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1 Charlas Plenarias / Plenary Talks

Differential operators and the geometry of domains in Euclidean spaces

Tatiana Toro, University of Washington.

In this talk we will present an area of analysis that is concerned with the relationship between differential operators, and the properties of their solutions, and the geometry of the domain on which they are considered. We will initially describe the case where the differential operator sees the domain as a homogeneous medium. We will contrast this with several inhomogeneous cases and mention several recent results in that direction. The tools used come from analysis of partial differential equations, harmonic analysis and geometric measure theory.

What kind of mathematics do we need now?

Rochelle Gutiérrez, University of Illinois at Urbana-Champaign.

The combined events of Covid, Black Lives Matter, and climate change have opened the door for many mathematicians to question what is happening in the world and what is our place in it? This session supports mathematicians to reflect on what is considered "normal" in mathematics teaching and learning and what it will take to rehumanize mathematics when so many people and institutions are actively protecting the status quo.

2 Sesiones Temáticas/ Thematic Sessions

2.1 Recent advances in partial differential equations

This mini-symposium will bring together a diverse group of researchers in analysis of partial differential equations. The topics in the symposium will consist on recent advancements in diverse areas of partial differential equations and their relation to functional analysis, geometric analysis, control theory, calculus of variations, and other applications. Organized by Alejandro Velez Santiago.

Nonlocal diffusion problems in fractal domains

Maria Rosaria Lancia, Department of Basic and Applied Sciences for Engineering, Sapienza Università di Roma, Italy.

We consider nonlocal diffusion processes in non smooth domains of fractal type as well as in the corresponding smoother approximating domains. Existence, uniqueness and regularity issues will be discussed. The asymptotic behaviour of the smoother solutions, if any, will be discussed.

Keywords: nonlocal operators, fractal domains, M-convergence, dynamical boundary conditions

Measure functional differential equations with state–dependent delays

Jaqueline Godoy Mesquita, Department of Mathematics, University of Brasília.

In this work, we prove results concerning existence and uniqueness of solutions and periodic averaging principle for measure functional differential equations with state–dependent delays. Also, we establish a correspondence between these equations and generalized ODEs, and prove some applications from this correspondence. This is a joint work with Professor Hernán Henríquez and Henrique Costa dos Reis.

Keywords: measure functional differential equations, state–dependent delays, periodic averaging, existence and uniqueness, generalized ode's

The Neumann problem for higher order elliptic differential equations

Ariel Barton, Department of Mathematical Sciences, University of Arkansas.

The second order differential equation $\nabla \cdot A\nabla u = 0$ has been studied extensively. It is well known that, if the coefficients A are real-valued, symmetric, and constant along the vertical coordinate (and merely bounded measurable in the horizontal coordinates), then the Dirichlet problem with boundary data in L^q or $\dot{W}^{1,p}$, and the Neumann problem with boundary data in L^p, are well-posed in the half-space, provided $2-\varepsilon < q < \infty$ and $1 < p < 2+\varepsilon$.

It is also known that the Neumann problem for the biharmonic operator Δ^2 in a Lipschitz domain in $\mathbb{R}^d$ is well posed for boundary data in L^p, $\max(1, p_d - \varepsilon) < p < 2+\varepsilon$, where $p_d = \frac{2(d-1)}{d+1}$ depends on the ambient dimension d.

In this talk we will establish well posedness of the L^p Neumann problem, $p_d - \varepsilon < p < 2+\varepsilon$, in the half-space for higher-order equations of the form $\nabla^m \cdot A\nabla^m u = 0$, where the coefficients A are real symmetric (or complex self-adjoint) and vertically constant.

Keywords: elliptic differential equation, Neumann problem, higher order differential equation, layer potentials

What are the classical boundary conditions for the fractional Laplace operator?

Mahamadi Warma, Department of Mathematical Sciences, George Mason University.

In this talk we characterize all the classical boundary conditions (Dirichlet, Neumann and Robin) associated with the fractional Laplace operator or/and the regional fractional Laplace operator on bounded subsets of $\mathbb{R}^N$. We also given some well-posedness and regularity results of solutions to associated elliptic and parabolic problems. Finally we introduce a fractional Dirichlet to Neumann operator associated with the regional fractional Laplacian.

