function is a map  $f : \mathbb{F}_2^n \rightarrow \mathbb{F}_2$ , and the full space  $\mathcal{B}_n$  has  $2^{2^n}$  elements. This large number of Boolean functions makes exhaustive searches of Boolean functions with strong cryptographic criteria (e.g., high nonlinearity and balancedness) infeasible even for moderate values of  $n$ .

A fruitful and widely used method in the search of cryptographic Boolean functions is to impose symmetry by requiring invariance under the action of finite permutation groups. Given a subgroup  $G < S_n$ , a Boolean function  $f \in \mathcal{B}_n$  is  $G$ -invariant if

$$f(X_{\delta(1)}, X_{\delta(2)}, \dots, X_{\delta(n)}) = f(X_1, \dots, X_n), \quad \text{for all } \delta \in G,$$

and study the resulting class of  $G$ -invariant Boolean functions.

This thematic session focuses on cryptographic and combinatorial properties of Boolean functions fixed by specific group actions. In particular, we consider symmetric families fixed by the cyclic group  $\langle \sigma_n^k \rangle$  and discuss the study of key criteria such as nonlinearity and balancedness within these constrained spaces. We also address recent developments on cubic Boolean functions fixed by dihedral group actions, i.e. fixed by the group  $D_n$ , emphasizing structural classification, counting, and methods to analyze their cryptographic profiles. The session aims to bring together researchers working on group-invariant Boolean functions, symmetry-based constructions, and the interplay between algebraic structure and cryptographic strength.

## $G$ -invariant Boolean functions and cryptography

*Luis A. Medina, Department of Mathematics, University of Puerto Rico at Río Piedras, University of Puerto Rico at Río Piedras.*

Boolean functions are important objects in combinatorics, with applications in several scientific areas, including cryptography, coding theory, and information theory. In the particular

case of cryptography, properties such as balancedness and nonlinearity of Boolean functions play a crucial role in ensuring that certain implementations are robust and secure. However, computational limitations of current technology make these implementations computationally expensive and inefficient. This is the primary reason why researchers impose additional conditions on these functions, with the goal of mitigating these challenges.

Let  $G$  be a finite group of order  $n$ . We say that a Boolean function  $f$  in  $n$  variables is  $G$ -invariant if  $f$  is fixed under the natural action of the group  $G$ . Functions of this type have been extensively studied. In particular, the largest known nonlinearity of a Boolean function in 9 variables is 242. This value is attained within classes of Boolean functions that are invariant under the action of subgroups of  $\mathbb{Z}_9$ .

In this talk, we provide an introduction to the theory of  $G$ -invariant Boolean functions, discuss the current state of the field, and present several open problems and recent results that our research group is actively investigating.

**Keywords.** Boolean functions, finite groups,  $G$ -invariant

## $k$ -Rotation symmetric functions over Galois Fields

*José E. Calderón Gómez*, Department of Mathematical Sciences, University of Puerto Rico at Mayagüez.

Boolean functions form a central area at the crossroads of combinatorics and number theory, with important applications in coding theory, cryptography, and information theory. In the late 1990s, Pieprzyk and Qu introduced rotation symmetric Boolean functions and showed that their symmetry can lead to efficient and secure cryptographic implementations. More recently, certain subclasses of rotation symmetric Boolean functions have appeared as examples that surpass the bent concatenation bound when the number of variables is odd. These functions are known as  $k$ -rotation symmetric Boolean functions, a generalization of the classical rotation symmetric notion, introduced by Kavut and Yücel in 2007.

A significant portion of the theory of Boolean functions extends naturally to more general settings over finite fields. In this talk we discuss structural results for monomial  $k$ -rotation symmetric polynomials over Galois fields, and we use these structural properties to count the number of such monomials. We also present results on closed-form formulas for exponential sums of these functions over Galois fields. In particular, for a function  $f : \mathbb{F}_q^n \rightarrow \mathbb{F}_q$ , we define its exponential sum by

$$S(f) = \sum_{x \in \mathbb{F}_q^n} \omega^{\text{Tr}_{\mathbb{F}_q/\mathbb{F}_p}(f(x))},$$

where  $q = p^m$  with  $p$  prime,  $\omega = e^{2\pi i/p}$  is a fixed primitive  $p$ -th root of unity, and  $\text{Tr}_{\mathbb{F}_q/\mathbb{F}_p}$  denotes the absolute trace from  $\mathbb{F}_q$  onto  $\mathbb{F}_p$ .

**Keywords.**  $k$ -rotations, Galois Fields, exponential sums.

## Proof of the nonlinearity-weight conjecture for cubic monomial $k$ -rotation symmetric Boolean functions

Rodrigo A. Leon-Prato, Department of Mathematics, University of Puerto Rico at Río Piedras.

Boolean functions are fundamental objects in cryptography. Properties such as balancedness and nonlinearity of Boolean functions are critical for ensuring resilience against cryptographic attacks. In this talk, we study a specific class of Boolean functions that is invariant under the action of the cyclic group  $\langle \sigma_n^k \rangle$  where  $\sigma_n$  is the permutation

$$\sigma_n = \begin{pmatrix} 1 & 2 & \cdots & n-1 & n \\ 2 & 3 & \cdots & n & 1 \end{pmatrix}$$

and  $k$  is an integer that divides  $n$ . These functions are known as  **$k$ -rotation symmetric Boolean functions**. They are important due to their strong cryptographic properties.

In this talk we prove that the nonlinearity of a **cubic monomial  $k$ -rotation symmetric Boolean functions** is equal to its weight. It is conjectured that this is true for every monomial rotation Boolean function. These findings contribute to the formal characterization of this conjecture.

**Keywords.** Boolean functions,  $k$ -rotation symmetric functions, nonlinearity, Hamming weight, cubic monomials, Walsh spectrum

## Closed formulas for exponential sums of quartic $k$ -rotation monomial symmetric Boolean functions

Carlos E. Feria-Nieto, Department of Mathematical Sciences, University of Puerto Rico at Mayagüez, University of Puerto Rico at Mayagüez.

A Boolean function in  $n$  variables is a map from  $\mathbb{F}_2^n$  to  $\mathbb{F}_2$ , where  $\mathbb{F}_2 = \{0, 1\}$ . We say that a Boolean function is balanced if the number of zeros and ones obtained by evaluating the vectors in  $\mathbb{F}_2^n$  is equally distributed. The balancedness of a Boolean function can be studied via exponential sums, defined by

$$S(f) = \sum_{\mathbf{x} \in \mathbb{F}_2^n} (-1)^{f(\mathbf{x})};$$

a Boolean function is balanced if and only if  $S(f) = 0$ .

In 2007, Kavut and Yücel introduced the family of Boolean functions known as  $k$ -rotation symmetric Boolean functions. These functions are fixed by the action of  $\langle \sigma_n^k \rangle$ , where  $\sigma_n$  is

the rotation of  $n$  labels. They showed that this type of Boolean functions are excellent candidates for efficient implementations.

In this talk we present a study of the balancedness of quartic  $k$ -rotation monomial symmetric Boolean functions via exponential sums. We show that some families of quartic  $k$ -rotation monomial Boolean functions are splitting Boolean functions, then we use this to provide a closed formulas for the exponential sum of these families.

**Keywords.** Boolean functions,  $k$ -rotation, exponential sums

### 3 Charlas Concurrentes - Concurrent Talks

(To locate speakers check the index at the end of this document.)

#### Bases para ideales de anillos de polinomios sobre un dominio de ideales principales (PID)

Osmin Ariel Rodríguez Flores, Departamento de Matemáticas, Universidad de Puerto Rico, Recinto Universitario de Mayagüez.

En esta presentación se estudia la estructura de los ideales en anillos de polinomios, con énfasis en el caso clásico  $\mathbb{Z}[x]$  y su extensión a  $D[x]$  cuando  $D$  es un dominio de ideales principales (PID). El objetivo central es describir de manera explícita y sistemática los ideales no principales mediante conjuntos de generadores con propiedades de minimalidad, recurrencia y unicidad, de modo que la información aritmética de los coeficientes quede reflejada en la forma del ideal.

Para  $\mathbb{Z}[x]$ , se construye para un ideal no principal una sucesión de polinomios “mínimos”  $g_0(x), g_1(x), \dots, g_m(x)$ , caracterizados por tener, en cada grado, el menor coeficiente líder posible. A partir de una factorización entera de  $g_0$ , se obtiene una relación de recurrencia que conecta estos generadores y controla sus coeficientes:

$$q_k g_k(x) = x g_{k-1}(x) + \sum_{i=0}^{k-1} b_{ki} g_i(x), \quad q_k > 0, \quad 0 \leq b_{ki} < q_k,$$

lo cual conduce a una descripción concreta del ideal en términos de una base finita con restricciones aritméticas precisas y una representación canónica útil también para implementación computacional.

Posteriormente, el trabajo se generaliza a  $D[x]$  para  $D$  un PID incorporando el contenido de un polinomio y el ideal de contenidos asociado. En este contexto se consideran ideales que contienen una constante no nula (en particular,  $g_0 \in D \setminus \{0\}$ ) y se establece el marco de ideales primitivos; la recurrencia se adapta usando normalización módulo ideales principales y elección de coeficientes en sistemas de residuos adecuados, preservando la unicidad de los

datos que determinan el ideal. Finalmente, se incluyen ejemplos y casos de estudio en distintos PIDs, destacando el caso  $D = \mathbb{Z}[i]$ .

**Agradecimientos:** Agradezco de manera especial a mi asesor Luis F. Cáceres Duque por su guía y apoyo durante el desarrollo de este trabajo.

**Palabras clave:** ideales, anillos de polinomios,  $\mathbb{Z}[x]$ , PID, polinomios mínimos, base canónica, recurrencia, sistemas de residuos,  $\mathbb{Z}[i]$ .

## The 5-cube cut number, cut-complexes, and a vertex coloring game

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The hypercube cut-complexes are convex geometric presentations for threshold Boolean functions. The latter Boolean functions have been the core elements of study in threshold logic, and the original bases for modern deep learning. These complexes are, in fact, isometric subgraphs of the geometric  $d$ -cube, which are separable from the rest of the hypercube by a hyperplane in  $R^d$ . They are also very closely connected to the cut number of the  $d$ -cube. The cut number  $S(d)$  is the minimum number of hyperplanes in  $R^d$  that slices all the edges of the  $d$ -cube. The problem was originally posed by P. O’Neil in 1971 and then appeared as one of Victor Klee’s unresolved problems in his invited talk at the CCCG-1999 conference. Many other pioneers in convex or discrete geometry, including B. Grünbaum, M. Saks, and Z. Füredi have also raised the problem in different contexts. The identity  $S(d) = d$  has been well-known for  $d \leq 4$ , since Emamy presented two different solutions for the 4-cube, in 1986 and 1988. On the other hand, the 5-cube problem appeared to be much harder. It was not until the year 2000 that Sohler and Ziegler obtained a computational proof for  $S(5) = 5$ . Moreover, finding a theoretical and computer-free proof for the problem remains a challenging open problem. Based on a recent paper by the authors, we present a vertex coloring game over the 5-cube, that will be a fundamental basis for proving  $S(5) = 5$ .

**Keywords:** Convexity, Hyperplanes, Hypercube Cuts

# Damped Second-Order Evolution Equations: Intrinsic Phase Spaces and Dirichlet Solvability

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Let  $X$  be a Banach space and let  $A$  and  $B$  be closed, densely defined operators on  $X$ . We consider the damped second-order equation

$$u''(t) + 2Bu'(t) + Au(t) = f(t), \quad t \in [0, \pi].$$

Mild solutions are defined through the integrated equation of the associated first-order system on the space  $D(B) \times X$ . A pair of operator families  $(C(t))$  and  $(S(t))$  provides a variation-of-constants representation. From  $S$  we introduce an intrinsic phase space  $V_S$  and show that  $V_S$  is a Banach space continuously embedded into  $D(B)$ . If  $(x, y) \in (D(A) \cap D(B)) \times V_S$  and  $f \in C([0, \pi], V_S)$ , then the mild solution is a classical solution, namely  $u \in C^2([0, \pi], X) \cap C([0, \pi], D(A))$  and  $u' \in C([0, \pi], D(B))$ . The Dirichlet problem  $u(0) = x_0, u(\pi) = x_\pi$  is well posed within this regularity framework if and only if  $S(\pi) : V_S \rightarrow D(A) \cap D(B)$  is invertible, in which case an explicit representation formula holds.

**Keywords:**Damped cosine–sine families; mild solutions; abstract second-order evolution equations; Cauchy problem; Dirichlet boundary value problem; variation of constants; quadratic pencil

## Instabilities of compressible rotating disks

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The complementing condition (CC) for a boundary value problem is a compatibility condition between the principal part of a differential operator and the corresponding principal part of the boundary operators. Failure of the CC for problems in continuum mechanics have been associated with instabilities like wrinkling in materials. In their pioneer work, Rabier and Ogden (1987) studied such instabilities for steady states of rotating cylinders composed of an incompressible material. Specifically, they showed that for some value  $\omega^*$  of the rotation parameter, the linearized boundary value problem for such steady states possess eigenvalues accumulating at the value  $\omega^*$ . Moreover there is a value  $\omega_c > \omega^*$  for which the original boundary value problem loses ellipticity for rotations  $\omega > \omega_c$ . Although Rabier and Ogden pointed that the CC fails at  $\omega^*$ , we show that this is indeed the case for their problem. In this paper we study the corresponding problem for rotating disks in the case of

compressible materials. Contrary to the incompressible case, the trivial branch of solutions (purely radial expansions) can not be determined explicitly for compressible materials. This complicates considerably the local bifurcation analysis. However we are still able to characterize the values of the rotation parameter  $\omega$  for which the complementing condition for the linearized boundary value problem fails and those for which ellipticity is lost. Finally, we present some numerical results on the disposition of eigenvalues for the linearized problem for a family of Hadamard–Green type compressible materials in the so called incompressible limit.

**Keywords:** complementing condition, strong ellipticity, local bifurcation

## Pulsar Scintillation

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This work presents the effects of scintillation on pulsar (PSR) J2022+5154. We measure the effects of pulsar scintillation in the form of scintillation bandwidth, timescale, and other scintillation parameters. Our goal is to analyze how these scintillation parameters change over time and to estimate the location of the scattering screen, the region along our line of sight where scattering effects are dominant. Finding the location of these scattering screens could give hints of the structure of the ionized ISM. Our findings indicate that the scintillation bandwidth and timescale measured for PSR J2022+5154 decreased by almost two orders of magnitude compared to measurements reported in two decades of literature.

## Modeling and prediction of antimicrobial resistance in tuberculosis using Neural Ordinary Differential Equations

*Anthony S. Bustos-Espinosa*, Department of Mathematical Sciences, University of Puerto Rico at Mayagüez.

Tuberculosis remains one of the leading causes of mortality worldwide, a situation further aggravated by the emergence of antimicrobial resistance to combination therapies. In this work, we investigate the ability of machine learning models to predict the dynamics of bacterial resistance based on an underlying mathematical model formulated through ordinary differential equations.

A dynamical model describing the interaction between drug-sensitive and drug-resistant bacterial populations under the action of two first-line antibiotics, isoniazid and rifampicin, is considered. The model incorporates logistic growth, treatment-induced mutation, and a simplified description of pharmacokinetics. From this formulation, synthetic data are gener-

ated through numerical simulations, considering a variety of therapeutic regimens including combined, sequential, alternating treatments, and interruptions, with the aim of representing clinically realistic scenarios.

Using the generated dataset, two machine learning architectures are trained and compared: a recurrent LSTM model, which processes information in discrete time, and a Neural Ordinary Differential Equation (Neural ODE) model, which learns a continuous-time dynamics and incorporates treatment as a time-dependent control signal. Both models are evaluated on regression tasks involving the logarithmic reduction of bacterial load and the final fraction of resistance.

The results show that while both models exhibit comparable performance in predicting the overall reduction of the bacterial population, the Neural ODE model achieves a significant improvement in predicting antimicrobial resistance, with a relative error reduction exceeding 20%. These findings suggest that models with an inductive bias toward continuous-time dynamics are more suitable for describing biological processes governed by temporal accumulation. As future work, we propose extending the approach to additional antibiotics and evaluating the methodology using real clinical data.

**Keywords:** tuberculosis, antimicrobial resistance, ordinary differential equations, Neural ODE, machine learning

## **An Information Theoretic Based Deep Learning Model Based on Remote Sensing for Sargassum Detection and Estimation Along the Coasts of Puerto Rico**

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Recurrent Sargassum influxes along the coasts of Puerto Rico necessitate high-resolution, automated detection and quantification frameworks beyond conventional survey and low-resolution satellite methods. We present an information-theoretic deep learning approach integrating multispectral remote sensing and semantic segmentation for coastal Sargassum estimation. Sentinel-2 surface reflectance imagery (10m resolution, < 2% cloud cover) is processed via Google Earth Engine and entropy-filtered using Shannon information to prioritize high-complexity scenes. A modified Pix2Pix-derived architecture, CoastalUNet, is implemented as a five-class U-Net segmentation model with encoder–decoder skip connections, dropout regularization ( $p = 0.3$ ), and a composite loss function combining weighted cross-entropy ( $\alpha = 0.6$ ), Dice ( $\beta = 0.3$ ), and focal loss ( $\gamma = 0.1$ ) to address class imbalance. Transfer learning leverages 15,268 labeled coastal images from Quintana Roo and region-specific retraining on Palmas del Mar imagery. Model performance achieves 84.0% pixel accuracy, 58.6% mean IoU, and precision-biased  $F\beta$  behavior ( $f_{0.5} > f_2$ ), validated via 2,000-sample bootstrap confidence intervals. Quantitative Sargassum area maps are produced to support operational coastal monitoring.

**Acknowledgements:** This research was done in collaboration with Carlos A. Vázquez De Jesús (University of Puerto Rico at Río Piedras), Dimitri Vavoulis<sup>1</sup> (University of Puerto Rico at Río Piedras), Blessing Ekarume (University of Lagos, Nigeria), Andres Arroyo (University of Puerto Rico at Río Piedras) and Heeralal Janwa (University of Puerto Rico at Río Piedras).

**Keywords:** Sargassum quantification , Google Earth Engine, Remote Sensing , Costal monitoring , Shannon Information, semantic segmentation

## Chase-escape with Conversion on the Complete Graph

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*Matthew Junge*, Department of Mathematics, Baruch College.

*Chase-escape with conversion* is a stochastic process that takes place on a graph with vertices initially in either a red, blue, or white state. White vertices change to red according to independent rate- $\lambda$  Poisson processes along each edge leading to a red vertex. Red vertices change to blue according to independent rate-1 Poisson processes along each edge leading to a blue vertex. Additionally, each red vertex changes to blue according to an independent Poisson process with rate  $\alpha \geq 0$ . Blue is a terminal state.

Bailey et al. introduced the model to describe central nervous system damage from multiple sclerosis. In their interpretation, white sites represent healthy neurons, red sites have inflammatory activity, and blue sites regulatory activity.

In this talk, we introduce the chase-escape with conversion process and we present the techniques used to prove that it undergoes a phase transition at equal fitness on the complete graph. We show simple asymptotic formulas for the extinction probability, the total number of converted sites, and the expected number of surviving sites.

**Keywords:** interacting particle systems, complete graph, phase transition, competitive growth, poisson process

## Aplicación del algoritmo Hierarchical risk parity en la construcción de portafolios para index tracking

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El campo de las finanzas está en constante evolución y los inversores buscan estrategias novedosas para navegar en el mercado de forma eficiente. Una de estas estrategias es el *index tracking*, cuyo objetivo es replicar el comportamiento de un índice de referencia utilizando un subconjunto de activos pertenecientes a dicho índice, buscando minimizar el error de seguimiento y los costos asociados. Sin embargo, los métodos tradicionales de optimización de carteras presentan limitaciones prácticas asociadas a la estimación e inversión de la matriz de covarianzas, lo que puede generar portafolios inestables.

En este trabajo se propone utilizar el algoritmo *Hierarchical Risk Parity* (HRP) como una alternativa a los métodos tradicionales. Este algoritmo consiste en asignar pesos a los activos utilizando estructuras jerárquicas de correlación, permitiendo así construir portafolios sin necesidad de utilizar la inversa de la matriz de covarianzas. La metodología se evalúa utilizando datos históricos del índice bursátil Nasdaq 100, el cual contiene los valores de algunas de las compañías más importantes del sector tecnológico, incluyendo empresas de hardware y software.

La metodología propuesta contempla la construcción de portafolios utilizando métodos tradicionales y el método HRP para replicar el índice Nasdaq 100. Esto con el fin de comparar el desempeño de los portafolios replicantes mediante métricas de error de seguimiento y riesgo. Se espera que este trabajo contribuya al desarrollo de estrategias de replicación más robustas y estables frente a errores de estimación, aportando evidencia sobre la aplicabilidad de técnicas de optimización jerárquica en el contexto del *index tracking*.

## Socioeconomic and environmental factors in dengue malaria coinfection in Nariño, Colombia (2016–2024): a mathematical modeling approach

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Coinfection with dengue and malaria constitutes a growing challenge for public health in tropical regions, where the interaction between environmental, socioeconomic and climatic factors favors the persistence and complexity of transmission. In Colombia, and particularly in the department of Nariño, the coexistence of diverse ecological conditions, structural in-

equalities and simultaneous circulation of both pathogens has generated a favorable scenario for the occurrence of coinfection events during the period 2016–2024. However, the majority of existing studies have focused on descriptive or clinical approaches, with limited integration of socio-environmental variables and little use of empirically validated mathematical models. The objective of this research is to identify and quantify the socioeconomic and environmental factors associated with the persistence of dengue and malaria coinfection in the department of Nariño, Colombia, during the period 2016–2024, and analyze their influence on transmission dynamics through a mathematical modeling approach. To do this, official epidemiological data from public health surveillance will be used, complemented with socioeconomic and environmental information from validated institutional sources. Based on a comprehensive statistical scheme, robust empirical relationships will be established that support the formulation, analysis and validation of a deterministic compartmental model of coinfection. It is expected that the results will contribute to a better understanding of the local dynamics of dengue-malaria co-infection, strengthen mathematical epidemiology applied to vector-borne diseases and provide useful evidence for epidemiological surveillance and the design of vector control strategies in similar socio-environmental contexts.

**Keywords:** Dengue malaria coinfection; vector-borne diseases; socioeconomic factors; environmental factors; mathematical modeling; Nariño, Colombia

## Parametric Study of the Bouc-Wen Model for Nonlinear Systems

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*Luis E. Suárez*, Department of Civil Engineering and Surveying, University of Puerto Rico at Mayagüez.

In structures subjected to strong earthquakes, where dynamic loads degrade the initial properties of the materials, the Bouc–Wen model allows for a continuous and practical simulation of the nonlinear response over time. To calculate the response, it requires to solve a system of two nonlinear differential equations. The present study consists of a parametric analysis of the model, considering different ranges for its parameters, performing random sampling, and examining the hysteretic behavior present in the restoring force while it is subjected to seismic excitations. An interactive interface was developed to facilitate the interpretation of the results.

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**Keywords:** Hysteresis, seismic excitations, single-degree-of-freedom, restoring force.

## Fast–slow dynamics in a mathematical model for the fentanyl overdose epidemic

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*Karen Ríos-Soto*, Department of Mathematical Sciences, University of Puerto Rico at Mayagüez.

This work presents a mathematical analysis of a compartmental model for the fentanyl overdose epidemic formulated as a nonlinear system of ordinary differential equations. The model includes susceptible individuals, fentanyl users, individuals in overdose, and individuals undergoing treatment, with special emphasis on the role of relapse in the persistence of fentanyl use. Two formulations of the model are studied and compared: one incorporating linear relapse, representing spontaneous return to fentanyl use, and another incorporating nonlinear relapse, driven by interaction with active users. For each case, equilibrium points and basic reproduction numbers are derived, and the stability of drug-free and endemic equilibria is analyzed. The comparison shows that nonlinear relapse significantly alters the qualitative dynamics of the system. In particular, the analysis identifies conditions under which backward bifurcation occurs. When relapse is nonlinear, the model exhibits bistability and sustained fentanyl use even when the basic reproduction number is below unity, whereas the linear relapse formulation leads to a standard threshold behavior. This highlights the importance of relapse structure in epidemic-type models of substance use.

A key theoretical component of the work is the application of singular perturbation theory, exploiting the separation of time scales between fast overdose dynamics and slower population dynamics. The reduced system on the slow manifold provides insight into stability and bifurcation behavior. Numerical simulations support the analytical results, illustrating backward bifurcation, validating the perturbation analysis, and emphasizing the qualitative differences between the two relapse mechanisms.

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**Keywords:** *Fentanyl epidemic modeling, backward bifurcation, singular perturbation theory, relapse.*

## Visualization Dashboard of Bee Foraging Behavior in Flower Patch Assays using D3.js

Pablo U. Torres Arroyo, Department of Computer Science, University of Puerto Rico at Río Piedras.

Rémi Mégret, Department of Computer Science, University of Puerto Rico at Río Piedras.

This work presents the development of an interactive visualization dashboard designed to support the analysis of honeybee foraging behavior in flower patch assays. Implemented using the D3.js visualization library, the system provides multiple interconnected views of experimental data, including temporal chronograms, spatial flight trajectories, and statistical summaries of visit statistics. These coordinated visualizations enable dynamic cross-filtering and interactive exploration of large behavioral datasets involving hundreds of bee visits and numerous experimental variables. By allowing researchers to examine behavioral patterns across time, space, and individual identities simultaneously, the platform reduces reliance on manual tabular analysis and facilitates the identification of visitation preferences and temporal trends. This work contributes to the improvement of exploratory analysis and supports data-driven insights in complex ecological experiments.

**Acknowledgments:** This material is based upon work in the CyIndybee investigation supported by the National Science Foundation (NSF) under Grant No. 2318597. This work started as part of the CCOM4995 Topics in Computer Science - Interactive Visualization for Big Data with preliminary proof of concepts from Miguel Juan, Pablo Muñoz, and Omar Saleme.

**Keywords:** D3.js, data visualization, interactive visualization, honeybee behavior, flower patch assays, exploratory data analysis

## Determinants of First-Semester Academic Performance: A Comprehensive Analysis of Incoming University Students

Oscar Y. Castrillon-Velandia, Institute of Statistics and Computerized Information Systems, Faculty of Business Administration, University of Puerto Rico at Río Piedras.

This study examines determinants of first-semester academic performance among newly admitted undergraduate students at the University of Puerto Rico, Río Piedras Campus. Using institutional records for academic years 2013–2014 through 2024–2025 ( $n = 9,280$ ), academic performance is measured by first-semester grade point average (GPA) and, additionally, by a binary indicator of satisfactory performance ( $\text{GPA} \geq 2.0$ ). We evaluate demographic, academic-preparation, and socioeconomic indicators available at entry, including gender, type of high school, educational region, parental occupation, economic dependency status,

faculty, enrollment load, number of courses, and mathematics achievement. Descriptive comparisons are complemented with robust nonparametric inference and effect-size measures; trend analyses are conducted via the Cochran–Armitage test; and multivariate associations are assessed using logistic regression. Given the large sample size and multiple comparisons typical of institutional datasets, we incorporate adaptive significance levels to strengthen interpretability and replicability. The results emphasize the central role of mathematics preparation in early academic success, identify systematic but small gender and school-background differences, and highlight socioeconomic vulnerability patterns relevant for targeted first-semester interventions and retention strategies.

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**Keywords:** academic performance; first-year students; GPA; socioeconomic factors; non-parametric inference; effect size; logistic regression; higher education

## El efecto del uso de CalcPlot3D para la enseñanza de las derivadas parciales en diferentes contextos educativos

*Rafael Martínez Planell*, University of Puerto Rico at Mayagüez.

*Deborah Moore-Russo*, Department of Mathematics, University of Oklahoma.

Estudiamos los resultados del uso de la aplicación digital CalcPlot3D en la comprensión de las derivadas parciales por parte de los estudiantes. Para ello, comparamos las construcciones de los estudiantes de tres profesores que impartían cálculo multivariable en tres tipos diferentes de instituciones en los Estados Unidos. El profesor P enseñaba en un colegio comunitario (community college) de dos años, S en una institución universitaria de pregrado (undergraduate college) altamente competitiva y T en una universidad estatal integral (comprehensive state university). Los tres utilizaron enfoques pedagógicos diferentes. Empleamos el marco teórico APOS para clasificar las estructuras mentales de los estudiantes sobre las derivadas parciales a partir de su trabajo escrito en un instrumento. Los resultados indican que el uso de un recurso digital para la enseñanza de las derivadas parciales es insuficiente para garantizar la comprensión de los estudiantes. Los factores institucionales y pedagógicos contribuyen de manera significativa a determinar los resultados de aprendizaje de los estudiantes.

## Task-Based Proposal: Using Chess to Develop Random and Variational Thinking in Secondary Education

*Rubiela Sanchez Penagos*, Department of Mathematics, University of Puerto Rico at Mayagüez, Department of Mathematics, Universidad Pedagógica Nacional de Colombia.

This work presents a sequence of tasks designed to promote the teaching and learning of school mathematics by using chess in the classroom. Building on an inquiry into theoretical references on game-based learning, four tasks were created to contribute to the development of aleatorio (random/statistical) and variacional (variational) thinking, addressing concepts such as patterns, the Cartesian plane, probability, and tree diagrams. The sequence was specifically designed for seventh grade within the Colombian educational system, following national curriculum guidelines (MEN, 1998; MEN, 2016), with the aim of providing an innovative, non-conventional learning experience. An initial implementation with a group of students showed progress in areas such as determining sequences, finding sample spaces, handling the Cartesian plane, and calculating simple probabilities.

**Acknowledgements:** This undergraduate thesis (Sánchez, 2022), submitted in partial fulfillment of the requirements for the Bachelor's degree in Mathematics at the Universidad Pedagógica Nacional de Colombia, is publicly available in the institutional repository at: <http://hdl.handle.net/20.500.12209/18154>.

**Keywords:** Chess; Random (or Statistical) Thinking; Variational Thinking; Algebraic Thinking; Probability; Teaching Tasks; Secondary Education

## Uso del cómic como recurso interdisciplinario para potenciar la integración de destrezas matemáticas y lingüísticas

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*Eduardo Ortiz Maldonado*, Departamento de Español, Universidad de Puerto Rico en Arecibo.

Esta presentación compartirá las lecciones aprendidas de la investigación-acción realizada con estudiantes de quinto grado de escuela elemental. Este proyecto interdisciplinario (Matemáticas, Artes del Lenguaje) requirió que estudiantes de quinto grado integraran el razonamiento matemático y el sentido numérico con la comprensión lectora. Los estudiantes fueron expuestos a la lectura de cuentos cortos que incluían problemas matemáticos. Los cuentos fueron diseñados previamente para proporcionar un contexto narrativo atractivo, basado en los intereses de los estudiantes, que estimulara y facilitara la resolución de problemas matemáticos. Trabajando en grupos colaborativos, se instruyó a los estudiantes para que identificaran la estructura tradicional de un cuento corto y establecieran la correspondencia entre el punto culminante (clímax) y el problema matemático. Además, debían elaborar un

final para el cuento basado en la resolución del problema planteado y la trama de la historia. Posteriormente, trabajaron en la creación de un cómic basado en los cuentos y los problemas matemáticos discutidos en sus respectivos grupos. Los resultados preliminares muestran que los alumnos fueron capaces de demostrar el dominio de destrezas de comprensión de lectura (identificación de estructuras narrativas, síntesis, reformulación, etc.) y sentido numérico (resolución de problemas, operaciones numéricas, reconocimiento de relación part-todo, etc.) las cuales extrapolaron a una experiencia interdisciplinaria mediante el diseño de una historieta o cómic.

**Palabras claves:** resolución de problemas, sentido numérico, comprensión de lectura, cómic, aprendizaje interdisciplinario

## Modeling Students' Perceived Utility of Mathematics in Large-Scale Assessments: An IRT-GRM and SEM Approach

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Students' perceived utility of mathematics is a latent construct reflecting students' beliefs about the usefulness of mathematics for daily life, academic advancement, and future occupational goals. Large-scale assessments such as the Trends in International Mathematics and Science Study (TIMSS) provide an opportunity to analyze eighth-grade students' perceived utility of mathematics. The student questionnaire includes interesting questions, and we analyzed some of them for this research. Question 20, in particular, contains Likert-type items that capture students' perceptions of the utility of mathematics, such as "I think learning mathematics will help me in my daily life", "I would like a job that involves using mathematics", and "I need to do well in mathematics to get the job I want". In this study, student's perceived utility of mathematics was modeled as a latent construct using Item Response Theory through the Graded Response Model (IRT-GRM). Also, according to a general latent variable modeling framework, the IRT-GRM can be integrated with Structural Equation Modeling (SEM), allowing the latent traits estimated to be incorporated into structural models examining relationships among contextual constructs. Our results indicate the IRT-GRM model converged successfully and stable estimation of the latent trait ( $\theta$ ). The items exhibited good discrimination parameters ( $\alpha$  ranging from 1.61 to 3.37). The estimated threshold parameters ( $\beta_1$ - $\beta_3$ ) are a logically ordered progression across response categories for the items and support the ordinal structure of the Likert-type responses. Furthermore, SEM shows a standardized path coefficient of  $\beta \approx 0.38$ , indicating that both teaching practices and students' attitudes toward mathematics are meaningfully associated with higher levels of students' perceived utility of mathematics. These findings suggest that students' perceived utility of mathematics is positively influenced by teaching practices in

the mathematics classroom, highlighting the central role of pedagogical and affective factors in shaping students' valuation of mathematics.

**Keywords:** utility of mathematics, ordinal items, latent construct.

## Multidimensional Periodic Costas Arrays

*Sona Tau Estrada Rivera*, Department of Computer Science, University of Puerto Rico at Río Piedras.

John Peter Costas originally defined Costas arrays as square binary matrices that have 1 dot per column and per row with autocorrelation 1. Having autocorrelation 1 is sometimes called as the *Costas property*. Costas arrays can be interpreted as bijections  $f : \mathbb{Z}_n \rightarrow \mathbb{Z}_n$  that satisfy the Costas property.

The definition of Costas arrays has been extended to allow constructions of non-square and multidimensional arrays defined by injections  $f : \mathbb{Z}_{p^{r-1}} \rightarrow \mathbb{Z}_p^r$  that preserve the Costas property periodically. The injections in these extensions are almost onto since they only miss one point in the co-domain. This begs two questions,

1. Can we define extended Costas arrays with injections  $f : \mathbb{Z}_{p^{r-c}} \rightarrow \mathbb{Z}_p^r$  that miss  $c > 1$  points?
2. Can we give constructions for these arrays that preserve the Costas property periodically?

This talk presents theory and new definitions to answer these questions.

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## Maximizing Subgraphs in Regular Graphs

*Gabor Lippner*, Department of Mathematics, Northeastern University.

*Arturo Ortiz San Miguel*, Department of Mathematics, Northeastern University.

We determine the  $d$ -regular graphs  $G$  on  $n$  vertices with the highest  $H$ -density for any  $H$ . We reframe the problem as a continuous optimization problem on the eigenvalues of  $G$  by relating injective homomorphism numbers from  $H$  and homomorphism numbers from

quotient graphs of  $H$ . For almost all  $H$ , this relation has *non-spectral terms*, which require bounding by *spectral terms* in a way that is sharp at the optimal graph.

For bipartite  $H$  and  $d$  large enough, we show  $G$  consists of disjoint copies of  $K_{d,d}$ . For non-bipartite  $H$  and  $d$  sufficiently large,  $G$  is a collection of disjoint  $K_{d+1}$  graphs. For  $H = C_5$  and  $d = 3$ , disjoint Petersen graphs emerge. Moreover, a corollary gives formulas for the number of 5-cycles of a graph with respect to its spectrum, regardless of regularity.

It is easy to notice that copies of  $K_{d,d}$  maximize the number of closed walks of even length vertex-wise. We prove that copies of  $K_{d+1}$  do the same for closed walks of odd length. We note that these structures do not maximize cycles vertex-wise, but they do globally.

**Keywords:** Extremal graph theory, regular graphs, homomorphism numbers, spectral graph theory

## A Continuum of Bacterial Coexistence Equilibrium States Sustains *mcr*-Mediated Colistin Resistance at the Human-Animal Interface: A Case Study in Rural Regions of Ecuador

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The emergence of plasmid-mediated colistin resistance through *mcr* genes jeopardizes last-resort antimicrobial therapy, yet the ecological drivers that regulate resistance persistence at the human–animal interface remain insufficiently characterized. In this study, we introduce a new deterministic mathematical model that captures *mcr*-mediated resistance dynamics in cohabiting human and animal populations and is parameter-calibrated using empirical surveillance data from rural Ecuadorian communities in Ecuador.

We formulated a coupled ODE system integrating bacterial growth, interspecies transfer, colistin pharmacokinetics, and *mcr* gene acquisition, and showed analytically via normal hyperbolicity theory that it supports a continuum of coexistence equilibria lying on a normally attracting invariant manifold (NAIM) with transverse stability. Guided by this structure, we ranked the influence of 10 uncertain parameters using Latin Hypercube Sampling and PRCC model integrations for *E. coli* and *K. pneumoniae*.

Contrary to pharmacodynamic expectations, bacterial carrying capacity  $K$  emerged as the dominant driver of resistance (PRCC > 0.92,  $p < 10^{-300}$ ), surpassing gene acquisition rate ( $\eta$ ), elimination by colistin ( $\delta$ ), and drug absorption parameters ( $\gamma_a, \gamma_e$ ), all of which exhibited negligible impact ( $p > 0.05$ ). Competitive suppression by sensitive strains ( $\beta_s, \alpha_s$ ) showed strong negative correlation with resistance burden ( $|\text{PRCC}| > 0.79$ ). We also proved the existence of a NAIM representing a continuum of coexistence equilibria. Critically, *E. coli* exhibited symmetric human-animal resistance patterns, while *K. pneumoniae* showed pronounced human-biased asymmetry, revealing species-specific transmission architectures.

Ecological competition, not antimicrobial pharmacodynamics, governs *mcr*-mediated resistance at endemic equilibrium. Our results challenge the paradigm that reducing colistin

use alone suffices to control resistance, demonstrating instead that interventions targeting bacterial load reduction, microbiota restoration, and competitive exclusion offer superior leverage. The mathematical proof of a NAIM structure provides the first rigorous theoretical foundation for understanding why resistance persists as a stable ecological state rather than a transient pharmacological response. These findings mandate a fundamental reorientation of One Health antimicrobial resistance strategies toward ecological management rather than solely pharmacological restriction.

**Acknowledgements:** This research was done in collaboration with Yuliana Rodriguez (University of Quindío, Armenia, Colombia), Carlos Bastidas-Caldes (University of the Americas, Quito, Ecuador), Liliana Esquivel (University of Puerto Rico at Mayagüez).

**Keywords:** BLEE gene, *mcr-1* gene, *E. coli*, *K. pneumoniae*, model validation, stability

## Deformations of rotating disks under self gravitation and variable rotational frequency

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*Jey Sivaloganathan*, Department of Mathematical Sciences, University of Bath, U.K..

In this paper we study the problem of characterizing the deformed configurations of rotating self-gravitating solid disks. We work on a known stress free reference configuration in which the density distribution is known or given. The mathematical problem is that of finding stationary solutions of an action functional that includes terms for the kinetic energy due to rotation, gravitational energy due to self-gravity, and the potential mechanical energy due to the internal composition of the body. We present mathematical results about the existence of minimizers of the action potential both for the displacement and traction free problems. In addition we show that these minimizers satisfy the Euler–Lagrange equations and thus correspond to stationary points for the action functional. For the so called elastic–fluid mechanical energy function, we consider the problem with variable rotating frequency profiles, but without gravitational effects. In this case the the Euler–Lagrange equations can be solved explicitly. We show that these explicit solutions are actually global minimizers for the action potential. We present some numerical simulations of how these minimizers look for various variable rotating frequency profiles.

**Keywords:** rotating bodies, self-gravitation, action potential

# An Introduction to Polynomial Invariants in Knot Theory: The Alexander-Conway and Kauffman Bracket

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*Gabriel Montoya-Vega*, Department of Mathematics, University of Puerto Rico at Río Piedras.

Polynomial invariants constitute a dynamic and essential area of study in knot theory. From the Alexander polynomial and the revolutionary Jones polynomial to the collectively discovered HOMFLYPT polynomial, these algebraic expressions have been fundamental to the understanding of knots and links. Moreover, with the recent introduction of Khovanov homology, significant interest has arisen in the categorification of these polynomials, providing deeper insight into their topological and algebraic properties.

In this talk, we introduce the notion of polynomial invariants of links, focusing on the Alexander-Conway polynomial and the Kauffman bracket polynomial. Our main emphasis is on families of pretzel links, where the special structure of these links allows for explicit and efficient computations of their associated invariants. In particular, we discuss how the Alexander-Conway polynomial can be computed for the family of pretzel links  $P(1, 1, n)$ , leading to a formula that depends solely on the integer parameter  $n$ .