Acknowledgments: Partially supported by the Air Force Office of Scientific Research under Award NO: FA9550-18-1-0242 and the Army Research Office (ARO) under Award NO: W911NF-20-1-0115.

Unilateral bounds for nonlinear semigroups and time-inversion

Enrique Zuazua, Friedrich-Alexander-Universität Erlangen-Nürnberg, Germany; Fundación Deusto, Bilbao, Basque Country, Spain; Universidad Autónoma de Madrid, Spain.

We shall discuss the inverse (or inverse-design) problem, for a time-evolution Hamilton–Jacobi equation and the 1-d analog in the context of scalar conservation laws. More precisely, given a target function and a time horizon, we aim to construct all the initial conditions for which the viscosity solution coincides the given target at the given time. As is common in this kind of nonlinear equation, the target might not be reachable. We first study the existence of at least one initial condition leading the system to the given target. The natural candidate, which indeed allows determining the reachability of the target , is the one obtained by reversing the direction of time in the equation. When is reachable, we construct the set of all the initial conditions for which the viscosity solutions lead to the final target.

We shall also discuss a number of open problems arising in this area and the possible link with other control problems through value functions, in particular in the context of reinforcement learning.

Keywords: scalar conservation laws, Hamilton-Jacobi equations, entropy and viscosity solutions, one-sided Lipschitz condition, semiconcavity, time inversion, inversion design, reachable set, reinforcement learning

Quantitative stability for minimizing Yamabe metrics

Robin Neumayer, Department of Mathematics, Northwestern University.

The Yamabe problem asks whether, given a closed Riemannian manifold, one can find a conformal metric of constant scalar curvature (CSC). An affirmative answer was given by Schoen in 1984, following contributions from Yamabe, Trudinger, and Aubin, by establishing the existence of a function that minimizes the so-called Yamabe energy functional; the minimizing function corresponds to the conformal factor of the CSC metric.

We address the quantitative stability of minimizing Yamabe metrics. On any closed Riemannian manifold we show—in a quantitative sense—that if a function nearly minimizes the Yamabe energy, then the corresponding conformal metric is close to a CSC metric. Generically, this closeness is controlled quadratically by the Yamabe energy deficit. However, we construct an example demonstrating that this quadratic estimate is false in the general. This is joint work with Max Engelstein and Luca Spolaor.

Almost minimizers for obstacle problems

Mariana Smit Vega Garcia, Department of Mathematics, Western Washington University.

In the applied sciences one is often confronted with free boundaries, which arise when the solution to a problem consists of a pair: a function u (often satisfying a partial differential equation), and a set where this function has a specific behavior. Two central issues in the study of free boundary problems and related problems in the calculus of variations and geometric measure theory are:

(1) What is the optimal regularity of the solution u?

(2) How smooth is the free boundary (or how smooth is a certain set related to u)?

The study of the classical obstacle problem - one of the most renowned free boundary problems - began in the '60s with the pioneering works of G. Stampacchia, H. Lewy, and J. L. Lions. During the past decades, it has led to beautiful developments, and its study still presents very interesting and challenging questions. In contrast to the classical obstacle problem, which arises from a minimization problem (as many other PDEs do), minimizing problems with noise lead to the notion of almost minimizers.

In this talk, I will introduce obstacle type problems and overview recent developments in almost minimizers for the thin obstacle problem, illustrating techniques that can be used to tackle questions (1) and (2) in various settings.

This is joint work with Seongmin Jeon and Arshak Petrosyan.

Keywords: free boundary problems, obstacle problem, almost minimizers

2.2 Declive poblacional de Puerto Rico: Análisis estadísticos y matemáticos para políticas de población

Organizador: Luis R. Pericchi Guerra.

Mesa redonda

Luis R. Pericchi Guerra (moderador), Departamento de Matemáticas, Universidad de Puerto Rico en Rio Piedras.
Angélica M. Rosario Santos, University of Puerto Rico at Rio Piedras.
Hernando Mattei, Graduate School of Public Health, Medical Sciences Campus, University of Puerto Rico.
Carmen E. Albizu-García, Graduate School of Public Health, Medical Sciences Campus, University of Puerto Rico.