We also introduce the Kauffman bracket polynomial and explain its computation through Kauffman states. For specific families of pretzel links, we show how the behavior of these states can be systematically analyzed to obtain explicit expressions for the bracket polynomial without performing a full state enumeration. This approach highlights how combinatorial and structural features of pretzel links simplify the computation of classical polynomial invariants.

**Keywords:** Knots and links, pretzel links, Alexander-Conway polynomial, Kauffman bracket polynomial.

## Finding Exceptional Trinomials of Given Degree-Gap over $\mathbb{F}_{q^2}$ and Applications to Permutation Polynomials

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*Carlos A. Agrinoni*, Department of Mathematics, University of Puerto Rico at Río Piedras.  
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A multivariate polynomial is said to be absolutely irreducible over a given field  $\mathbb{F}$  if it is irreducible over the algebraic closure of  $\mathbb{F}$ . In algebraic geometry, coding theory, and cryptography, determining absolute irreducibility for certain polynomials is important for solving various problems such as: counting rational points, determining error-correction

capabilities, and determining suitability for use in cryptographic systems.

One particular class of polynomials of interest in coding theory and cryptography are the exceptional polynomials over a finite field. A polynomial  $f(x) \in \mathbb{F}_q[x]$  (of  $\deg \geq 2$ ) is said to be exceptional, provided that no irreducible factor of:

$$\Phi_f(X, Y) = \frac{f(X) - f(Y)}{X - Y}$$

is absolutely irreducible. Exceptional polynomials correspond to exceptional permutational polynomials. We define the degree-gap of  $\Phi_f(X, Y)$  to be the difference between the degrees of the leading form of  $\Phi_f(X, Y)$  and the next form of  $\Phi_f(X, Y)$  of highest degree. Moreover, when  $f(x)$  is a trinomial with no linear term, then  $\Phi_f(X, Y)$  is a generalized trinomial. We determine, given a trinomial  $f(x) = x^d + x^{d-\gamma} + x^{d-2\gamma}$ , where  $\gamma$  is the degree-gap of  $\Phi_f(X, Y)$ , whether  $f(x)$  is an exceptional polynomial. We work over the quadratic extension field  $\mathbb{F}_{q^2}$ , for various values of  $q$  and use computationally efficient absolute irreducibility criteria to determine whether  $f(x)$  is exceptional, for various degree-gaps of  $\Phi_f(X, Y)$ .

**Keywords:** Exceptional Polynomial, Permutation Polynomial, Absolute Irreducibility, Generalized Trinomial, Coding-Theory, Cryptography, Algebraic Geometry, Degree-Gap

## Dynamics of MRSA in Hospital Settings: Mathematical Modeling of Healthcare Worker-Mediated Transmission Pathways

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This investigation presents a data-informed mathematical modeling framework to study the transmission dynamics of methicillin-resistant *Staphylococcus aureus* (MRSA) in hospital environments. The database was generated from Carlos Andrade Marín Hospital (HCAM), the largest tertiary hospital in Quito, Ecuador, by collecting nasal swab samples from health care workers (HCW) to identify MRSA. Based on this, we describe HCW-mediated pathways across heterogeneous service units. MRSA transmission within hospitals is also strongly influenced by workforce organization, contact structure, and adherence to infection-control practices. Motivated by these considerations, we develop a base model that contains a single service unit and then expands to a metapopulation model that explicitly represents both patient, administrative, and laboratory personnel, which remain service-specific and HCWs populations who are allowed to rotate between units, distinguishing between susceptible and colonized patients as well as clean and transiently contaminated HCWs, under a frequency-dependent contact formulation. The model incorporates key hospital processes, including the admission of colonized  $\Lambda_P\pi$  and non-colonized patients  $\Lambda_P(1 - \pi)$ , patient discharge or decolonization  $\mu_P P_S$  and  $\mu_P P_C$ , HCW contamination through patient contact  $\beta_H H_S \frac{P_C}{P}$ , patient contamination through HCW contact  $\beta_P P_S \frac{H_C}{H}$  and definitive exit of HCWs from service units  $\mu_H H_S$  and  $\mu_H H_C$ , allowing MRSA burden to be interpreted as a combined effect of exposure intensity, clearance capacity, and staff turnover. The baseline model

extends to account for HCW mobility across  $j = 3$  hospital units and the term  $\rho_{j \rightarrow k} H_{S,j}$  represents the rotation of HCWs from one unit  $j$  to another one  $k$  with a movement rate of  $\rho_{j \rightarrow k}$ . A correlational study of preventive variables in the data (protective equipment, nasal ointment, antibiotic use, and hand hygiene capacitation) was conducted to observe if these preventive measures decrease the transmission of MRSA. This study serves as a foundation for future studies on modeling antimicrobial resistance using healthcare worker-level data and its transmission pathways within a rotational model.

The rotational model for HCWs across hospital services is:

$$\begin{aligned}
\frac{dP_{S,j}}{dt} &= \underbrace{\Lambda_{P,j}(1 - \pi_{P,j})}_{\text{non-colonized admissions in } j} - \underbrace{\beta_{P,j}P_{S,j}\frac{H_{C,j}}{H_j}}_{\text{colonization by HCWs in } j} - \underbrace{\mu_{P,j}P_{S,j}}_{\text{patient exit from } j}, \\
\frac{dP_{C,j}}{dt} &= \underbrace{\Lambda_{P,j}\pi_{P,j}}_{\text{colonized admissions in } j} + \underbrace{\beta_{P,j}P_{S,j}\frac{H_{C,j}}{H_j}}_{\text{nosocomial MRSA in } j} - \underbrace{(\mu_{P,j} + \gamma_{P,j})P_{C,j}}_{\text{exit or decolonization in } j}, \\
\frac{dH_{S,j}}{dt} &= \underbrace{\Lambda_{H,j}(1 - \pi_{H,j})}_{\text{new clean HCWs in } j} - \underbrace{\beta_{H,j}H_{S,j}\frac{P_{C,j}}{P_j}}_{\text{HCW contamination in } j} + \underbrace{\theta_j H_{C,j}}_{\text{cleaning in } j} - \underbrace{\mu_{H,j}H_{S,j}}_{\text{HCW exit from } j} \\
&+ \underbrace{\sum_{k \neq j} \rho_{k \rightarrow j} H_{S,k}}_{\text{clean HCWs rotating into } j} - \underbrace{\sum_{k \neq j} \rho_{j \rightarrow k} H_{S,j}}_{\text{clean HCWs rotating out}}, \\
\frac{dH_{C,j}}{dt} &= \underbrace{\Lambda_{H,j}\pi_{H,j}}_{\text{new colonized HCWs in } j} + \underbrace{\beta_{H,j}H_{S,j}\frac{P_{C,j}}{P_j}}_{\text{HCW contamination in } j} - \underbrace{(\theta_j + \mu_{H,j})H_{C,j}}_{\text{cleaning or exit in } j} \\
&+ \underbrace{\sum_{k \neq j} \rho_{k \rightarrow j} H_{C,k}}_{\text{contaminated HCWs into } j} - \underbrace{\sum_{k \neq j} \rho_{j \rightarrow k} H_{C,j}}_{\text{contaminated HCWs out of } j}.
\end{aligned}$$

**Acknowledgements:** This research was done in collaboration with Orlay J. Rivera Rodríguez (University of Puerto Rico at Arecibo), Jhoana P. Romero Leiton (University of Puerto Rico at Mayagüez), Esteban J. Rolón Gutiérrez (University of Puerto Rico at Arecibo), and Carlos Bastidas-Caldes (Universidad Espíritu Santo, Samborondón, Ecuador).

**Keywords:** nosocomial, heterogenous, antimicrobial resistance, metapopulation model

# Modeling Spatial Dependence: A Simulation-Based Comparison of Parametric and Semi-Parametric Approaches

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This research aims to compare the performance of spatial regression models that rely on predefined weight matrices with that of semi-parametric regression models using spatial smoothers. The preliminary results show that the best performing model is the Queens model as this is the model used to generate the data. The second best performing model is the penalized tensor products. This shows that if there is no reasonable argument for picking the spatial weights matrix the penalized tensor products are a reasonable starting point for controlling for spatial variability.

**Keywords:** Spatial simulation, Spatial Regressions, GAMs, Tensor Products

**Acknowledgements:** This research was sponsored by the Mathematics Department of the University of Puerto Rico, Mayaguez.

## Automated Detection of Identification Documentation with Open Source Face Detection and Text Recognition libraries

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Capture The Flag (CTF) competitions have become a widely adopted pedagogical tool in cybersecurity education due to their ability to provide hands-on, problem-based learning experiences. These competitions allow students to engage with realistic security scenarios while developing practical technical skills. However, designing CTF challenges remains a labor-intensive process that requires significant technical expertise and time investment, often limiting their use in institutions with constrained resources or large student populations.

In this work, we present the design and partial implementation of a framework for the automated generation of beginner-level, Jeopardy-style CTF competitions. The proposed system is built around a modular Python-based backend that generates complete technical challenges from structured JSON specifications. Each module is responsible for producing challenges in a specific cybersecurity domain, including networking, cryptography, forensics, steganography, and web security. By standardizing the exercise definition format and au-

tomating artifact generation, the framework enables rapid creation of new challenges while reducing instructor workload.

The framework is designed for extensibility and supports the composition of multistage challenges that combine multiple cybersecurity categories into a single investigative workflow. Current results demonstrate that a diverse set of beginner-friendly exercises can be generated automatically with minimal manual intervention. Future development will focus on integrating Large Language Models (LLMs) to automatically generate narrative elements, culturally relevant themes, and contextual hints, further enhancing engagement and accessibility for diverse student populations.

**Acknowledgements:** Thanks to CSLab and my mentor, José Ortiz Ubarri, for his guidance and support throughout this project. Special thanks are extended to Tatiana Castro and Rafael Arce for their collaboration in developing the project idea, and to Gabriel Romero for his contributions to creating the web security exercises.

**Keywords:** Cybersecurity Education, Capture The Flag, Large Language Models, Educational Technology

## The Relevance of Compound Events in Bee Traffic Monitoring

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Bees play a crucial role in human agriculture, making the accurate characterization of their behavior essential. In the field of automatic bee traffic tracking, individual monitoring has been prevalent in the past two decades to collect detailed data on foraging behavior. To support analysis, these data must be classified into entry and exit events, and assembled into flight trajectories. However, existing classification methods largely consider only simple exits and entrances, which ignore the existence of U-turn or guarding movements which represent a non-trivial fraction of bee activity at the hive entrance. Identifying these movements as compound events is necessary to accurately track all movements over time while avoiding classifications which may produce misleading movement records. In this presentation, we analyze existing event classification methods to evaluate their accuracy for two different types of movements: simple and compound. We then propose extended event classification methods that explicitly account for compound events, enabling more accurate reconstruction of bee traffic dynamics.

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**Keywords:** automatic monitoring, bee activity, foraging behavior

## **Zorzal: Una aplicación web geoespacial para visualizar la gentrificación en Puerto Rico**

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El proceso de gentrificación y el desplazamiento que lo acompaña están arrojando muchas comunidades en Puerto Rico. El concepto de la gentrificación ha sido objeto de estudio extenso en las áreas de geografía y economía y por ende hay varias teorías que se pueden utilizar para entender este proceso y sus dinámicas. Rent Gap es una de estas teorías y expone que la gentrificación se puede entender en términos de una brecha entre el valor actual de una propiedad y su valor potencial. Esta teoría fue propuesta por Neil Smith y se ha aplicado en muchos países como Australia, Estados Unidos y Chile con una variedad de métodos y datos. En este trabajo creamos una aplicación llamada Zorzal que provee visualizaciones de la gentrificación en Puerto Rico utilizando la teoría del Rent Gap mediante el análisis de transacciones de compraventa.

Zorzal es un Full Stack Geospatial Web Application que consiste de dos piezas. Un backend que se encarga de: recopilar datos de transacciones de compraventa, georeferenciar esos datos usando datos catastrales y proveer estos datos y análisis de los mismos mediante un API. Un frontend que contiene un Dashboard Geoespacial que utiliza los datos y los análisis proveídos para para crear visualizaciones de la gentrificación en comunidades de Puerto Rico. Esta aplicación está enfocada en comunidades particulares que están pasando por el proceso de gentrificación para que sus miembros puedan entender las dinámicas de este proceso e idear soluciones para atender la problemática y evitar ser desplazados.

**Keywords:** Geospatial Data Analysis, Web Application, Gentrification

## Conocimiento profesional para enseñar matemáticas: el caso del concepto matemático de función

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Se llevó a cabo un estudio cualitativo donde por medio de entrevistas grupales se determinó el conocimiento profesional de un grupo de docentes asistentes a un seminario con el propósito de elaborar materiales educativos para desarrollar el concepto matemático de función. Definimos el conocimiento profesional como el conocimiento en cuatro dimensiones: (1) conocimiento del contenido y de la forma de enseñarlo; (2) sus creencias sobre la profesión y ellos mismos; (3) participación en una comunidad profesional; y, (4) elaboración de materiales para los procesos de enseñanza y aprendizaje. Encontramos que, aunque los docentes se apropiaron tardíamente del concepto de función en sus estudios universitarios, ellos entienden que es importante introducir a sus estudiantes el tema por medio del uso de contextos y programas computarizados. Sin embargo, reconocen obstáculos de su aplicación en el salón de clase por limitaciones de tiempo, extensión del currículo y poca creatividad para diseñar actividades innovadoras.

En esta charla se presentarán los resultados del estudio, así como los materiales educativos creados, con base en la educación matemática realista, para la enseñanza del concepto de función a nivel preuniversitario.

**Reconocimientos:** Este trabajo fue realizado en colaboración con Omar Hernández Rodríguez (UPR Río Piedras), Ana Helvia Quintero (UPR Río Piedras), Liliana Torres Rodríguez (UPR Bayamón), y Aileen Velázquez Estrella (Departamento de Educación de Puerto Rico).

**Palabras clave:** Educación Matemática Realista; educación preuniversitaria; estudio de la lección; funciones; investigación cualitativa.

## An LDG-Based Computational Framework for Variational Optical Flow Estimation

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Optical flow estimation is a fundamental problem in computer vision, often addressed through variational methods that minimize an energy functional. Although these approaches achieve high accuracy, their computational cost limits their use in real-time scenarios. In this work, we present a computational framework that applies the Local Discontinuous Galerkin (LDG) method to the variational optical flow problem.

Our formulation employs directional numerical fluxes and a zero-stability condition to discretize the underlying PDEs, reducing numerical dissipation and enabling efficient treatment of boundary conditions. To solve the resulting large-scale linear systems, we use iterative

solvers based on the Preconditioned Conjugate Gradient (PCG) method with several block preconditioners. Experimental results on standard optical flow benchmarks demonstrate that the proposed approach achieves competitive accuracy while significantly reducing computation time, making it suitable for real-time applications.

**Keywords:** Optical flow, Local Discontinuous Galerkin method, computer vision

## Machine Learning Analysis of Natural Disaster’ Impact on Mathematics Education in Puerto Rico

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Natural disasters such as hurricanes and prolonged infrastructure disruptions have had significant and recurring impacts on the educational system of Puerto Rico, particularly in mathematics instruction. In this study, we investigate the effects of Hurricane Maria on mathematics education outcomes using machine learning–based data analysis. Educational indicators, specifically standardized academic proficiency, are analyzed alongside disaster-related variables and demographics. Supervised and unsupervised machine learning techniques are employed to identify patterns, correlations, and latent structures linking disaster events to changes in educational outcomes. The results reveal measurable disruptions in mathematics education following the 2017 hurricane season, with differential impacts across geographic regions and school sizes. Clustering and predictive models highlight spatial zones of heightened vulnerability as well as distinct patterns of performance stagnation versus resilience. This work demonstrates how machine learning can be used as an analytical tool to quantify the educational impacts of natural disasters and to support data-driven planning for resilience in Puerto Rico’s educational system.

**Keywords:** machine learning; mathematics education; educational data analysis; natural disasters; disaster impact assessment; resilience; education policy

## The generalized anisotropic dynamical wentzell heat equation with nonstandard growth conditions

Carlos Carvajal-Ariza, Ana G. Méndez University, Carolina Campus.

We study a class of anisotropic parabolic problems with fully dynamical Wentzell boundary conditions. The model couples an interior anisotropic  $\vec{p}(\cdot)$ –Laplace operator with a boundary  $\vec{q}(\cdot)$ –Laplace–Beltrami operator acting on distinct variable-exponent spaces, al-

lowing heterogeneous diffusion and boundary dynamics on Lipschitz domains and compact manifolds.

We first establish the well-posedness of the time-dependent Wentzell problem by showing that the associated Wentzell functional generates a nonlinear, order-preserving, submarkovian  $C_0$ -semigroup  $\{T_\sigma(t)\}$  on anisotropic variable-exponent spaces  $\mathbb{X}^{r(\cdot)}(\Omega) = L^{r(\cdot)}(\Omega) \times L^{r(\cdot)}(\partial\Omega)$ , ensuring the existence and uniqueness of strong solutions for all measurable exponents  $r(\cdot)$  with  $1 \leq r_- \leq r_+ < \infty$ .

A key contribution is the establishment of a *hierarchy of semigroup domination* that captures the influence of boundary dynamics. By associating appropriate convex functionals to the Dirichlet, Wentzell, and Neumann–Wentzell settings, we obtain the ordering

$$T_D(t) \preceq T_W(t) \preceq T_{N-W}(t),$$

thereby quantifying how Wentzell boundaries interpolate between absorbing and reflective regimes in nonlinear anisotropic diffusion.

We additionally prove Hölder-type ultracontractivity estimates for the generated semigroup: there exist constants  $C_1, C_2, \kappa > 0$  and  $\gamma \in (0, 1)$  such that

$$\|T_\sigma(t)u_0 - T_\sigma(t)v_0\|_{L^\infty} \leq C_1 e^{C_2 t} t^{-\kappa} \|u_0 - v_0\|_{r(\cdot), s(\cdot)}^\gamma,$$

for all  $u_0, v_0 \in \mathbb{X}^{r(\cdot), s(\cdot)}(\overline{\Omega})$  and  $t > 0$ . These results reveal strong smoothing, stability, and structural ordering properties of anisotropic diffusion flows with heterogeneous interior and boundary growth conditions.

## Dual Ensemble Machine Learning System for Real-Time Hydrometeorological Event Prediction in Puerto Rico

*Carlos J. Corrada Bravo*, Department of Computer Science, University of Puerto Rico at Río Piedras.

Accurate prediction of hydrometeorological events such as flash floods remains a critical challenge for operational forecasting in tropical environments. These events arise from complex multi-scale atmosphere-land-ocean interactions that traditional numerical weather prediction models struggle to resolve at the precise spatial and temporal scales required for effective early warning systems. We present a dual ensemble machine learning framework combining two gradient boosting decision tree algorithms, XGBoost and LightGBM, to address the operational requirements of high recall, real-time processing, and uncertainty quantification for hydrometeorological hazard prediction in Puerto Rico.

Our methodology integrates physics-informed automated feature engineering that derives 51+ meteorologically-relevant predictors from raw upper-air soundings and surface observations. Using 15 years of observational data (2010–2025) comprising 5,718 days with 2,403 hydrometeorological events (42.0%), we demonstrate that systematic regularization

strategies achieve minimal overfitting (train-test performance gap  $\leq 0.03$ ) while maintaining exceptional event detection capability.

The optimized XGBoost model achieves 90.0% recall (479 of 532 test events detected) with an F1-score of 0.794, representing a 10.3 percentage point improvement over Random Forest. The weighted dual ensemble provides robust uncertainty quantification through model disagreement analysis, with 94.8% prediction agreement.

Feature importance analysis reveals moisture parameters (34%) and stability indices (26%) as dominant predictors, validating physical interpretability essential for operational acceptance. The complete system processes observations to final predictions in under 100 milliseconds, demonstrating operational viability for real-time warning applications in resource-constrained forecasting centers.

**Acknowledgements:** This research utilized upper-air sounding data from the National Weather Service San Juan, surface observations and storm event databases from NOAA's National Centers for Environmental Information, and the global upper-air sounding archive maintained by the University of Wyoming.

**Keywords:** machine learning, hydrometeorological prediction, gradient boosting, ensemble methods, XGBoost, LightGBM

## Optimization of Academic Schedules Using Genetic Algorithms: Development of a Web Application for University Courses at UPRM

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The organization of academic schedules is a combinatorial optimization problem classified as NP-Hard, a complexity well-documented by authors such as Carter and Laporte, and fundamental for university management. The main objective is to coordinate limited resources (professors, classrooms, and time blocks) to generate feasible solutions that comply with institutional regulations and maximize teaching satisfaction.

In this work, following the evolutionary computing paradigm established by Holland, we propose an application of Genetic Algorithms (GAs) for the optimized generation of academic timetables. The developed model addresses the system's complexity through a dual constraint approach: Hard Constraints ( $R_f$ ), which guarantee institutional viability (avoiding resource conflicts), and Soft Constraints ( $R_s$ ), oriented towards educational quality and resource efficiency.

The implemented methodology includes automatic data processing, a chromosomal representation of solutions, and specialized genetic operators (selection, crossover, and mutation). The core of the model lies in a scalar fitness function ( $f(H)$ ) designed to severely penalize violations of  $R_f$  and reward compliance with  $R_s$ . To ensure its practical applicability, the system has been materialized into an interactive web application developed in Streamlit.

We present a rigorous experimental validation using real data from the University of Puerto Rico, Mayagüez (UPRM). The results demonstrate the robustness of the algorithm, capable of generating schedules that comply with most of the institutional requirements of institutional regulations and significantly optimize the use of academic infrastructure.

**Keywords:** Genetic Algorithms, Combinatorial Optimization, Academic Timetabling

## Battery Materials Discovery For Energy Storage Using M3GNET, Deeplearning and DFT

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The discovery of next-generation battery materials is severely limited by the high computational cost of traditional ab initio methods, especially density functional theory (DFT). This restricts the large-scale exploration of the extensive chemical and structural design space relevant to energy storage technologies. As the demand for high-performance, sustainable batteries grows, there is an urgent need for computational frameworks that can rapidly and accurately screen materials. In this study, we present a hybrid computational framework that integrates a physics-informed graph neural network (M3GNet). This network is trained using the Materials Project database and is validated using DFT. This framework accelerates the discovery of battery-relevant materials while maintaining predictive reliability. In this framework, crystalline materials are represented as graphs that explicitly encode atomic species, interatomic distances, and higher-order many-body interactions, including pairwise and three-body terms. This representation enables the model to learn meaningful structure-property relationships and predict formation energies directly from crystal structures, eliminating the need for handcrafted descriptors. We evaluated the framework on a dataset of approximately 1,000 lithium-, sodium-, and sulfur-containing compounds relevant to electrochemical energy storage applications. This dataset includes candidate cathode, anode, and solid electrolyte materials. The pretrained M3GNet formation energy model showed strong agreement with reference density functional theory (DFT) calculations, achieving a coefficient of determination of  $R^2 = 0.954$ , a mean absolute error of  $0.116 \text{ eV/atom}$ , and a root mean square error of  $0.259 \text{ eV/atom}$ . These results suggest that machine learning-assisted screening could reduce computational costs by several orders of magnitude compared to

conventional DFT-based workflows while maintaining a high level of quantitative accuracy. The proposed approach efficiently identifies thermodynamically stable and near-stable compounds, enabling targeted DFT refinement and experimental validation and significantly narrowing the search space. In general, this framework provides a robust and scalable pathway for accelerating the discovery and optimization of advanced battery materials.

**Keywords:** battery materials discovery; machine learning; graph neural networks; M3GNet; density functional theory; formation energy; materials informatics; energy storage

## Agent-Centered Architecture for Socratic Tutoring in Scientific Skills Development

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*David Flores*, University of Puerto Rico at Río Piedras.

*Edusmildo Orozco*, University of Puerto Rico at Río Piedras.

In this work we present the development of an agentic architecture designed to foster scientific skills in undergraduate STEM students through structured Socratic dialogue. The system leverages large language model agents to simulate a guided, inquiry-based tutoring method that prompts critical thinking, hypothesis refinement, and logical reasoning. The agent operates on a foundational framework of perception, reasoning, and action. Its perception module ingests and interprets student inputs, including textual responses and conceptual models. This triggers a continuous loop where a specialized reasoning engine, employing chain-of-thought and reflection techniques, formulates strategic pedagogical responses. Our core architecture integrates a late fusion retrieval-augmented generation framework. This system serves as the agent's dynamic memory, providing long-term context, accessing curated scientific corpora. This architecture also integrates a database that stores the interaction history of the users for dialogue personalization.

A dedicated reasoning module drives the Socratic process by decomposing complex problems, generating sequential, thought-provoking questions, and evaluating student responses for conceptual soundness and argumentative coherence. This dual-component design enables adaptive scaffolding, where the agent identifies misconceptions, supplies counterexamples, and adjusts its tutoring strategy in real time. The implementation aims to enhance metacognitive skills and deeper conceptual mastery by engaging learners in a reflective, iterative dialogue process. The architecture incorporates a self-evolving component where the agent's performance is recursively analyzed. Through a continuous feedback loop, the system evaluates the efficacy of its Socratic strategies and knowledge retrievals against student learning outcomes. Preliminary evaluations focus on measurable improvements in problem-solving abilities, argument construction, and self-efficacy in scientific inquiry. This work contributes to the field of intelligent tutoring systems by providing a scalable, reasoning-driven framework for developing advanced pedagogical agents that support higher-order

scientific skill development.

**Acknowledgement:** This is joint work with Dr. Elizabeth Dvorsky and Dr. Joseph Carroll–Miranda, all from the University of Puerto Rico at Río Piedras. This project is supported by the National Science Foundation under Award #2421165.

**Keywords:** Education, inquiry–based tutoring, research skills, Socratic dialogue

## Compression Robustness of a Family of Video Watermark Arrays Based on Composition

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Families of periodic arrays based on composition are useful in various applications, including multiple target recognition, optical communications, and digital watermarking. In video digital watermarking, these arrays can be used as watermarks to ensure copyright protection or to verify the authenticity of the original video. However, video content is commonly subjected to compression during storage, transmission, and streaming, which can significantly degrade or destroy embedded watermarks, making reliable detection a challenging task. Therefore, robustness against compression is a critical requirement for video watermarking schemes.

Watermarks based on periodic arrays are embedded in an imperceptible manner for users, while allowing the owner to detect them without requiring access to the original content. Watermark detection is performed using cross-correlation between the watermarked video frames and the corresponding watermark arrays. Reliable detection relies on the presence of a dominant correlation peak, which results from the design of the periodic array families exhibiting a unique high autocorrelation peak and low non-peak autocorrelation and cross-correlation values among the arrays within the family. Achieving an appropriate trade-off between robustness and imperceptibility under compression therefore requires not only suitable embedding methods, but also a careful theoretical design of the watermark array families.

In this talk, we present an embedding and detection process for video watermarking using families of periodic arrays based on composition introduced in our previous work. Experimental results demonstrate that the proposed method maintains reliable detection and imperceptibility performance under H.264 video compression, which is frequently used in web-based video and streaming applications, highlighting the robustness of the proposed watermarking approach and the underlying watermark array families.

**Keywords:** Periodic arrays, video watermarking, H.264 compression, cross-correlation

## Bayesian Peaks-Over-Threshold Modeling for Category-5 Hurricane Risk in Puerto Rico

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Extreme tropical cyclones have profound demographic and socio-economic impacts on Puerto Rico, as evidenced by Hurricane Maria (2017). Traditional hazard assessments rely on block maxima and the Generalized Extreme Value (GEV) distribution, often underestimating tail risk due to limited data and restrictive assumptions. In this study, we advance risk estimation by introducing a **Bayesian Peaks-Over-Threshold (POT) framework** for wind extremes, coupled with a Poisson occurrence model. Using historical best-track data (NOAA HURDAT2) and declustered exceedances above a high wind threshold, we fit a **Generalized Pareto Distribution (GPD)** with informative priors for tail parameters and occurrence rates. This hierarchical Bayesian approach leverages Markov Chain Monte Carlo (MCMC) to propagate uncertainty and compute posterior probabilities of Category-5 hurricane exposure ( $\geq 157$  mph) within a defined radius of Puerto Rico. Our results indicate that the probability of at least one Category-5 hurricane affecting Puerto Rico in the next 10 years is substantially higher than classical estimates. Furthermore, based on prior Bayesian analysis of extreme rainfall associated with Hurricane Maria, the probability of a similar major hurricane occurring in the next 25 years is approximately 17.66%, compared to traditional estimates exceeding 1,000-year return periods. These findings underscore the need for modern statistical methods in resilience planning. The proposed methodology integrates spatial and temporal dependence, improves tail inference under data scarcity, and provides actionable risk metrics for infrastructure design and emergency management in the Caribbean.

## On the Classification of Stabilizable Monomial Control Systems over Finite Fields

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An open problem in the theory of discrete dynamical systems is determining when a system can be "stabilizable". These systems have applications in cellular automata, biology, and engineering. Criteria for determining when a monomial dynamical system over a finite field is a fixed point system (FPS) have been previously studied by O. Colón et. al. These results can be used to determine when a monomial dynamical control system is stabilizable,

meaning its behavior can be influenced to achieve a desired goal. In this work, we present a family of control systems that can be stabilized by applying linear algebra over finite fields and provide the necessary conditions under which such systems, in general, can be stabilized. These findings offer a deeper understanding of stabilizability in discrete systems with potential applications across multiple scientific and engineering disciplines.

**Keywords:** Monomial dynamical systems, dynamical control systems, state space, finite fields

## Comparing Gaussian Processes Regression Methods for Very Large Datasets: Fixed Rank Kriging vs. Modern Sparse Approximations

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*Roberto Rivera*, Department of Mathematical Sciences, University of Puerto Rico at Mayagüez.

In this work, we discuss the numerical and computational aspects of modeling large-scale datasets using Gaussian Process Regression (GPR). GPR is a flexible non-parametric framework that provides optimal predictions, and the variance of these predictions. Nevertheless, its cubic computational complexity,  $O(N^3)$ , expensive storage cost, and the assumption of stationarity make it costly for large  $N$ .

To address this problem, we evaluate a custom implementation of Fixed Rank Gaussian Process Regression (FRGPR) which is a modification of the original Fixed Rank Kriging work used in spatial statistics. This modification includes an iterative algorithm to ensure the estimated covariance matrix is positive definite, avoiding the high cost of standard maximum likelihood estimation. All the work is produced using Python.

We compare predictive accuracy and total execution time across high-dimensional benchmark datasets of this statistical method against established machine learning approximations, including Subset of Data (SoD), Fully Independent Training Conditional (FITC), Local GP and a Hybrid method that combines SoD and FITC. All the work is produced using Python. Results illustrate the effectiveness of the FRGPR algorithm in achieving fast and accurate predictions.

**Keywords:** Gaussian Processes, Fixed Rank Kriging, Approximation Methods, Large-scale Data, Machine Learning

## El interior de las cosas: visualización volumétrica utilizando ray marching

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El *ray-marching* es una técnica eficiente para la visualización volumétrica de campos escalares tridimensionales, ya que permite el muestreo continuo del espacio mediante la integración numérica a lo largo de rayos sobre funciones de densidad, opacidad o distancia. Esta presentación aborda el *ray-marching* como un método general para reconstruir y explorar volúmenes 3D a partir de datos simulados o medidos, con el propósito de identificar estructuras internas, transiciones y patrones que no se aprecian en representaciones basadas en cortes 2D. La implementación, desarrollada en GLSL y ejecutada en la unidad de procesamiento gráfico (GPU), aprovecha el paralelismo de los *fragment shaders* para producir visualizaciones interactivas de alta resolución. Se incorporan funciones de transferencia (mapeo valor-color/opacidad), iluminación volumétrica y estrategias de control del muestreo para mejorar la interpretación visual. Los resultados evidencian que el *ray-marching* facilita la exploración de estructuras complejas en datos volumétricos y constituye una herramienta versátil para el análisis computacional en contextos científicos y de ingeniería, así como para aplicaciones de visualización 3D.

## On the effectiveness of Spectral Kurtosis Estimators in detecting RFI in Radio Astronomy Data from the Arecibo 12m Telescope

Emmanuel J. Morales Butler, Department of Natural Sciences, University of Puerto Rico at Utuado and Center for Advanced Radio Sciences and Engineering, Mayagüez.

Given the devastating effects of radio frequency interference (RFI) on radio astronomical data, efforts to combat RFI with both hardware and software approaches are crucial. In this work, we illustrate a successful software implementation which combines two statistical estimators, namely, generalized spectral kurtosis (GSK) and multi-scale GSK (MS-GSK) to detect and excise RFI in radio data. As examples of the application of these techniques, we employ the methods on data from a 2023 pilot survey of the Methyldyne (CH) 3.3 GHz lines observed in the galactic plane. Specifically, we consider four case studies all taken from a  $1.5^\circ$  by  $1.5^\circ$  map of the Milky Way's galactic center and a single-pointing observation on the Rho Ophiuchi star-forming nebula. The CH detections in these regions sit in the midst of a radio frequency band fraught with diverse RFI. The procedure we present is applied to multiple types of RFI such as high-intensity pulsed, steady narrowband, and drifting signals, and represents both a significant step forward in salvaging RFI-contaminated astronomical data.

**Acknowledgements:** This research was done in collaboration with Allison J. Smith (Center for Advanced Radio Sciences and Engineering, Mayagüez and the University of Puerto Rico at Mayagüez), D. Anish Roshi (Center for Advanced Radio Sciences and Engineering, Mayagüez and University of Central Florida, Orlando), David J. Reyes Soto (Center for Advanced Radio Sciences and Engineering, Mayagüez and the University of Puerto Rico at Mayagüez), Alexander Cingoranelli (University of Central Florida, Orlando), Adriana M. Bonilla-Romacho (Center for Advanced Radio Sciences and Engineering, Mayagüez and University of Puerto Rico at Mayagüez), and Alanis P. Alvarado Gierbolini (Center for Advanced Radio Sciences and Engineering, Mayagüez and University of Puerto Rico at Mayagüez).

## On the Distribution of Functionals of One Dimensional Brownian Motion via a Feynman–Kac Approach

Eugenio Guerrero-Ruiz, Department of Mathematics, University of Puerto Rico at Río Piedras.

Perpetual integral functionals of Brownian motion of the form

$$\int_0^\infty f(W_s, s) ds,$$

are considered, where  $\{W_t\}_{t \geq 0}$  is a standard Brownian motion on  $\mathbb{R}$  and  $f : \mathbb{R} \times [0, \infty) \rightarrow [0, \infty)$  is piecewise continuous. The Laplace transform of these functionals is analyzed through the Feynman–Kac formula; after a boundary–straightening change of variables, the problem reduces to a stationary, piecewise-elliptic boundary-value problem.

The framework recovers, in particular, the classical case of D. Dufresne: for  $f(x, s) = \exp(ax - \mu s)$  with  $a \in \mathbb{R}$  and  $\mu > 0$ , the perpetual functional  $\int_0^\infty e^{aW_s - \mu s} ds$  has an inverse-Gamma law, with shape parameter  $2\mu/a^2$  up to the natural scaling factor. Related families studied by M. Yor, H. Matsumoto, and P. Salminen are encompassed as special cases.

As an application, it is shown how such Brownian functionals naturally arise within the construction of upper and lower bounds for the finite-time blow-up of coupled semilinear SPDEs with multiplicative noise.

**Keywords:** Perpetual integral functionals; Brownian motion; Feynman–Kac formula; blow-up in SPDEs

## Multiple Comparison and Parsimony in Objective Bayesian Analysis

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*Luis R. Pericchi*, Department of Mathematics, University of Puerto Rico at Río Piedras.

When we test many possible models (for example, all subsets of a large set of predictors), some models will look good just by chance, even if none of the extra predictors are truly important. This is the multiple comparison problem: without adjustment, we would systematically over-report spurious effects just because we searched widely. A Bayesian way to address this is to control how we distribute prior probability across the whole model space (Jeffreys 1961). Following Jeffreys(1961) & Scott and Berger (2010), one principled choice is to assign the *same total prior probability* to each model size (that is, to each value of  $k$ , the number of included predictors), and then spread that mass uniformly across the models of that size. Parsimony is related but conceptually different. Parsimony is the idea that, before seeing the data, simpler models should be considered more plausible than highly parameterized models. In practice, this means imposing a prior on the model space that decreases as model size increases. In this talk we would show a way this two problems can be solve simultaneously by imposing a simple prior that on the model space. Furthermore the prior we propose has the property of a decreasing constant rate on the model space.

**Keywords:** Model Selection, Bayesian Statistics or Inverse Probability

## Majority Logic Decoding of Affine Grassmann Codes Over Nonbinary Fields

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We discuss how to find a sets of  $2^r$  rank  $r$  matrices which form parity check equations of a nonbinary affine Grassmann code incident on a single positions. These sets form a majority voting decoding procedure for affine Grassmann codes. We compare the decoder's performance to a product code iterative decoder.

**Keywords:** affine Grassmann codes, decoding, LDPC codes, finite fields

# A Quantum-Classical Hybrid AI Model Based on Transfer Learning For Sargassum Image Classification

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*Heeralal Janwa*, Department of Mathematics, University of Puerto Rico at Río Piedras.

Sargassum inundation has become a persistent environmental challenge along the coasts of Puerto Rico and the wider Caribbean, adversely affecting coastal ecosystems, public health, and local economies. While classical deep learning models have been widely applied to image-based Sargassum detection, most approaches rely exclusively on conventional neural network architectures. In this work, we investigate a hybrid quantum–classical transfer learning framework for multi-level Sargassum image classification. A pretrained MobileNetV2 network is employed as a classical feature extractor, compressing high-dimensional image features into a low-dimensional representation that is subsequently processed by a parameterized quantum circuit implemented using PennyLane. The quantum layer uses angle embedding and entangling gates on four qubits, producing expectation values that are mapped to five Sargassum severity classes: none, low, moderate, abundant, and excessive. The model is trained end-to-end using a weighted cross-entropy loss to mitigate class imbalance and evaluated on a publicly available, manually labeled coastal image dataset. Results indicate modest overall accuracy, with stronger performance for low-Sargassum cases and reduced effectiveness for higher-density classes, reflecting challenges associated with data imbalance and visual variability. Nevertheless, this study demonstrates the feasibility of applying hybrid quantum machine learning techniques to real-world environmental monitoring tasks and establishes a baseline for future improvements through enhanced data balancing, augmentation, and more expressive quantum architectures.

**Keywords:** sargassum, quantum machine learning, transfer learning, hybrid models, image classification, PennyLane

## SUMMIT: Microservices Application to Forecast and Optimizing network operations using machine learning for temporary IT infrastructure in high-demand scenarios

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*Edusmildo Orozco*, University of Puerto Rico at Río Piedras.

This is a work-in-progress that builds upon our 2025 study, which focused primarily on applying machine learning models such as long–short–term memory (LSTM), auto–regressive integrated moving average (ARIMA), and Gradient Boosting to forecast network resource utilization in short term, high demand IT infrastructures. Although the earlier work es-

tablished the feasibility and potential value of predictive analytics for temporary network deployments, it remained largely conceptual and model oriented, without an integrated system for operational use.

In the 2026 stage of the project, we introduce several new contributions. First, we narrow and refine the forecasting pipeline to a hybrid LSTM–ARIMA approach specifically optimized for short lived telemetry datasets typical of temporary infrastructures. Second, and representing a major advance from 2025, we design and implement a microservices based web application that integrates real time telemetry with model generated forecasts. This system provides interactive visualizations of both observed and predicted network behavior, enabling proactive resource management during rapid fluctuations common in temporary deployments.

The microservice architecture, real time data ingestion, and integrated visualization tool are all new components developed since the 2025 phase and collectively shift the project from theoretical modeling to a deployable decision support platform. During this presentation, we will demonstrate the current prototype, describe the architecture of the system, and discuss preliminary results based on real telemetry streams.

**Acknowledgements:** We acknowledge the advice and recommendations to guide the direction of this research to **Dr. Jose Ortiz** and **Dr. David Flores**, from Computer Sciences Department of UPR Rio Piedras Campus.