Bayesian hierarchical models as a tool to generate and analyze probable future scenarios for the population of Puerto Rico

Angélica M. Rosario Santos, University of Puerto Rico at Rio Piedras.

The dramatic decrement in the population of Puerto Rico will have a huge impact on many areas of society. For this reason, probabilistic population projections are indispensable to have an idea of the panorama studying the most probable scenarios for the next 30 years. Bayesian Probabilistic Projections for Life Expectancy and Total Fertility Rate were realized following the models proposed by Raftery and his colleagues. These demographics components are used to generate the different scenarios for the Population of Puerto Rico. Since Net Migration is the most difficult demographic component to model because of its variability in the last cohort, we have been focused on considering different plausible scenarios given the trends in migration not mainly due to catastrophic events. For this project, we carefully choose the data to be used to justify possible scenarios for the Population of Puerto Rico and their demographic components using recent information from the World Population Prospects and the US. Census Bureau.

According to one of the scenarios, the population of Puerto Rico will decline to 2.14 million by 2050 bounded by the 95% probability interval $(1879.3, 2406.2)$.

R packages bayesLife, bayesTfr, and bayesPop were used to obtain the corresponding projections and to verify the convergence of the MCMC simulations to get the posterior distributions of the parameters estimated using the Bayesian Probabilistic Models.

Population decline in Puerto Rico: how bad can it get?

Hernando Mattei, Graduate School of Public Health, Medical Sciences Campus, University of Puerto Rico.

Population projections by the United States Census Bureau and the United Nations show Puerto Rico's population declining by 25 percent (over one million persons) in just a few decades. Such a dramatic decrease in such a short time may seem unrealistic, but we will argue that this scenario has to be taken seriously and that it also can be overly optimistic. This decline is being fueled by high out-migration and very low fertility, in fact Puerto Rico has one of the lowest fertility levels in the world. We will compare the Island's fertility trends with other low fertility countries to show how the Island's route to low fertility makes a prolonged period of very low fertility a real possibility. A scenario where the Island loses more population than that projected by the Census

and the United Nations is possibility that has to be taken seriously.

Evidence-based population policies in Puerto Rico: the road ahead

Carmen E. Albizu-García, Graduate School of Public Health, Medical Sciences Campus, University of Puerto Rico.

Puerto Rico is facing a demographic crisis that cannot longer be ignored. A large drop in births, extreme low fertility and high rates of out-migration have resulted in a declining population and the rapid aging of the population. Without formal modelling of Puerto Rico's demographic trends we will not be able to develop effective population policies to address the demographic challenges facing the Island. There is an urgent need for data driven and evidence-based population policies to address the negative consequence of these trends. These efforts will also require identifying intersectoral factors that need to be considered in policy formulation as well as the political forces that influence policy decisions. We will discuss challenges and opportunities that will be faced in Puerto Rico to develop and adopt evidence-based policies.

Keywords: evidence-based policies, population policies

3 Discussion panels/ Paneles de discusión

3.1 Estrategias de enseñanza de las matemáticas y ciencia de cómputo en tiempos de pandemia

Bárbara L. Santiago Figueroa (moderadora), Departamento de Matemáticas, Universidad de Puerto Rico en Humacao.
Elio Ramos Colón, Departamento de Matemáticas, Universidad de Puerto Rico en Humacao.
Arturo Portnoy, Departamento de Ciencias Matemáticas, Universidad de Puerto Rico en Mayagüez.
Anneliesse Sánchez Zambrana, Departamento de Matemáticas, Universidad de Puerto Rico en Arecibo.

Los Departamento de Matemáticas y/ó de Ciencia de Cómputo, en general, brindan servicio a toda (o a una mayoría) la población estudiantil en las instituciones universitarias. La experiencia presencial provee una oportunidad única para exponer a los(as) estudiantes al lenguaje técnico de un curso de matemática o programación. Escribir expresiones algebraicas, ecuaciones, integrales, instrucciones en lenguajes de programación como Python, R o C++ son destrezas que podemos catalogar como "rutinarias" en nuestros cursos. Tan pronto salimos del entorno presencial, y nos trasladamos a uno virtual, debemos seleccionar con responsabilidad y cuidado la forma en que transmitimos nuestro "lenguaje matemático" a nuestros(as) estudiantes. Ciertamente no es tarea trivial...y menos si se debe realizar inesperadamente.