**Keywords:** time–series forecasting, LSTM, ARIMA, network telemetry, temporary IT infrastructure, microservices, web visualization

## **A Self-Supervised Learning Approach to the Detection and Mitigation of Radio Frequency Interference in Radio Data**

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Frequency Interference (RFI) poses a significant and growing challenge in radio astronomy, frequently contaminating observations and limiting the quality of scientific analysis. As modern radio telescopes generate increasingly large and complex datasets, effective and scalable RFI mitigation has become essential for reliable scientific discovery. However, traditional mitigation strategies often rely on manual or supervised learning approaches that require curated datasets, which are costly, time-consuming, and difficult to obtain in practice. This work presents a preliminary evaluation of a self-supervised learning (SSL)-based framework for the unsupervised analysis of RFI in radio astronomy observations. Specifically, we investigated the performance of DINOv3, a vision foundation model pre-trained via SSL, in capturing spectrotemporal RFI signatures from longitudinal time–frequency spectrograms

acquired with the Arecibo 12 m radio telescope. The spectrograms were segmented into non-overlapping windows and projected into a patch-level high-dimensional latent space using DINOv3. Unsupervised clustering techniques were then applied in combination with dimensionality reduction methods to assess the quality of the learned representations. Evaluation was performed using structure-oriented clustering metrics, including the Davies–Bouldin Index, and complemented by low-dimensional visualizations. To enhance interpretability, an explicit patch-to-latent mapping mechanism was developed to correlate embedding structure to physical time–frequency patterns in the data. The preliminary results suggest that DINOv3 embeddings exhibit coherent organization, with clusters corresponding to visually and physically meaningful RFI-related patterns, such as narrowband interference and localized high-energy structures. Notably, this organization emerges naturally without fine-tuning the model or using labeled data. These early findings suggest that vision foundation models may provide an interpretable and scalable signal processing tool for RFI analysis in modern radio astronomy pipelines. This study highlights the potential of SSL-based approaches for data quality assessment, interference characterization, and future extensions toward automated RFI detection and mitigation to support large-scale observational surveys at Arecibo and other radio telescopes.

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**Keywords:** Self-Supervised Learning, DINOv3, Representation Learning, Radio Frequency Interference, Radio Astronomy, Deep Clustering

## Fractional Evolutions Systems: resolvent families and duality

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*Valentin Keyantuo*, Department of Mathematics, University of Puerto Rico at Río Piedras.

We study evolution systems involving the so-called Hilfer time-fractional derivative (it interpolates between the Riemann-Liouville and the Caputo fractional derivatives) associated with the generator  $A$  of an  $(\alpha, \beta)$ -Hilfer resolvent family, which is denoted by  $(S_{\alpha, \beta}(t))_{t>0}$ . Assuming that the dual space  $X$  has the Radon-Nikodým property, we prove the strong continuity of the dual family  $(S_{\alpha, \beta}(t))_{t>0}$  on  $(0, \infty)$ , furthermore we obtain an integration by parts formula and hence the corresponding dual evolution system is presented.

**Keywords:** Hilfer fractional derivative, Mittag-Leffler function, Banach spaces, resolvent families, strong continuity, dual system

## A metric space defined on set partitions

István Mező, University of Puerto Rico at Mayagüez.

Motivated by the well-known Hamming distance between subsets of a fixed finite set, we present a new metric on the family of partitions of the positive integers. This novel metric has some interesting properties but behaves rather pleasantly: it is a zero-dimensional, separable, compact Hausdorff space. The partitions form a lattice, therefore, apart of finding the main topological properties of this space, we also investigate how the metric and lattice-theoretical properties interact.

## Construction of Linear Fractional Transformations With a Prescribed Cycle Length

H. F. Mattson, Jr., College of Engineering and Computer Science, Syracuse University.

Ivelisse Rubio, Department of Computer Science, University of Puerto Rico at Río Piedras.

The cycle structure and fixed points of permutations of finite fields constructed algebraically have been studied by several authors due to their applications to digital communications. Linear fractional transformations (LFTs)  $\frac{ax+b}{cx+d}$  over “extended” fields  $\mathbb{F}_{p^n} \cup \{\infty\}$  permute the elements of the “extended” field, have 0, 1 or 2 fixed points and, ignoring the fixed points, decompose in cycles of the same length  $m$ .

We prove that  $m = p$  or  $m|(q \pm 1)$ , present a mysterious polynomial  $D_m(x) \in \mathbb{Z}[x]$  whose roots  $z \in \mathbb{F}_q$  provide all LFTs over  $\mathbb{F}_{p^n} \cup \{\infty\}$  that decompose in cycles of length  $m \neq p$ , and characterize all LFTs that decompose in cycles of length  $m = p$ . This provides constructions for all LFTs of any possible cycle length.

## Extensions to the Relative Risk of Rounding for Additional Discrete Distributions

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Roberto Rivera, Department of Mathematical Sciences, University of Puerto Rico at Mayagüez.

In practice, it is common to work with nonnegative count random variables whose observed values have been previously rounded due to reporting. This rounding process introduces a

different variable than the one we wish to draw inference from. In this work, we study the consequences of this rounding.

Specifically, let  $Y$  be the nonnegative count random variable that comes from a given probability mass function and let  $U = n[Y/n]$ , where  $[Y/n]$  represents the rounded average of  $Y$  over  $n$  observations. We derive  $E(U)$  and  $\text{Var}(U)$  as functions of  $E(Y)$  and  $\text{Var}(Y)$  when  $Y$  follows negative binomial, geometric, and discrete uniform distributions.

Moreover, we investigate the relative risk of rounding (RRoR) through combined theoretical and computational approaches to assess conditions under which rounding may lead to erroneous statistical inference. One of the main findings is that the risk associated with rounding exhibits an oscillatory behavior, which arises as a consequence of the complex analytical expressions obtained for the moments of  $U$ . This behavior depends both on  $n$  and on the parameters specific to each distribution. Furthermore, it is shown that the impact of rounding is more pronounced when the model parameters take relatively small values.

## **Modelación y análisis de datos del sistema eléctrico y su vínculo con la actividad económica de Puerto Rico**

*Jeremis Morales-Morales*, Applied Mathematics, Inter American University, San German, Puerto Rico.

Este estudio desarrolla un análisis de series de tiempo y estadística aplicada para caracterizar el estado del sistema eléctrico de Puerto Rico y su relación con variables macroeconómicas. Mediante evidencia descriptiva y ejercicios econométricos sobre datos agregados, evaluamos la asociación entre consumo energético y PIB per cápita, y la asociación entre indicadores de confiabilidad del servicio, SAIDI y SAIFI, y el desempeño económico. Los resultados muestran regularidades consistentes con una relación positiva entre consumo energético y PIB per cápita, y una relación negativa entre SAIDI/SAIFI y el PIB per cápita. Con el fin de organizar estos hallazgos, se propone una interpretación basada en un marco inspirado en la Teoría Austriaca del Ciclo Económico y su formalización garrisoniana, integrando la tasa de interés, el ahorro e inversión (mercado de fondos prestables), el intercambio entre consumo e inversión (frontera de posibilidades de producción) y la estructura temporal de producción (SOP) en un modelo determinístico. En este esquema, la centralización institucional, la distorsión de señales de precios y el endeudamiento recurrente sin anclaje en flujos futuros de ingresos ni en el costo del capital se consideran mecanismos potenciales que afectan la asignación de capital hacia activos eléctricos y la confiabilidad del sistema.

# UNA unidad didáctica para el abordaje de la demostración matemática para su abordaje en la formación inicial de profesores de matemática

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En esta ponencia se presentará una unidad didáctica como resultado final de un trabajo de tesis para el grado de Licenciatura en la Enseñanza de la Matemática, en la Universidad Nacional de Costa Rica (UNA). Este documento es una propuesta para el abordaje de los métodos de la demostración matemática: directa e indirecta, así como de las demostraciones de proposiciones con los cuantificadores existenciales, universales y anidados.

Su elaboración se fundamentó en el marco teórico del *Análisis Didáctico*, planteado por Rico y Fernández-Cano (2013), y para su validación, fue sometida a una revisión de expertos, siendo estos algunos docentes de la Escuela de Matemática de la Universidad Nacional, quienes han abordado la demostración en el curso MAC401 Principios de Matemática I, dentro del Plan BLEM (2017).

**Palabras clave:** Unidad didáctica, demostración matemática, análisis didáctico, formación docente

## Visualizing Preventive Healthcare Engagement through Clinical Testing Utilization in the Puerto Rican Population

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Visualizing Preventive Healthcare Engagement through Clinical Testing Utilization in the Puerto Rican Population Data visualization is an essential tool for gaining insights from complex information and for effectively communicating findings to diverse audiences. In the context of public health, preventive healthcare plays a critical role in maintaining a healthy population and reducing long-term medical costs. However, understanding and addressing disparities in preventive care engagement remains a significant challenge.

We are developing a web application that visualizes clinical laboratory testing utilization

as a proxy for preventive healthcare engagement in Puerto Rico. By examining patterns of test usage across demographics and over time, the application aims to reveal how different sectors of the population participate in preventive care. This tool helps address existing data gaps and supports more informed decision-making regarding the allocation of healthcare resources throughout the island.

**Keywords:** Preventive healthcare, data visualization, public health, clinical testing utilization, health disparities, Puerto Rico, demographic analysis, healthcare resource allocation

**Acknowledgments:** This work is in collaboration with Abartys Health and Efrain Betancourt, a bio-statistician working with Abartys Health.

## **Assessing the effect of mock exams on precalculus I performance using generalized linear mixed models**

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During the first semester of 2024, the Department of Mathematical Sciences at the University of Puerto Rico, Mayagüez Campus, implemented mock exams prior to each midterm examination in the MATE 3173 course (Precalculus I – Corequisite Support) as an academic support strategy. In the first semester of 2025, this initiative was maintained for MATE 3173 and extended through the implementation of a single mock exam prior to the first midterm examination in the MATE 3171 course (Precalculus I).

This study presents the results of a statistical analysis based on generalized linear mixed models, aimed at evaluating the effect of attending the mock exams on students' academic performance in the course.

The results show statistically significant differences in scores and in the proportion of students passing the course between students who attended the mock exams and those who did not. In contrast, no statistically significant differences were found associated with the specific course enrolled or the academic year in which the course was taken.

These findings suggest that the implementation of mock exams constitutes an effective academic support strategy in precalculus courses and provides evidence for the design of interventions aimed at improving student performance in undergraduate mathematics.

## Graph-Based Algorithms for Testing Convexity of 2DNF

Josué A. Ruiz Rodriguez, Department of Computer Science, University of Puerto Rico at Río Piedras.

Testing the convexity of Boolean formulae has applications in problems such as the convertibility of access control policies. In this paper, we exhibit graph-based polynomial-time algorithms for testing the convexity of the set of minterms of a formula in disjunctive normal form formula where every term has exactly two literals in it (*2DNF*). Our approach leverages a graph representation in which each term of the formula corresponds to an edge in the graph, allowing us to reduce the convexity check to a problem of graph structural analysis. The motivation for this problem comes from the convertibility of rule-based access control policies, where evaluating convexity helps determine whether a model can be transformed into a form that is more preferable by security administrators in terms of comprehension.

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**Keywords:** convex, upward-closed, disjunctive normal form

## On the Problem of the Inscribed and Circumscribed Hyperellipsoid and Hyperrectangle

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Arturo Portnoy, Department of Mathematical Sciences, University of Puerto Rico at Mayagüez.

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Hyperellipsoids and hyperrectangles play a fundamental role in convex geometry, optimization, and multivariate statistics. The interaction between these geometric objects gives rise to a variety of optimization problems, many of which have both theoretical interest and practical applications in areas such as data science, robust statistics, and control theory.

This talk focuses on three optimization problems involving a given hyperellipsoid  $\mathcal{E} \subset \mathbb{R}^n$ , defined in vector form  $\mathbf{x}^T \mathbf{A} \mathbf{x} = 1$ , where  $\mathbf{A}$  is a positive-definite matrix. The first problem is to determine the minimum volume hyperrectangle, aligned with the coordinate axes, that completely contains  $\mathcal{E}$ . This problem is relevant for bounding confidence regions in high-dimensional spaces of random variables and appears in optimization complexity estimates.

The second problem deals with constructing the hyperrectangle, also aligned with the coordinate axes, with the maximum volume that can be completely inscribed within  $\mathcal{E}$ , a question that arises in sampling theory and approximation algorithms.

In the third problem, the objective is to find the hyperrectangle of minimal volume that contains the ellipse  $\mathcal{E}$ . We will show that this hyperrectangle is aligned with the axes of the ellipsoid and is obtained from the unit box  $C = [-1, 1]^n$ , which is minimal in the hypersphere of radius 1.

These problems are closely related to Fritz John's fundamental results on extremal ellipsoids. In particular, John's ellipsoid theorem provides necessary conditions for the optimal containment of convex bodies, and his results offer insights into the optimal configuration of circumscribed or inscribed boxes.

This talk aims to explore these problems, providing geometric interpretations, optimization frameworks, and connections to known results.

**Keywords:** Hyperellipsoid; Hyperrectangle; John's ellipsoid, Convex bodies

## Fraction of B-meson decays in $J/\psi$ yields at midrapidity in proton-proton collisions at relativistic heavy ion collider energies of 200 and 510 giga-electronvolts

*Lázaro Cabán Cabrera*, Department of Physics, University of Puerto Rico at Río Piedras.  
*Rachid Noucier*, Department of Physics, Brookhaven National Laboratory, Upton, NY.

This work focuses on analyzing data from the PHENIX experiment to study the fraction of the B-meson decay to  $J/\psi$  ( $c\bar{c}$ ) at midrapidity in proton-proton ( $p + p$ ) collisions at energies of 200 and 510 GeV at the Relativistic Heavy Ion Collider (RHIC). The measurement was performed using the central silicon vertex detector (VTX), which provides precise tracking and distance-of-closest-approach ( $DCA_T$ ) determinations, enabling the statistical separation of the  $J/\psi$  meson due to B-meson decays from prompt  $J/\psi$ . The analysis and Crystal-Ball function fitting of the  $J/\psi$  peaks in the dielectron invariant mass spectrum and measurements of the fraction of B-meson decays to  $J/\psi$  are presented, and shown across a large rapidity and transverse momentum ( $p_T$ ) ranges. The PHENIX results are compared to other experiments CDF/ALICE/CMS/LHCb/STAR as a function of transverse momentum and center-of-mass energy and the fixed-order-next-to-leading-logarithm (FONLL) plus color-evaporation-model (CEM) predictions on the fraction of B-meson decays to  $J/\psi$ . It is crucial to highlight that the measurement of B-mesons in  $p + p$  collisions is of interest to constrain the total bottom cross-section as well as test our understanding of bottom quark production mechanisms. The present results in  $p + p$  collisions serve as a crucial baseline for the future measurements of B-meson  $\rightarrow J/\psi$  in more complex environments like in small-collision systems  $p+Al$ ,  $p+Au$ ,  $d+Au$ ,  $He+Au$ , and in the large collision system  $Au+Au$  at RHIC energies. The current work supports Brookhaven's mission to understand the phenomena of high-energy environments and further explore the phase diagram of quantum chromodynamics. In this project I

have practiced with various phases of the identification of signals of interest from PHENIX sub-detector data using large-dataset-oriented software like ROOT, such as applying energy and momentum cutoffs to mass spectra, subtracting background events from signal events, and fitting simulation data from Pythia with experimental data from the PHENIX experiment.

**Acknowledgements:** This material is based upon work supported by the U.S. Department of Energy, Office of Science, Office of Nuclear Physics, Reaching a New Energy Sciences Workforce (NP-RENEW) and the Office of Nuclear Physics Research Traineeships to Broaden and Diversify Nuclear Physics program. This work was done using the ROOT data analysis framework. Special thanks to Dr. Ratnakar Palai and Dr. Mickey Chiu. No export control.

**Keywords:** B-meson decay, PHENIX central arm, Crystal-Ball function, distance of closest approach,  $J/\psi$

## Elliptic Problems on Ramified Domains with Fractal Boundary

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*Alejandro Vélez-Santiago*, Department of Mathematics, University of Puerto Rico at Río Piedras.

We investigate the solvability and fine regularity of elliptic boundary value problems posed on *ramified domains* whose boundary exhibits a self-similar fractal structure. The analysis is carried out in a geometric framework that allows the definition of Sobolev and trace spaces over the fractal boundary  $\Gamma^\infty$ , even in the critical non-extension case  $\tau = \tau^*$ .

$$\begin{cases} -\sum_{i,j=1}^2 \partial_j(\alpha_{ij}(x) \partial_i u) + \sum_{i=1}^2 \eta_i(x) \partial_i u + \lambda(x) u = f(x) & \text{in } \Omega, \\ u = 0 & \text{on } \Gamma \setminus \Gamma^\infty, \\ \frac{\partial u}{\partial \nu_A} + \beta(x) u = g(x) & \text{on } \Gamma^\infty. \end{cases}$$

We consider uniformly elliptic second-order operators with bounded measurable coefficients and lower-order non-symmetric terms, under mixed Dirichlet-to-Robin boundary conditions on  $\Gamma^\infty$ . Using variational methods and localized inequalities adapted to the ramified geometry, we establish existence and uniqueness of weak solutions, together with global  $L^\infty$  and oscillation estimates that yield Hölder regularity. These results extend classical elliptic theory to highly irregular (non-Lipschitz) fractal interfaces, providing the first example of global uniform regularity of weak solutions on a non-extension domain.

**Keywords:** elliptic boundary value problems, ramified domains, fractal boundary, localized inequalities, weak solutions.

## A Riemann-Hilbert approach to the existence results for the Benjamin-Ono equation on a half-line

Liliana K. Esquivel, Department of Mathematical Sciences, University of Puerto Rico at Mayagüez.

The main problem addressed in this talk is the study of the local-in-time existence of solutions to the non-homogeneous Neumann initial-boundary value problem for the Benjamin-Ono equation on the half-line. We observe how the boundary data influence the behavior of solutions. To obtain a characterization of the solution, it is essential to use the theory of Riemann-Hilbert problems. We prove local-in-time existence of solutions.

## Gauss-Lobatto Method for Nuclear Reactivity Calculation

Luis E. Cardoso Paez, Department of Mathematical Sciences, University of Puerto Rico at Mayagüez.

In this talk, we introduce a novel approach to numerical solving for nuclear reactivity using the inverse equation of point kinetics as a model. Our method leverages the Gauss-Lobatto quadrature, incorporating multiple time steps and nodes derived from Legendre polynomials of varying orders. To enhance the accuracy of the differential component of the inverse equation, we employed a differential scheme based on the Gauss-Lobatto quadrature nodes. To address fluctuations in neutron population density, we implemented a second-order low-pass Butterworth filter with a minimal window length of  $M = 3$  samples. Through extensive numerical simulations, we assessed the precision of our proposed method and filtering process by varying time steps and standard deviations associated with noise or uncertainty. Additionally, we benchmarked our results against the Savitzky-Golay filter, which uses a significantly larger sampling window of  $M = 225$ . Our findings reveal that the integration of the Gauss-Lobatto quadrature method with the Butterworth filter not only significantly reduces fluctuations but also demonstrates potential for effective implementation in digital reactivity meters.

**Acknowledgements:** Thank the research seed of Computational Physics, the research group in Applied Physics FIASUR at the Surcolombiana University, Neiva, Colombia.

**Keywords:** inverse point kinetic equations; Gauss-Lobatto quadrature; nuclear reactivity; Butterworth filter; Numerical simulation

## Incorporating Agentic AI Models in Personalized Gamification

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Gamification is a technique that incorporates game elements in non-gaming related fields. The goal of gamification is to align intrinsic motivation with extrinsic rewards so that it can promote changes in behavior. Because of this, it has been increasingly adopted in education to increase student engagement, particularly through academic counseling. However, almost all gamification systems only integrate reward mechanics, such as points, badges, and leaderboards, and do not fully implement a complete gamification framework. Additionally, many gamification systems do not take advantage of user data in order to create personalized content.

Personalized gamification is seen as the preferred approach over general systems as it can identify unique user profiles and address distinct motivators. Examples of personalization in gamification systems include tailored activities, adaptive feedback based on user actions, and personalized recommendations. The implementation of Large Language Model (LLM) agents in personalization has seen a lot of promise due to its adaptive nature, allowing it to provide evolving feedback as the user engages with the system.

This study will investigate how we can adopt LLM agents in gamified virtual experiences focused on education. Specifically, this work will investigate how agentic AIs can collect user data, such as user profiles and activity logs, and use it in order to provide personalized recommendations, unlock tailored content, and offer real-time feedback for the user. The goal is to explore how LLMs can be used to create new forms of personalization, and make the gamification system a more responsive and dynamic experience for the user.

## Bounds on Intrinsic Bayes Factors and Least Favorable Intrinsic Priors for General Statistical Hypothesis Testing

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*Richard Clare*, Financial Consultant.

*Fernando Betancourt*, Department of Mathematics, University of Puerto Rico at Río Piedras.

Hypothesis Testing is the most contentious procedure in statistical Methodology. P values rejects Null Hypotheses far too easily, *Do you want to Reject a Hypothesis, take a lot of data!*, *Wonnacott and Wonnacott*. On the other hand, Bayes Factors depends on assumptions, for

example regarding Intrinsic Bayes Factors, which average? Arithmetic, Geometric, Median? Our bound is the infimum over all the averages.

We develop a lower bound on Intrinsic Bayes Factors that adjust automatically with the sample size. Furthermore, we introduce the new idea of *Least Favorable Intrinsic Prior*, which corresponds to the least favourable possible training samples.

The bound sets a bridge between Intrinsic Bayes Factors and Adrian Smith and David Spiegelhalter methodology.

**Keywords:** Dynamic Bounds on Bayes Factors, Intrinsic Bayes Factors, Least Favourable Priors, Robust inference.

## On the Generalization of Deep Feature Learning of Honey Bee Reidentification

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Recent advances in the pretraining of large vision transformers have created deep learning models that produce powerful multipurpose numerical features from images. By leveraging large amounts of available image data and expressive pre-training objectives, these “foundation” models can generate representations that show impressive generalization to numerous datasets, modalities, and downstream tasks. Reliable individual identification of honey bees from images has potential to greatly improve managed pollinator monitoring by automating existing methods and enabling more detailed understanding of behavior in these crucial insects. However, individual identification of insects is a difficult fine-grained classification task in a domain frequently underrepresented in most existing large model training sets. Previous work has shown strong initial performance for the adaptation of pretrained vision transformers to individual reidentification of honey bees in images. Foundation model features are projected into reID features using a single layer finetuning process using ArcFace loss. On a dataset of 45 paint marked honey bees, this method achieved 81% average top1 accuracy using only a single input track of supervision. Additionally, single track fine tuning even on different individuals improves performance 15% compared to foundation model features alone, showing even simple model adaptation increases invariance to difficulties such as pose and luminance changes. Current work compares these methods’ performance on new individuals and the detection of new identities. Quantitative analysis and visualization of both foundational and reID features will help establish best practices for the incorporation of these novel large models into honey bee monitoring and other niche biological applications.

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**Keywords:** Computer Vision, Re-Identification, Vision Transformers

## Cubic Boolean functions fixed by the Dihedral group

Manuel E. Amaya-Marin, Department of Mathematical Sciences, University of Puerto Rico at Mayagüez.

An  $n$  variable Boolean function is a map from  $\mathbb{F}_2^n$  to  $\mathbb{F}_2$ , where  $\mathbb{F}_2 = \{0, 1\}$ . The study of Boolean functions is computationally challenging due to the memory limitations of current computers. To alleviate this issue, one may restrict attention to Boolean functions possessing particular properties. One such property, widely studied in the literature, is invariance under the action of a finite group.

In this talk, we study cubic Boolean functions that are fixed by the dihedral group; that is,

$$F(\delta \cdot (X_1, X_2, \dots, X_n)) = F(X_1, X_2, \dots, X_n)$$

for all  $\delta \in D_n$ ,  $D_n = \langle \sigma_n, \tau_n \mid \sigma_n^n = e, \tau_n^2 = e, \tau_n \sigma_n \tau_n = \sigma_n^{-1} \rangle$ , where  $\sigma_n = (1\ 2 \cdots n)$  acts by cyclically permuting the variables and  $\tau_n$  acts by reflection, sending  $(X_1, X_2, \dots, X_n)$  to  $(X_n, X_{n-1}, \dots, X_1)$ . We present results concerning the counting of such functions, their exponential sums, and affine equivalence.

**Keywords.** Boolean functions, dihedral symmetry, cubic Boolean functions, exponential sums

## Limiting the Shrinkage for the Exceptional by Objective Robust Bayesian Analysis: “Clemente Problem” revisited

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María-Eglée Pérez, Department of Mathematics, University of Puerto Rico at Río Piedras.

Modern Statistics is made of the sensible combination of direct evidence (the data directly relevant or the “individual data”) and indirect evidence (the data and knowledge indirectly relevant or the “group data”). The admissible procedures combine the two sources of information, and technology advances make indirect evidence more substantial and ubiquitous. It has been pointed out, however, that an important problem of Statistics when “borrowing strength” is to treat in a fundamentally different way exceptional cases that do not adapt to the central “aurea mediocritas”. This is what has been coined as “the Clemente problem” in honor of R. Clemente, an exceptional batter (Efron, 2009). In this talk, we argue that the

problem is caused by the simultaneous use of square loss function and conjugate (light-tailed) priors, which is the usual procedure. We propose in their place to use robust penalties, in the form of losses that penalize more severely huge errors, or (equivalently) priors of heavy tails which make the exceptional more probable. Using heavy-tailed priors, we can reproduce, in a Bayesian structured way, Efron and Morris' "limited translated estimators" (with Double Exponential Priors) and "discarding priors estimators" (with Cauchy-like priors), which discard the prior in the presence of prior-likelihood conflict. We show that both Empirical Bayes and Full Bayes approaches can alleviate the Clemente problem and beat the James-Stein estimator in terms of smaller square errors, for sensible Robust Bayes priors. We model in parallel Empirical Bayes and Fully Bayesian hierarchical models, illustrating that the differences among sensible versions of both are relatively small, as compared with the effect due to the robust assumptions. We follow Pérez, Pericchi and Ramírez (2011) in using a heavy-tailed (scaled) Beta2 distribution for (squared) scales that arise naturally as an alternative to the usual Inverted-Gamma distribution. Finally, we calculate the predictive intervals and the Robust models covers the Clemente average at 80% of probability, which the conjugate do not. This is an instance of the convergence of the best frequentist and Bayesian analyses (Berger 2023).

**Keywords:** Cauchy-Scale2 Beta2 Prior, Clemente Problem, Robust Loss Functions, Horseshoe Priors, Indirect Evidence, Objective Robust Bayesian Analysis, Scaled Beta2 Priors

## Using Support Vector Machines to predict patient responses to transcranial photobiomodulation (tPBM) treatment

*Maria D. Gonzalez-Lima*, Department of Mathematics, University of Puerto Rico at Río Piedras.

Support Vector Machines (SVMs) are machine learning algorithms that can be used for classification problems. They were developed in the 1990s within the framework of statistical learning theory. Although many alternative machine learning techniques have been introduced in recent years, SVMs continue to occupy a gold position among machine learning methods, mainly due to their elegant theoretical foundation (based on optimization principles) and their robustness. SVMs are particularly suitable for classification problems involving a small number of subjects and a large number of features, a scenario frequently encountered in functional neuroimaging data analysis.

In this talk, we will introduce SVMs and present an application aimed at predicting high and low cognitive responders after six weeks of tPBM treatment in a group of bipolar patients. Transcranial photobiomodulation (tPBM) is a safe, non-invasive technique using infrared lasers that improves mitochondrial oxygen metabolism and brain oxygenation by delivering photons to the prefrontal cortex, leading to improvements in cognitive performance. The SVM model utilizes functional near-infrared spectroscopy (fNIRS) data from the anterior prefrontal cortex collected prior to tPBM treatment to define the features. To mitigate

overfitting, we consider ridge regularization, Leave-One-Subject-Out cross-validation, feature extraction, and multiple classification metrics, including accuracy and F1-score. The impact of different kernels, hyperparameters, feature definition, and feature selection strategies will also be discussed.

**Acknowledgments:** This research was supported in part by the Institutional Research Fund (FIPI) and seed funds from UPRRP, and by the Texas Consortium in Behavioral Neuroscience at the University of Texas at Austin, which provided the dataset used in the experiments.

**Keywords:** Support Vector Machines; classification; machine learning applications

## **Problem-Solving Process of a Deaf-Mute Student at a Rural School in Honduras**

Manuel M. Aguilera, Department of Mathematical Sciences, University of Puerto Rico at Mayagüez.

This report presents a narrative study that examines the mathematical problem-solving abilities of a student with deaf-mutism within a specific educational context operating under the regular public-school curriculum. The investigation involves two students, referred to as  $J_1$  and  $J_2$ .  $J_1$  is the student with deaf-mutism, while  $J_2$  is the peer who communicates effectively with him. The purpose of this study is to explore how  $J_1$  approaches and resolves mathematical problems and exercises by relying on the interpretations and explanations provided by  $J_2$ . The study focuses on understanding  $J_1$ 's strategies and performance in mathematical problem-solving, highlighting how collaboration with  $J_2$  facilitates his learning and helps him overcome communication barriers associated with deaf-mutism.

**Acknowledgments** I would like to express my sincere gratitude to Jesus Majano and Daniel Hernandez for their valuable technical assistance.

**Keywords;** Lower Secondary Education; Mathematical Thinking; Problem Solving; Deaf Education

# Machine learning models focused on spectrophotometry for the chemical detection of urea concentrations

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Spectrophotometric measurements, which measure the absorbance of a solution at different wavelengths to quantify concentration. However, the efficient implementation of machine learning and artificial intelligence (ML/AI) algorithms, along with appropriate computational and statistical tools for spectrophotometric data analysis, remains limited. In this work, several machine learning approaches were applied to quantify the urea concentration from spectrophotometric data. Exploratory data analysis showed an increase in mean absorbance values over time, from 0.137 (0.00727) at 0 hours to 0.668 (0.00649) at 4 hours. Linear regression models, using predictors such as time, wavelength, and absorbance, achieved a low mean squared error (MSE), indicating good predictive performance, although they are constrained by linear assumptions. Also, because it can analyze continuous data, Random Forest was implemented using the same variables mentioned earlier. The MSE indicated good predictive performance; however, this approach presents computational challenges. Furthermore, to reduce the effect of the wavelength factor, dimensionality-reduction techniques were applied. Principal Component Analysis (PCA) was applied to the spectral derivative, which explained approximately 89% of the variability in the first three principal components and revealed separation of urea concentration over time. However, linear approaches may overlook nonlinear patterns present in spectral derivatives. Therefore, Kernel Principal Component Analysis (KPCA) was applied, where the first two kernel principal components captured sufficient information from the spectral derivative. Finally, a Generalized Additive Model (GAM) was implemented using the first two kernel components, which produced a lower MSE than both the linear model and the Random Forest, yielding the best predictions of urea concentrations.

**Keywords:** Spectrophotometric data, machine learning, random forest, principal components analysis, kernel principal components, mean squared error

## On the transient of boolean dynamical systems

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A boolean dynamical system is a map  $f = (f_1, f_2, \dots, f_n) : Z_2^n \rightarrow Z_2^n$  where  $Z_2$  is the finite field with 2 elements and each coordinate map  $f_i$  is a polynomial in  $n$  variables over  $Z_2$ . Given a state  $a \in Z_2^n$ , there are positive integers  $t_a \geq 0$ , and  $s_a \geq 1$  such that  $f^{t_a}(a) = f^{t_a+s_a}(a)$ . We say that  $f$  is a **fixed point system** if  $s_a = 1$ , for every  $a$ . The **transient** of a state  $a$  is the “time” that it takes to reach an attractor, i.e. the smallest of such integer  $t_a$ . The *transient* of  $f$ , is the maximum of the transients among every  $a \in Z_2^n$ .

Currently there are very few practical results to determine the transient of  $f$ . When  $f$  is linear, O. Colón et. al, see [1], provide a method using the minimal polynomial of  $f$ . For the non linear case, this is still an open problem. We contribute to a solution, presenting a formula to compute the transient of a system in which at most two coordinate maps are non-linear. More over, a relationship with previous works on primate graphs is presented.

## Friendship factorization and its irreducible divisor graph

Mia I. Gonzalez-Ramirez, Department of Mathematical Sciences, University of Puerto Rico at Mayagüez.

The notion of friend factorization was introduced in 2014 by Ortiz and Rivera as a concrete example within the broader theory of  $\tau$ -factorizations, originally developed by Anderson and Frazier in 2006. In this framework, the usual multiplicative structure of an integral domain is restricted by a symmetric relation  $\tau$ : a promaduct of two or more elements is called a  $\tau$ -product when all factors are pairwise  $\tau$ -related.

The friendship relation, denoted by  $\tau$ , first appeared in the XXIII Colombian Mathematical Olympiad, where two elements  $x$  and  $y$  satisfy  $x\tau y$  precisely when  $\sqrt{x \cdot y} \in Z$  is an integer. Subsequent work by Ortiz and Rodríguez, in 2020, examined structural patterns in  $\tau$ -products and the associated irreducible divisor graphs. Later, Ortiz and Jiménez, in 2022, extended the framework by replacing the square-root condition with general  $n$ -radicals, obtaining results for several values of  $n$ .

The present research returns to the original friendship relation and aims to give a more detailed characterization of the irreducible divisor graph. Several illustrative examples will be presented, along with new partial results from this ongoing investigation.

# A Low-Cost Approach for Sports Performance Assessment Using Computer Vision and Artificial Intelligence Tools

*Javier Osorio*, Facultad de Salud, Universidad Manuela Beltrán; Department of Physical Education and Recreation, University of Puerto Rico at Río Piedras.

Traditional sports training workflows rely heavily on manual observation, leading to subjective assessments and limited temporal resolution. High end motion tracking systems exist, but their cost and deployment complexity restrict use in most training environments. This project presents a low cost, AI driven framework for automated sports performance analysis that leverages modern computer vision architectures and GPU accelerated processing to generate objective performance metrics.

The system integrates the YOLOv11 object detection model ( 25.3M parameters) to track ball motion across standard video recordings. During preprocessing, users annotate key spatial landmarks—such as goal boundaries and initial ball positions—to establish reference coordinates for downstream metric computation.

From these detections, frame level ball coordinates are extracted and missing values are estimated through interpolation and size based heuristics, enabling trajectory reconstruction and the computation of objective performance metrics.

To enhance interpretability, the system produces annotated output videos with overlaid trajectories and generates analytical plots summarizing temporal and spatial performance distributions. The full processing stack is implemented in Python and optimized for GPU execution via Google Colab. For scalability, the pipeline supports parallel video processing through a Python multiprocessing module, offering significant throughput improvements when multiple GPU cores or high memory runtimes are available.

By combining lightweight deployment, deep learning-based detection, and modular post processing analytics, this system provides an accessible alternative to commercial sports tracking platforms. The framework demonstrates how modern AI models can be adapted for real world athletic environments with constrained computational and financial resources, enabling reproducible, objective evaluation of sports performance.

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**Keywords:** AI-assisted sports analysis, computer vision, distributed processing, object detection, YOLOv11

# Applications of Our Generalized W-HITS to Gene Regulatory Networks

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Gene regulatory networks (GRNs) provide a natural graphical representation of relationships between genes, enabling systemic pathway analysis. We construct GRNs using gene expression data from the central nervous system (CNS) of fruit flies (*Drosophila melanogaster*), a model organism reared under microgravity conditions aboard the International Space Station (ISS). We infer both directed and undirected GRNs via machine-learning algorithms that rely exclusively on gene expression data. We then apply specialized implementations of our generalized Hyperlink-Induced Topic Search (HITS) algorithm to the resulting networks. This approach provides a refined framework for assessing the regulatory importance of individual genes by distinguishing between hub genes and authority genes as candidates for further investigation and analysis.

We present insights and results related to the following methodological components: (1) incorporating positive and negative edge weights derived from gene–gene coexpression and protein–protein interaction data in GRN construction; (2) generalizing Kleinberg’s HITS algorithm to a weighted formulation (W-HITS); (3) implementing and applying W-HITS to infer the relative importance of hub genes and authority genes within the inferred networks; (4) developing efficient parallel implementations of HITS and W-HITS; (5) proving convergence of the proposed algorithms using Perron–Frobenius theory; and (6) leveraging the Fiedler vector to quantify gene importance.

**Acknowledgements:** This research was done in collaboration with Heeralal Janwa (University of Puerto Rico at Río Piedras), Carlos Agrinosoni (Purdue University, West Lafayette), Airined Montes Mercado (University of Puerto Rico at Río Piedras).

**Keywords:** gene regulatory networks; protein–protein interaction networks; network analysis; HITS algorithm; hub and authority genes; algorithm convergence; parallel computation; OpenMP

# A Real-Time, Interactive Web Application for Automated Behavioral Monitoring of Honeybees

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Artificial flower patch experiments are traditionally conducted manually, making it extremely difficult to accurately track individual bee identities, record flower visits, and measure handling and flight times when multiple bees visit a patch simultaneously. To address these scalability issues, this project presents a web application designed to record and annotate honey bee activity in real time with minimal human intervention.

To achieve this, the system adopts a modular architecture, where each component is independently containerized using Docker. The pipeline leverages NVIDIA DeepStream and YOLO models to detect bee keypoints for quantifying flower visits and to classify paint colors for re-identifying individual bees. This setup enables two workflows: a fully automatic mode where identities are annotated based solely on color predictions, and a semi-automatic mode where researchers interactively review and override model predictions. Detection data flows via Apache Kafka to a Flask backend for processing and MongoDB storage, while a D3.js frontend visualizes activity for real-time monitoring.

The system was validated during preliminary experiments investigating alcohol preference in honey bees. The application proved capable of handling complex tracking scenarios over extended periods; during a specific 3.5-hour trial, the system successfully tracked 12 unique bees and accurately recorded 488 distinct flower visits. These metrics demonstrate the platform's ability to deliver consistent, high-volume behavioral data, validating the hybrid classifier approach and effectively automating the data collection process.

**Acknowledgments:** We would like to thank the National Science Foundation (NSF) for supporting this work under Grant no. 2318597.

**Keywords:** Real-time system, data visualization, experiment data annotation, behavioral analysis, DeepStream, Kafka, Flask, D3.js, MongoDB, Docker

## DanceSketch: Providing Choreography Scripting Capabilities in EarSketch

*Nicole M. Ramirez-Mulero*, Department of Computer Science, University of Puerto Rico at Río Piedras.

*Rafael A. Arce Nazario*, Department of Computer Science, University of Puerto Rico at Río Piedras.

The concept of dance functions is an effective pedagogical vehicle for teaching core concepts of programming and computer science, as both domains share fundamental structural and linguistic characteristics. Both areas share similar concepts and a sequential instruction following that completes one instruction after the other. Concepts like loops, if-statements, and functions are shared between both disciplines. Dance also provides a metaphor for students to better understand computer science by allowing artistic ideas to be turned into code. Integrating dance into computer science education allows students to internalize abstract programming ideas through coordinated physical movement. Dance choreography mirrors key computational thinking skills such as sequencing, decomposition and pattern recognition, making complex logic more intuitive and relatable.

EarSketch is an online coding environment designed to teach programming in a dynamic and engaging way through music. On this platform, users create their own songs using a predefined sound library while practicing core programming concepts such as variable definition, loops, conditional statements, data types, and function creation and invocation. We are creating DanceSketch, an enhancement for the EarSketch platform that introduces choreography functionality. DanceSketch allows users to program choreographies for a digital three-dimensional avatar using functions similar to those already available in the EarSketch API. The new features are being integrated into EarSketch's codebase, which uses React and Typescript. To create and control avatar movements, we are using assets from Mixamo, a library of pre-made 3D character animations, and the Three.js library to render the animations in the browser.

**Keywords:** Computational Thinking, Computer Science Education, EarSketch, creative learning, dance-based learning.

## Exploring New Forms of Learning Assessment in the AI Era

*Ollantay Medina*, Department of Mathematics, University of Puerto Rico at Humacao.

The widespread adoption of generative AI in higher education has created a critical challenge for academic assessment. With an ever-increasing percentage of students using AI tools in their academic work, higher education institutions have not yet established well-defined responses or policies. This talk proposes a paradigm shift from policing AI use to strategically

channeling it based on students' cognitive development stages. Early-stage students building foundational mental models require careful AI supervision to prevent cognitive debt and the illusion of understanding, while advanced students with consolidated mental models can leverage AI as a collaborative tool for complex problem-solving.

I will present two types of intelligent tutoring systems: the Socratic tutor and the direct instruction tutor. These systems can be tailored and refined to democratize access to personalized educational support. The presentation will outline concrete assessment strategies that evaluate verification processes and thought architectures rather than final products, fostering "Knowledge Architects" capable of wielding AI effectively rather than becoming dependent users.

**Keywords:** artificial intelligence, educational assessment, intelligent tutoring systems, cognitive development, Socratic method

## A compartmental model of HIV dynamics with virological suppression and optimization of antiretroviral therapy

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*Pedro Vásquez Urbano*, Department of Mathematical Sciences, University of Puerto Rico at Mayagüez.

In this talk we study the population-level impact of antiretroviral therapy (ART) on HIV transmission, emphasizing the role of sustained virological suppression ( $U=U$ ). To explicitly capture these mechanisms, we propose a compartmental model that distinguishes treated individuals without viral suppression ( $T_u$ ) and with viral suppression ( $T_s$ ), and incorporates a force of infection weighted by clinical stage and treatment status. We prove positivity of solutions and invariance of the feasible region, and derive a closed-form expression for the control reproduction number  $\mathcal{R}_c = \rho(FV^{-1})$ .