Ante la nueva realidad que nos hemos visto forzados(as) a enfrentar por la emergencia mundial del COVID-19, el profesorado asumió grandes retos. En un tiempo mínimo (unas dos semanas

o menos), montamos cursos en plataformas digitales, rediseñamos contenidos y asumimos nuevas responsabilidades. En este foro, presentamos algunos de los retos que enfrentamos y las estrategias de enseñanza que utilizamos en cursos de matemáticas y/ó ciencia de cómputo para realizar nuestro trabajo docente ante la pandemia que enfrentamos.

4 Charlas Concurrentes / Concurrent Talks

(In alphabetical order using the last name of the speaker.)

Structure preserving-field directional splitting difference methods for nonlinear Schrödinger systems

Axi Aguilera, Department of Mathematical Sciences, University of Puerto Rico at Mayagüez.
Paul Castillo, Department of Mathematical Sciences, University of Puerto Rico at Mayagüez.
Sergio Gómez, Department of Mathematics, University of Pavia, Italy.

A computational framework of high order conservative finite difference methods to approximate the solution of a general system of N coupled nonlinear Schrödinger equations (N-CNLS) is proposed. Exact conservation of the discrete analogues of the mass and the system's Hamiltonian is achieved by decomposing the original system into a sequence of smaller nonlinear problems, associated to each component of the complex field, and a modified Crank- Nicolson time marching scheme appropriately designed for systems. For a particular model problem, we formally prove that a method, based on the standard second order difference formula, converges with order $\tau + h^2$; and, using the theory of composition methods, schemes of order $\tau^2 + h^2$ and $\tau^4 + h^2$ are derived. The methodology can be easily extended to other high order finite difference formulas and composition methods. Conservation and accuracy are numerically validated.

Keywords: mass (charge) and Hamiltonian conservation, coupled nonlinear Schrödinger systems, finite difference, splitting and composition methods

Gold degree polynomials with even second highest term with 2-adic value 1 mod 4 are not exceptional APN in the context of the APN function conjecture

Carlos A. Agrinsoni Santiago, Department of Mathematics, University of Puerto Rico at Rio Piedras.
Heeralal Janwa, Department of Mathematics, University of Puerto Rico at Rio Piedras.
Moises Delgado, Department of Mathematics, University of Puerto Rico at Cayey.

An almost perfect non-linear (APN) function is a function on the field $\mathbb{F}_2^n$ directional derivative at every point is at most two to one. APN function have applications in cryptography and coding theory. A function defined over $\mathbb{F}_{2^n}$ is exceptional APN if it is APN in infinitely many extensions of $\mathbb{F}_{2^n}$. A well known conjecture states that the only two families of exceptional APN function up to CCZ equivalence there only two families of exceptional APN functions, namely the Gold and the Kasami monomials. When the degree of the polynomial is odd the only remaining cases

are the Gold and Kasami Welch degree. Polynomials of the form $f(X) = X^{2^n+1} + h(X)$ are not exceptionally APN when $h(X)$ is a nonlinear polynomial of odd degree. In this presentation we will prove that $f(X)$ is not exceptional APN when $\deg(h) = 2^m e$, where $e \cong 1 \mod 4$, and e not a Gold exponent.

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Keywords: exceptional APN conjecture, gold case, polynomials

AMS Classification: 94B, 11T

Additive Decompositions of Matrices with Applications to Total Acquisition in Graphs

Austin Allen et al., Carnegie Mellon University.

The question of graph acquisition, recently studied in a series of papers by Doug West and his REGS students, led to the conjecture that each diameter two graph has acquisition number 2 or lower. In 2015, Rose McCarty led an REU team that showed, in unpublished work, that the acquisition number of a diameter 2 graph is 3 or lower provided that the following auxiliary result, on zero-one matrices, could be established. Conjecture: Each integer $n \times n$ matrix with row and column sums equal to n can be decomposed as $A + B$, where the row and column sumsets of A, B are, respectively $\{1, 2, ..., n\}$ and $\{0, 1, ..., n-1\}$. Although the conjecture remains unproven, here we present four methods, from different areas of mathematics, which we have attempted. These are the Combinatorial Nullstellensatz, a Graph theoretic approach, the Lovasz Local Lemma and a Linear Programming approach.