Deterministic simulations and sensitivity analysis reveal clear effects: increasing the rate of achieving viral suppression ( $\theta$ ) decreases  $\mathcal{R}_c$ , whereas higher loss of suppression ( $\psi$ ) increases it. Moreover, maintaining near-zero infectivity under suppressive ART ( $\varepsilon_s \approx 0$ ) is shown to be critical, in agreement with the U=U principle. Based on these results, we formulate an optimization problem solved using genetic algorithms to identify feasible programmatic policies (e.g., targets on  $\sigma_A, \sigma_C, \sigma_Y, \theta, \psi$ ) that minimize cumulative incidence and costs under adherence and dropout constraints. The results suggest that improving  $\theta$  and reducing  $\psi$  accelerates the decline of  $\mathcal{R}_c$ ; however, achieving  $\mathcal{R}_c < 1$  may require combined strategies that also reduce transmission rates or the infectivity of non-suppressed individuals. Overall, the work links clinical evidence with public health decision-making through a reproducible mathematical–heuristic framework.

**Keywords:** HIV, antiretroviral therapy, virological suppression, reproduction number, optimization

## 17 years since the Conjecture of Exceptional APN functions

Moises Delgado, Department of Mathematics-Physics, University of Puerto Rico at Cayey.  
Heeralal Janwa, Department of Mathematics, University of Puerto Rico at Río Piedras.  
Carlos A. Agrinoni Santiago, Department of Mathematics, Purdue University.

Kaisa Nyberg, in her 1993 paper: *Differentially uniform mappings for cryptography* (EUROCRYPT 1993) stated over a finite field  $L = \mathbb{F}_{2^n}$ : A function  $f : L \rightarrow L$  is said to be almost perfect nonlinear (APN) on  $L$  if for all  $a, b \in L$ ,  $a \neq 0$ , the equation  $f(x + a) - f(x) = b$  have at most 2 solutions. An **exceptional** APN function is one that is APN on infinitely many extensions of  $L$ .

Around 2009–2010, Aubry, McGuire, and Rodier formulated in the paper: *A few more functions that are not APN infinitely often* (arXiv: 0909.2304, 2009) the conjecture that the only exceptional APN functions are the Gold and Kasami monomial functions:  $f(x) = x^{2^k+1}$ ,  $f(x) = x^{2^{2k}-2^k+1}$ . In this talk, we show some new mathematical concepts and techniques towards the resolution of this conjecture, as well as recent results which guaranty that infinite families of polynomials are not exceptional APN. In particular, we show that Gold degree polynomials of the form  $x^{2^k+1} + h(x)$ , where  $\deg(h)$  is any integer (up to natural exceptions), can not be exceptional APN, terminating a significant part of this conjecture.

**Keywords:** APN function, Exceptional APN function, Exceptional APN Conjecture, Gold function, Degree gap

## Diagnostic tools for mixed models with inflation of zeros

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Raúl E. Macchiavelli, College of Agriculture Sciences, University of Puerto Rico at Mayaguez.

In applied statistics, it is common to encounter dependent observations representing counts with Poisson, Binomial, ZIP, etc. distribution. To model data of this type, we use Generalized Linear Mixed Models (GLMM), which require different diagnostics tools to assess whether the model is appropriate for our observations. For example, we have to evaluate the need of taking into account overdispersion, inflation of zeros, or problems in the obtained residuals. Traditional residual plots are difficult to interpret when evaluating these features of the model, The use of Pearson and Deviance residuals in these situations do not provide sufficient information to assess the goodness of fit, and randomized quantile residuals (RQR)

are more appropriate. In this presentation, we will demonstrate, using simulated data and a case study, the usefulness of these techniques for selecting an appropriate model for our data, as well as the usefulness of different R v4.4.1 libraries such as DHARMa and glmmTMB, which have graphical tools to evaluate these models correctly.

**Keywords:** GLMM, Overdispersion, Inflate Zeros, DHARMa, glmmTMB, RQR

## **Developing an infrastructure at the University of Puerto Rico to promote and support research with restricted-use data through the Federal Statistical Research Data Center (FSRDC) network of the U.S. Census Bureau**

*Mario Marazzi Santiago*, Puerto Rico Federal Statistical Research Data Center, U.S. Census Bureau.

The Federal Statistical Research Data Center (FSRDC) network of the U.S. Census Bureau offers secure computing labs in 37 locations across the United States where qualified researchers conduct approved statistical analysis on restricted-access federal and private microdata. Since the passings of Hurricane Maria and Irma over Puerto Rico in 2017, there is a greater awareness at the federal level for the need for high-quality statistics on the economy of Puerto Rico, prompting the Census Bureau to open its latest FSRDC computing lab in an office it maintains in Puerto Rico. The new computing lab is attracting local researchers and administrative datasets that are the key to expanding research in Puerto Rico, while at the same time advancing the Census Bureau's mission. Going forward, the Bureau seeks to identify in the coming years a suitable research organization where it can be permanently located in Puerto Rico.

To get the most out of the opportunity to analyze federal restricted-use datasets, we need to strengthen the social science research infrastructure at the University of Puerto Rico. We will discuss a proposal to develop a research center between the Río Piedras and Medical Sciences Campus. Some of the services that the center will provide include: 1) making available a common infrastructure to support projects from individual researchers, 2) offer training and consulting services on modern statistical and demographic techniques, including principles of reproducible research, 3) offer workshops on modern principles of data management and analysis of complex survey data, 4) mentoring early career researchers. The last section of the session will be an open discussion with the general public interested in collaborating with the new Center.

# The Actuarial Profession

*Arnaldo Cruet Rivera*, Actuarial Services Department, SSS Puerto Rico.

The actuarial profession plays a pivotal role in managing and mitigating risks in various industries. The profession relies heavily on mathematics, statistics, finance, and business to solve various problems. This abstract provides an overview of the basics of the actuarial profession, its key functions, educational requirements, and an overview of the various applications.

Actuaries are highly skilled professionals who use mathematical and statistical methods to analyze the financial consequences of risk and uncertainty. Primarily employed in insurance, pension, and investment sectors, actuaries are instrumental in designing insurance policies, pension plans, and investment strategies that balance risk and financial stability.

Actuaries typically pursue a rigorous course of study that includes mathematics, statistics, economics, and finance. Many actuaries obtain professional credentials, such as those offered by renowned actuarial societies like the Society of Actuaries (SOA) or the Casualty Actuarial Society (CAS), to validate their expertise and enhance their career prospects.

The core functions of actuaries involve assessing risk, determining premium rates, and projecting future financial outcomes. In the insurance sector, actuaries analyze demographic data, health trends, and historical claims to set insurance premiums that ensure the financial viability of insurance companies. In pension planning, actuaries calculate contributions required to meet future pension obligations while considering factors like life expectancy and market conditions. As part of their daily work, actuaries contribute significantly to investment decision-making by evaluating the financial risks associated with different asset classes.

The actuarial profession has expanded beyond traditional domains, finding applications in diverse fields such as healthcare, government, and consulting. Actuaries in healthcare analyze the financial impact of medical treatments, evaluate health insurance programs, and design cost-effective strategies. Employment for actuaries may be found both in the public and private sectors. Government agencies may employ actuaries to assess the financial implications of policy decisions and demographic changes.

In conclusion, the actuarial profession is a dynamic and multidisciplinary field crucial to managing risks and ensuring financial stability across various industries. Actuaries are valued for their strong mathematical foundation and professional credentials. They provide invaluable insights that drive informed decision-making in a dynamic financial landscape. As the world continues to grapple with uncertainties, the role of actuaries remains in high demand in order to mitigate the impact of risks on individuals, businesses and society.

**Keywords:** actuarial, actuaries, SOA, risk management, insurance, financial modeling, data analysis, mathematics, statistics

## 4 Afiches / Posters

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### **Sistema de detección de intrusiones basada en anomalías en entornos IoT en tiempo real**

*Alexander Suárez Gómez*, Departamento de Ingeniería Eléctrica y de Computadoras, Universidad de Puerto Rico Recinto de Mayagüez.

IoT (Internet de las cosas) ha crecido de manera exponencial en los últimos años; sin embargo, el incremento en el número de dispositivos conectados ha aumentado la exposición de servicios críticos a amenazas cibernéticas, las cuales comprometen los pilares centrales de la seguridad de la información. Por otra parte, los sistemas IoT presentan limitaciones en recursos energéticos y computacionales, lo que dificulta la adopción de paradigmas tradicionales de ciberseguridad.

Considerando los retos anteriores, una herramienta ampliamente explorada en la literatura son los sistemas de detección de intrusiones basados en anomalías, debido a que pueden detectar ataques de día cero. En este contexto, el presente estudio evaluó el rendimiento de un sistema de detección de intrusiones basado en anomalías en tiempo real, ejecutado en un dispositivo de borde (Raspberry Pi 4B), el cual monitoreaba el tráfico de red de un sistema IoT. Dicho dispositivo de borde recibía datos de sensores ambientales simulados desde un microcontrolador (ESP8266) mediante una conexión WiFi. El sistema IoT fue sometido a cinco tipos de ataques.

El propósito de este proyecto fue evaluar el uso eficiente de recursos y la fiabilidad de la predicción de los sistemas de detección basados en anomalías en entornos IoT. Para ello, la evaluación consideró el uso de algoritmos multiclase (K-means y un Autoencoder multiclase) y algoritmos de clase binaria (OCSVM e Isolation Forest). Las predicciones se compararon tanto de manera offline como en tiempo real. En tiempo real, Isolation Forest mantuvo métricas de predicción similares a las obtenidas de manera offline, mientras que el Autoencoder multiclase presentó métricas de predicción en tiempo real inferiores a las obtenidas en la evaluación offline; no obstante, mostró mejores métricas que K-means. Por otra parte, en términos de eficiencia computacional, Isolation Forest y el Autoencoder multiclase presentaron un bajo tiempo de predicción y un bajo consumo de CPU.

**Colaboradores:** Este trabajo fue realizado en colaboración con Fernando Gutiérrez Portela (Universidad Cooperativa de Colombia), Oscar Augusto Diaz Triana (Universidad Cooperativa de Colombia), y Deiver Suárez Gómez (Universidad de Puerto Rico Recinto de Mayagüez).

## **Ciencia de datos en la cancha de baloncesto: estudio de caso de Los Artesanos de Las Piedras**

*Axel J. Ortiz Rivera*, Departamento de Matemáticas, Universidad de Puerto Rico en Humacao.

*Elio Ramos Colón*, Departamento de Matemáticas, Universidad de Puerto Rico en Humacao.

Este trabajo explora la aplicación de la ciencia de datos al análisis del baloncesto puertorriqueño mediante un estudio de caso con Los Artesanos de Las Piedras. A partir de datos recopilados en vivo y del play-by-play, se desarrollaron varias herramientas computacionales para generar información utilizable en la toma de decisiones antes, durante y después del partido. El análisis integra métricas de eficiencia ofensiva, puntos por posesión (PPP), distribución y efectividad de tiro por zona y tipo, impacto de los rebotes ofensivos y secuencias de juego bajo distintos contextos tácticos. Asimismo, se construyeron grafos dirigidos de asistencias para modelar la interacción colectiva de los equipos, identificar patrones de creación ofensiva y roles clave dentro del sistema y, así, diseñar estrategias defensivas en respuesta a estos hallazgos. Los resultados evidencian que el uso contextualizado de herramientas analíticas y visualizaciones personalizadas permite traducir datos complejos en tendencias relevantes para entrenadores y cuerpo técnico, demostrando el potencial de la ciencia de datos como apoyo estratégico en el baloncesto puertorriqueño.

## **Análisis funcional de la señalización de calcio en poblaciones extensas de células T expuestas a múltiples antígenos**

*Deiver Suarez-Gomez*, University of Puerto Rico at Mayagüez.

El calcio intracelular desempeña un papel fundamental en múltiples procesos fisiológicos y constituye un indicador clave de la actividad celular. Comprender los patrones de señalización de calcio en respuesta a estímulos es esencial en investigación biomédica e inmunológica, particularmente cuando se analizan grandes poblaciones celulares. En este estudio presentamos un marco de trabajo para el análisis automatizado de películas de fluorescencia de calcio en extensas poblaciones de células T expuestas a distintos antígenos: UCHT1, 9V:MHC, OKT3, 4D:MHC, además de un control negativo sin antígeno.

Los videos fueron preprocesados en Fiji y la segmentación de regiones de interés (ROIs), junto con la extracción de transientes temporales de calcio, se realizó mediante CaImAn. Posteriormente, se aplicaron análisis estadísticos basados en modelos empíricos, incluyendo regresión lineal y polinomial, regresión con splines y modelos aditivos funcionales. Los resultados mostraron que el modelo de ANOVA funcional fue el más adecuado para capturar la dinámica temporal de la señal, revelando efectos significativos sobre la señalización de calcio para los antígenos evaluados y el control negativo en intervalos de tiempo específicos.

Como producto adicional, desarrollamos una aplicación interactiva en Shiny denominada

SignalPredict, que implementa el modelo de ANOVA funcional y facilita el análisis a investigadores sin experiencia en programación. En conjunto, estos hallazgos respaldan la existencia de efectos distintivos de cada antígeno sobre la señalización de calcio en células T y proveen una metodología robusta y accesible para explorar respuestas celulares en contextos fisiológicos y patológicos.

**Colaboradores:** Este trabajo fue realizado en colaboración con Daniel Rocha-Clavijo (University of Puerto Rico at Arecibo), Deiver Suarez-Gomez (University of Puerto Rico at Mayagüez), Alibeth E. Luna Alvear (University of Puerto Rico at Mayagüez), Santiago Colom Braña (University of Puerto Rico at Mayagüez), Clara E. Isaza (University of Puerto Rico at Mayagüez), y Mauricio Cabrera-Rios (University of Puerto Rico at Mayagüez).

## Monte Carlo Simulation and Inverse Modeling of Photoplethysmography Signals

*Gladymar Colon*, Department of Computer Science, University of Puerto Rico at Río Piedras.  
*Michael Alvarez*, Department of Computer Science, University of Puerto Rico at Río Piedras.

This work presents a Monte Carlo-based computational model for studying light propagation in biological tissue and for generating synthetic photoplethysmography (PPG) signals. Photoplethysmography is a non-invasive optical technique whose behavior can be described by the Radiative Transfer Equation, with Monte Carlo methods providing a robust framework for modeling highly scattering and absorbing media.

The model was implemented in MATLAB using MCmatlab and considers a simplified three-dimensional domain composed of blood and water, with optical properties defined at a wavelength of 660 nm. Ellipsoidal geometries are used to represent blood vessels, and variations in vessel position and dimensions are introduced to emulate physiological changes such as blood pressure variations. The normalized fluence rate obtained from the simulations is used as an approximation of the PPG signal.

In addition, real PPG signals from publicly available PhysioNet databases are incorporated to formulate an equivalent inverse Monte Carlo approach. In this framework, optical and geometric parameters of the model are iteratively adjusted so that the simulated PPG signal approximates the real measured signal. This strategy enables the exploration of inverse relationships between observed PPG waveforms and underlying tissue properties.

Preliminary results indicate that the model can reproduce consistent signal variations associated with geometric changes and that comparison with real PPG data is a promising approach for model validation and physiological parameter estimation.

**Acknowledgements:** The authors would like to thank the Department of Computer Science at the University of Puerto Rico, Río Piedras, for providing an academic environment that supported this undergraduate research. This work did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

**Keywords:** Photoplethysmography (PPG), Monte Carlo simulation, Light–tissue interaction, Computational modeling, Inverse problem, Synthetic biomedical signals.

## Framework for Analyzing Rhythmic Time Series Data

*Jaime R. Marrero-Perez*, Department of Biology, University of Puerto Rico at Río Piedras.

The analysis of biological circadian rhythms requires the use of methods that can handle noisy and irregularly sampled time series data. Statistical packages capable of implementing pipelines to detrend and smooth the data to isolate signals, detect periodicity and fit models have been extensively used in the field of chronobiology. However, these analysis strategies can be used to analyze time series data beyond biological rhythms. As part of the Arecibo C3 project, we have adapted our circadian rhythm analysis package “Circadian Dynamics”, originally developed in R, to focus on the analysis of environmental rhythmicity. Our aim is to treat circadian analysis as a general framework for rhythmic signal inference. We present a new implementation of this analysis pipeline, developed in C++ and deployed with WebAssembly, enabling execution through a web browser. Ongoing development includes incorporating multi-harmonic cosinor models that enable the exploration of non-sinusoidal rhythmic patterns, permitting the analysis of periodic signals with multiple peaks per cycle that are not adequately described by a cosinor fit.

**Acknowledgments:** This work was supported in part by funding from the Arecibo C3 project. This research was done in collaboration with Eddie Perez Claudio (University of Pittsburgh), Manuel Antonio Giannoni-Guzmán ( Tennessee State University), and Jose L. Agosto-Rivera (University of Puerto Rico at Río Piedras).

**Keywords:** time series analysis, rhythmic signal inference, WebAssembly

## Impacto de los factores socioeconómicos en el rendimiento académico: Un análisis estadístico en la UPR-RP

*Jennifer A. Quintero-Silva*, Escuela Graduada de Administración de Empresas, UPR-RP.

La preparación académica con la que ingresan los estudiantes a la Universidad de Puerto Rico, Recinto de Río Piedras (UPR-RP), ha mostrado un descenso significativo en los últimos años, debido a las deficiencias en los fundamentos básicos, especialmente en matemáticas, los cuales son clave para el éxito en los estudios superiores. Este trabajo se realizó como un estudio piloto tomando particularmente los estudiantes de nuevo ingreso en la Facultad de Administración de Empresas (FAE), realizando un análisis cuantitativo, inferencial, de corte

transversal. El objetivo de la investigación busca identificar los factores socioeconómicos que inciden en el rendimiento académico, y cuales de estos factores persisten en el tiempo. La base de datos usada para este estudio se consolidó a partir de la contribución de información de las oficinas del (Registrador y Asistencia Económica) de la UPR-RP. Entre los principales predictores se identificaron el GPA de escuela superior, los puntajes del College Board, el acceso a becas, el sexo y el tipo de escuela. Se observaron diferencias por cohorte, siendo destacable el rendimiento superior en la cohorte 2020–2021. Los hallazgos aportan evidencia para orientar políticas académicas que permitan dirigir sus mayores esfuerzos para mitigar el bajo rendimiento académico, problemática que podría incrementar la deserción académica y generar retos importantes en su desarrollo profesional, que a futuro también podría afectar su desempeño laboral.

**Agradecimientos:** Esta investigación fue patrocinada por el programa de Fondos Institucionales para la Investigación (FIPI) del Decanato de Estudios Graduados e Investigación (DEGI), de la Universidad de Puerto Rico, Recinto de Río Piedras. Este trabajo fue realizado en colaboración con Jairo A. Ayala-Godoy (UPR-RP), Daiver Velez-Ramos (Universidad Politécnica de Puerto Rico), Rafael Aparicio-Cuello (UPR en Ponce, Eugenio Guerrero Ruiz (UPR-RP), y Óscar Castrillón Velandia (UPR-RP).

**Palabras clave:** factores socioeconómicos, rendimiento académico, educación superior, modelos estadísticos

## **Applications of Convolutional Neural Networks in the Embedding and Detection of Digital Watermarks: An Exploratory State-of-the-Art Review**

*Jose D. Gomez Acuna*, Department of Mathematical Sciences, University of Puerto Rico at Mayagüez.

In the last decade, the need for mechanisms to protect intellectual property and verify integrity without affecting the user experience has increased. In this context, deep learning-based visual watermarking has emerged as an alternative to classical methods by learning embedding and extraction strategies that can adapt to common distortions used as attacks against watermarked files. This work presents a review of the recent state of the art in watermarking for images and video from 2020 to 2025. We compare end-to-end encoder-decoder approaches, models with attention mechanisms, adversarial training with GANs, multiscale video frameworks, and dual schemes for combining copyright and authentication.

The results show an ongoing search for balance among quality, robustness, and capacity, though one must always sacrifice a bit of one to gain in another. In addition, we discuss modern deep learning-based threats that degrade watermarks while maintaining high visual quality. Finally, we identify trends and challenges, highlighting generalization to unseen

attacks, severe geometric robustness, standardization of evaluation protocols, and reduced complexity in video watermarking.

## Reconocimiento automático de esporas de hongo en imágenes de microscopio para monitoreo ambiental

*Luis Aparicio*, Departamento de Ciencias de Cómputos, Universidad de Puerto Rico en Río Piedras.

El monitoreo de esporas de hongos en el aire es un componente clave para la vigilancia ambiental y la salud pública. Actualmente en Puerto Rico, la identificación y cuantificación de esporas se realiza de forma manual por especialistas, lo cual demanda tiempo, limita la escalabilidad y la generación de reportes continuos. En este trabajo presentamos un modelo de visión por computadora para el reconocimiento automático de esporas de hongo en fotos de laminilla obtenidas de un microscopio automatizado. El sistema propuesto está basado en una arquitectura de dos etapas: (i) un módulo de detección que localiza y segmenta todas las esporas presentes en imágenes microscópicas, y (ii) un módulo de clasificación que asigna a cada detección una categoría taxonómica o morfológica relevante. La propuesta busca separar el problema de encontrar esporas del problema de distinguir tipos, aumentando robustez ante variaciones de iluminación, densidad y ruido visual. Actualmente, 110 imágenes han sido anotadas con 3982 anotaciones para entrenar los modelos, los cuales detectó 90corto plazo se busca entrenar el modelo de clasificación y refinar el sistema completo. Para el futuro se considera integrarlo en la aplicación Totaal que reporta niveles de esporas, polen y calidad del aire para acelerar el flujo de análisis y mejorar la disponibilidad de información para el público general.

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**Keywords:** visión por computadora, detección de objetos, clasificación de imágenes, esporas de hongo, monitoreo ambiental, aprendizaje profundo

## On a $\tau$ -Divisor Topology

Luis F. Durán-Rivera, Department of Mechanical Engineering, University of Puerto Rico at Mayagüez.

This research looks to define a basis and the behavior of the  $\tau_2$ -divisor topology. This can be viewed as a permutation of the usual divisor topology by implementing the  $\tau_2$ -factorization theory which modifies the list of available divisors for each nonzero non-unit integer. That is,  $x$  and  $y$  can be multiplied if they are related under  $\tau_2$ , the equivalence relation modulo on the nonzero non-unit integers. In other words,  $x$  and  $y$  are related under  $\tau_2$  if divides their difference. By understanding the  $\tau_2$ -products and observing the  $\tau_2$ -factors, three integer forms were discovered, each determined by the power of that divides each integer. With these three types of sets, it was possible to define a basis for the  $\tau_2$ -divisor topology, which turns out to satisfy the first axiom of separability.

**Keywords:**  $\tau_2$ -factorizations, Divisor topology

## Using a Covariance Matrix Shrinkage Estimator to Assess Multivariate Normality

Melany Roldán, School of Statistics, Universidad del Valle, Cali, Colombia.

The null hypothesis of the Generalized Shapiro-Wilk test is defined as  $H_0 : \mathbf{Y}_1, \dots, \mathbf{Y}_n \in \mathbb{R}^p$  is a sample that comes from a  $N_p(\boldsymbol{\mu}, \boldsymbol{\Sigma})$ . For the calculation of the  $W^*$  statistic of this test, the estimators of the covariance matrix  $\mathbf{S}$  and the precision matrix  $\mathbf{S}^{-1}$  are used. It is well known that the sample covariance matrix  $\mathbf{S}$ , in situations where the number of variables is greater than or even equal to the number of available observations, generates poor estimates of the covariance matrix  $\boldsymbol{\Sigma}$ . Since  $\mathbf{S}^{-1}$  is part of the statistic of the Generalized Shapiro-Wilk test; the power of the test is expected to be affected.

A Monte Carlo study was developed to evidence the effect on the power of the test. It was identified that this presents problems when it is used in data that do not follow a multivariate normal distribution. On the contrary, this affectation is not evident when it is used in data that come from a multivariate normal distribution. Next, as a methodological proposal to deal with the loss of power of the test, the shrinkage estimate  $\mathbf{S}^*$  was incorporated into the Generalized Shapiro-Wilk test and its performance was analyzed via simulation versus performance. of the traditional test. The evaluation was carried out under different scenarios of sample size, significance levels and shrinkage estimates. Thus, it is concluded that the modified version of the Generalized Shapiro-Wilk test has a better performance than the traditional test, under  $n \cong p$ . Finally, an application with real data is presented, consisting of air quality measurements in the City of Cali, Colombia. The verification of the multivariate Normality assumption in these data is important since it opens the possibility

of applying new methodological proposals for handling missing data, which are very frequent in this context.

**Acknowledgements:** This research was done in collaboration with Javier Olaya, Elizabeth Ospina, Luz Adriana Pereira, and Jarvi Rodríguez, all from the Universidad del Valle, Cali, Colombia.

**Keywords:** Shrinkage, Generalized Shapiro-Wilk, covariance matrix, malconditioning, precision matrix, simulation, multivariate normal, environmental quality.

## **Strengthening logical thinking through cooperative strategies for primary level students with mathematical talent**

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Children with mathematical talent often excel at solving problems individually; however, when teamwork is properly structured, it can enhance their abilities and significantly improve their performance in competitions such as mathematics olympiads. This study presents the application of specific cooperative learning strategies in a group of mathematically talented children at the elementary school level, with the aim of improving their performance on questions related to logical thinking. To achieve this, a methodology based on group cohesion activities, the cooperative structure "Think, Share, and Solve," and the "Rotating Folder" technique was implemented. The group's scores in Phases I and II of the Mathematics Olympiad were analyzed and compared with the results obtained in Phase III, after implementing the strategy. The findings show significant improvements in student performance, supporting the effectiveness of cooperative learning in strengthening logical thinking in high-performing mathematics students.

**Keywords:** Cooperative learning, logical thinking, math Olympiads

# Random Cascade Ensembles: A Novel Bagging Approach for Classification on Imbalanced Datasets

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In the field of supervised learning, binary classification models aim to assign observations to one of two categories based on their features. However, their performance is severely hindered by class imbalance, a phenomenon where the prevalence of one category (majority class) overshadows the other (minority class). In such scenarios, traditional models tend to maximize global accuracy—the overall percentage of correct predictions—at the expense of ignoring the minority class, leading to a systematic bias toward the dominant group.

This paper introduces a novel machine learning method that re-engineers the conventional Random Forest architecture. Instead of aggregating independent decision trees, the proposed approach implements an ensemble of multiple variable-depth cascades based on bagging principles. Each ensemble unit operates within a hierarchical structure: the first level evaluates the sample; the second level re-evaluates only those observations classified as “0” (majority class) by the previous stage, aiming to recover potential false negatives. This process repeats sequentially, allowing the model to specialize in “hard-to-classify” instances. The final output is determined by the mode of all cascade predictions, integrating the “1s” identified at any stage of the hierarchical process.

The methodology was initially validated using student attrition data from Latin American universities and further tested through a simulation study with synthetic datasets under controlled imbalance ratios. The results demonstrate that this cascade architecture tends to be superior to simple class balancing strategies, as it prioritizes the enhanced detection of positive cases (1s) with minimal cost to the detection of negative cases (0s), offering robustness against bias compared to traditional methods that rely solely on global accuracy.

**Keywords:** Supervised learning, Data imbalance, Bagging, Cascade classifiers, Student attrition

## Improvement of the visual classification of pollen presence for foraging bees

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This investigation is focused on monitoring Puerto Rican honeybees, which collect pollen while foraging, keeping track of these bees is important because it gives indicators for colony

health benefiting our understanding of Puerto Rico’s principal pollinator. Previous work has collected video of bees entering and exiting hives, which are then tracked so that we end up with their path across the hives entrance. We then trained and implemented a YOLO detection model for pollen, to investigate pollinator bees, we evaluate various methods to use detections to determine pollen presence along a bee’s trajectory. In evaluating the results of the YOLO model’s detection in multi-instance classification of an individual bee, we saw that a simple majority in the trajectories predictions gave 97.90. Further analysis will refine methods to filter out the non-associated pollen detections.

**Acknowledgment:** This material is based upon work in the CyIndybee investigation supported by the National Science Foundation (NSF) under Grant No. 231859. This research was done in collaboration with Felix Arzola, Luke Meyers, Josué Rodríguez Cordero, and Rémi Mégret, all from the University of Puerto Rico at Río Piedras.

**Keywords:** Image detection, Image classification, multi-instance classification, automated pollen monitoring

## **Bebras Puerto Rico (2023–2025): Participación, observaciones descriptivas y estrategias para expandir la comunidad**

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El pensamiento computacional (PC) se ha consolidado como una competencia fundamental para la resolución de problemas mediante procesos algorítmicos. Es por esto que la iniciativa internacional Bebras se ha enfocado en fomentar el pensamiento computacional entre los estudiantes por medio de desafíos estimulantes. Tras los resultados preliminares presentados en el ciclo anterior (Flórez, 2024), donde se documentó el hito inicial de la llegada del desafío a la isla, este póster presenta una visión ampliada y multianual de la iniciativa.

En este trabajo se analiza el desarrollo de Bebras en Puerto Rico durante el periodo 2023–2025, integrando un volumen de datos significativo que supera las 3000 pruebas. Por medio de un análisis descriptivo del *Puntaje* y su comportamiento en función del *Género*, *Nivel* y el *Tipo de escuela*, Además, se contrastan los hallazgos actuales con las tendencias observadas en 2024.

Los resultados acumulados proporcionan una base empírica sólida que fundamenta la toma de decisiones estratégicas y las rutas de expansión de cara a los próximos años. Bebras PR enfocará sus esfuerzos en fortalecer la comunidad mediante programas de divulgación directa en escuelas, el desarrollo de recursos para el acompañamiento docente y la promoción de la computación creativa en contextos escolares diversos, buscando reducir las brechas identificadas en este análisis trienal.

**Agradecimientos:** Extendemos nuestro agradecimiento a las escuelas, docentes y estudiantes que han formado parte de esta trayectoria desde 2023, así como al equipo de voluntarios de la Universidad de Puerto Rico en Mayagüez por su compromiso con la educación computacional.

**Palabras clave:** Pensamiento computacional, Bebras Puerto Rico, K-12, Ciencias de la Computación, análisis multianual

## Computational Exploration of Prime Behavior within the Corbata Framework

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The Corbata system presents a novel mathematical framework that organizes numbers within a diamond-shaped lattice, unveiling previously unrecognized symmetries and sequences. Each cell in this lattice corresponds to a unique position derived from a recursive cross-pattern rule, resulting in a two-dimensional structure where arithmetic relationships and parity properties emerge organically. The expanded Corbata model explores the spatial distribution of prime numbers within this framework. By charting primes across successive rows, distinct geometric alignments and periodic-like behaviors become evident, suggesting that the Corbata system may capture hidden modular patterns associated with prime generation. Visual representations illustrate clusters, gaps, and mirror symmetries that are not readily apparent on the traditional number line, highlighting potential mathematical implications for number theory and visual pattern recognition. Further development of a computational modeling approach is required to extend the Corbata system and identify the underlying rules governing prime distribution.

**Keywords:** corbata system, number theory, primes, data mapping, nonlinear relationships, diamond-shaped lattice, number distribution

## Predicting pollen color in bees with DINOv3: patch-level embeddings and HSV/LAB integration with linear regression

Sebastián H Jansasoy Molina, Department of Computer Science, University of Puerto Rico at Río Piedras.

Identifying the pollen color carried by bees helps track which flowers are used, when they are available, and how resources change across landscapes. Field imagery, however, brings variable lighting, occlusions, and complex backgrounds that make purely color-based methods

brittle. This work introduces a low annotation pipeline that predicts pollen color from small image regions near the corbicula by combining foundation vision features with standard color representations and simple linear models. The workflow selects candidate patches, extracts robust visual features, integrates color information, produces continuous color estimates, and derives an interpretable color class. The approach offers an interpretable, field-friendly basis to scale datasets and normalize color across sessions for real-world deployments. Knowing pollen color is important because it provides ecological cues from bees, such as which flowers they are using, when, and their nutritional quality. Therefore, knowing pollen color would serve as a guide for beekeepers. Besides that, automatic identification of bee pollen color enables large-scale studies of pollination and flowering phenology, with lower annotation cost and higher reproducibility. However, in-the-wild acquisition introduces illumination changes, occlusions, and complex backgrounds that hinder purely chromatic methods. Advances in self-supervised representations have proven especially useful when annotation is limited; in particular, the foundational vision models (e.g., DINOv3) provide robust features transferable to downstream tasks. In this work, we integrate such representations with color space analysis to predict pollen color at the patch level in real field images.

**Acknowledgments:** This research is supported by NSF award 2318597. Special thanks to my mentor, Rémi Mégret, and colleagues Josué Rodríguez and Luke Meyers for their guidance and support throughout this work.

**Keywords:** Pollen color, Patch embeddings, Linear regression, Colorimetry.

## Spectral radii of arithmetical structures on broom graphs

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Given a finite connected graph  $G$ , an *arithmetical structure* on  $G$  is a pair of vectors  $(\mathbf{d}, \mathbf{r})$  with positive integer entries such that  $(\text{diag}(\mathbf{d}) - A_G)\mathbf{r} = \mathbf{0}$ , where  $A_G$  is the adjacency matrix of  $G$ . We call  $(\text{diag}(\mathbf{d}) - A_G)$  the *generalized Laplacian matrix* associated to  $(\mathbf{d}, \mathbf{r})$ . Dino Lorenzini defined arithmetical structures in 1989 motivated by the study of degeneration of curves in algebraic geometry, and they have recently been studied from combinatorial and linear algebraic perspectives. In this poster, we present results about the arithmetical structures that minimize the spectral radius of their associated generalized Laplacian matrices  $(\text{diag}(\mathbf{d}) - A_G)$  among all arithmetical structures on a broom graph.

**Acknowledgments:** This work was done in collaboration with We thank our advisors Dr. Alexander Díaz-López, Dr. Joel Louwsma, Paul J. McGinley and Rafi Mahmud for their help and guidance, Villanova’s Co-MaStER program for providing this opportunity, and NSF-DMS 2211379 and Villanova’s Center for Research and Fellowships for providing sup-

port.

## Queueing Theory, Optimization, and Age of Empires II

*Frank R. Sánchez-Monteza*, Department of Physics, University of Puerto Rico at Mayagüez.

Age of Empires II is an iconic real-time strategy game. This work explores ways of using ideas from the game to support the teaching of mathematical concepts such as optimization and queueing theory in mathematics education. The game presents situations involving resource management, decision-making, and critical thinking under constraints, making it a suitable environment for the development of mathematical thinking.

Focusing on one of the most important aspects of the game its economy, this proposal introduces modeling activities in which students represent resource production using simple functions. Students then analyze the relationships among resource availability, villager production, building construction, and military unit creation. Production and construction processes can be interpreted as waiting processes, which allows for an intuitive introduction to key ideas from queueing theory, such as waiting times, efficiency, and optimal use of resources and space, without relying on advanced formalism.

The central idea is structured as a learning sequence in which students explore, formulate models, compare results, and validate their conclusions through gameplay experience. The expected outcomes include a deeper understanding of constraints, proportional reasoning, and informed decision-making.

**Keywords:** queueing theory, optimization, mathematical modeling

## Bayesian Sample Size Calculation: The Impact of Prior Specification and Comparison with Frequentist Power Analysis

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*Quan Kevin Shan*, San Juan Saint John School.

Sample size determination is a critical step in research design, traditionally guided by frequentist power analysis that assumes a fixed effect size (e.g., Cohen's  $d = 0.5$ ), significance level ( $\alpha=0.05$ ), and power ( $1-\beta=0.8$ ). Using G\*Power or R, this yields a required sample size of 64 participants per group (128 total) for a two-sample independent t-test.

In contrast, Bayesian methods provide a probabilistic framework that integrates prior knowledge about the effect to compute the assurance, the probability that the future posterior will support a scientific conclusion (e.g., exclude zero). Through simulation-based assurance analyses in R, we compared the two approaches under three prior specifications:

(1) With a non-informative prior ( $N(0, 10^2)$ ), the Bayesian sample size ( $n=62/\text{group}$ ) converged to the frequentist result; (2) With a skeptical prior centered at null ( $N(0, 0.3^2)$ ), the required sample size increased to 74/group (148 total), reflecting the extra data needed to overcome prior skepticism; (3) With an enthusiastic prior aligned with the expected effect ( $N(0.5, 0.2^2)$ ), the required sample size decreased to 30 per group (60 total), representing a 53% reduction, because the prior is centered exactly at the true effect and is very informative (i.e., even tiny sample size can yield high assurance, as the prior alone already strongly supports the alternative hypothesis).

These results underscore that Bayesian sample size is not inherently smaller but rather adapts to prior information. Overly skeptical priors may inflate sample size requirements, while overconfident priors (e.g., using a very narrow prior with  $SD=0.2$ ) yields unrealistically low sample sizes (highlighting the risk of unjustified certainty). When priors are calibrated based on existing data, Bayesian designs can achieve substantial efficiency without compromising inferential reliability. Therefore, prior information acquisition (derived from pilot studies, meta-analyses, or expert judgment) should be transparent, and prior sensitivity analyses across a range of plausible priors should be advocated as a standard practice in Bayesian designs.

**Keywords:** power analysis, sample size, effect size, frequentist, Bayesian, prior distribution.

## Single-Pulse Analysis of the Millisecond Pulsar PSR J1713+0747

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Millisecond pulsars (MSPs) are highly stable, rapidly rotating neutron stars whose emission properties provide valuable insight into extreme physical processes and the interstellar medium. PSR J1713+0747 is a particularly bright MSP with sharp features in its pulse profile, exhibiting an effective width of 0.54 ms in the L band. These characteristics enable exceptionally precise time-of-arrival measurements and make the pulsar a key contributor to the detection of low-frequency gravitational waves through the Pulsar Timing Array (PTA) technique.

Pulsar mean pulse profiles are generally stable over long timescales. However, in April 2017, PSR J1713+0747 exhibited a significant, clearly visible change in pulse shape. In this poster, we apply data science techniques to investigate the pulsar's emission properties using observations from the Green Bank Telescope (GBT) conducted on 2 February 2022, with a total duration of two hours. By analyzing single-pulse data, we aim to identify and characterize key features of the pulsar's emission, thereby enhancing our understanding of its behavior.

**Keywords:** methods: data science - pulsars: individual: PSR J1713+0747

# Theory of the generalized divisor topology

Austin Johnson Colon, CROEM, Mayaguez.

This research aims to characterize divisor topologies within the framework of  $\tau$ -factorization where  $\tau$  is a symmetric relation on the set of non-zero, non-unit elements of an integral domain. The research will follow the open set construction outlined in Yigit and Koc(2024). Their idea considers building and understanding the set of factors of each non-zero, non-unit element of a commutative ring. In this case, the methods will be applied to the sets of  $\tau$ -factors of the elements on an integral domain. The collection of these sets of  $\tau$  factors is a basis to construct the  $\tau$ -divisor topology on the integral domain. There were three distinct conditions on relations that were determined to be sufficient to form a topological space by that method. Examples, characterizations, and subsequent properties for each of the three cases are analyzed and discussed. It was found that any relations in which  $\tau$ -division is transitive are able to form a Kolmogorov topological space.

**Keywords:** Factorization, divisor topology

# Non-Parametric Binomial Test Reveals High Prevalence of Insecticide Resistance Allele in *Aedes aegypti*

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One of the greatest limitations in genetic research is scale and resource management. Although PCR and genetic sequencing have become more financially accessible, maximizing resource efficiency while maintaining statistical significance and validity remains a primary concern. For studies with small sample sizes, non-parametric statistical methods help ensure accuracy. We applied a non-parametric binomial test to calculate the allele frequency of the sequenced RDL gene in an urban *Aedes aegypti* population in Puerto Rico. Mutations in this gene have been associated with resistance to insecticides in mosquito populations. The binomial test rejected the null hypothesis of equal distribution, suggesting a high presence of the RDL resistance allele in this population. All twelve sequenced alleles carried the RDL mutation, resulting in a 100% allelic frequency. A one-sample test for Cohen's  $h$  yielded a value of 1.57. This corresponds to a very large effect size ( $\Delta p = 0.50$ ), confirming the high prevalence of RDL mutations associated with resistance to common insecticides. These results support the implementation of integrated vector management strategies.

**Acknowledgements:** This research was sponsored by the Department of Biology at the University of Puerto Rico, Río Piedras Campus and was done in collaboration with Alejandra Flores, Cecilia Guzman and Stephanie Flores from the University of Puerto Rico at Río Piedras.

**Keywords:** binomial test, allelic frequency, insects, *Aedes aegypti*, insecticide resistance

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