Acknowledgements: This work was completed at the Puerto-Rico/East Tennessee State REU in Combinatorics, Probability, and Algebraic Coding Theory. This is joint work with Sebastian Papanikolaou-Costa, Universidad Ana G. Mendez; Heidi Perez, Inter American University of Puerto Rico - Bayamon Campus; Doel Rivera, Pontifical Catholic University of Puerto Rico; Dorothea Rugg, Haverford College.

Keywords: total acquisition, graph theory, linear programming, combinatorial nullstellensatz, Lovasz local lemma

Enumerating "good" permutations

Austin Allen et al., Carnegie Mellon University.

Two permutations π and σ are said to be order isomorphic if they are equivalent after "pattern" reduction. We call a permutation "good" if the first ℓ entries are order isomorphic to the last ℓ entries. Given a k, we wish to enumerate all good permutations on $[k]$ which overlap consecutively. We do this for whenever $\ell \leq k/2$, and via experimentation we conjecture that whenever $\ell > k/2$ the number of good permutations is polynomial in k. We also make a connection of enumerating good permutations to the problem of explicitly determining the expected number of distinct permutation patterns contained in a random permutation.

Acknowledgements: This work was completed at the Puerto-Rico/East Tennessee State REU in Combinatorics, Probability, and Algebraic Coding Theory. This is joint work with Vonnie Dobbs, Marquette University; Sebastian Papanikolaou-Costa, Universidad Ana G. Mendez; Christopher Soto, Queens College, CUNY; Lino Yoshikawa, University of Hawaii at Hilo.

Keywords: permutation patterns, good permutations, enumerative combinatorics, experimental mathematics

True Parameters of Algebraic Geometry Codes using Groebner Bases

Austin Allen, Carnegie Mellon University.

Algebraic Geometry (AG) codes are a class of codes studied for their resemblance to Reed-Solomon codes and their improvement of the Gilbert-Varshamov bound. These codes are defined by their parameters, i.e. defined by their length, dimension, and minimum distance. A particular parameter that is of interest is a code's minimum distance. The theory of algebraic function fields often gives nonconstructive bounds on the dimension, minimum distance, and decoding of AG codes. In this work we propose Groebner bases techniques as a simpler method to constructively determine the dimension, minimum distance, and decoding algorithms of AG codes generated from the Giulietti-Korchmaros curve and the Garcia-Guneri-Stichtenoth curve. We also expect to have explicit Locally Recoverable Codes (LRC's) generated from these curves.

Acknowledgements: This work was completed at the Puerto-Rico/East Tennessee State REU in Combinatorics, Probability, and Algebraic Coding Theory.

Keywords: slgebraic geometry codes, Groebner bases, Giulietti-Korchmaros curve

Maximal regularity for degenerate multiterm fractional integro-differential equations in Banach spaces

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

Fractional differential equations are increasingly used to model systems arising in various areas of science and technology. These include equations that appear in viscoelastic models, rheology, and more generally phenomena with memory effects.

We use the theory of operator-valued Fourier multipliers, to obtain maximal regularity results for a large class of degenerate multiterm fractional differential equations in Banach spaces. We consider the right-sided Liouville fractional derivative on the real axis for functions belonging to Lebesgue-Bochner spaces. We present some applications.

Keywords: well-posedness, maximal regularity, operator-valued Fourier multiplier, fractional derivative.

Assessment Mitigations Strategies for SARS-CoV-2 using a mathematical model

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COVID-19 disease is a respiratory infection caused by the SARS-CoV-2 virus and was declared a pandemic on March 11, 2020. Different interventions have been implemented to mitigate and/or suppress the epidemic in each country. In Puerto Rico, several executive orders and different resources as the Covimeter, Bio-portal, and SMICRC have being established to contact trace and cut transmission chains of the virus while using Non-Pharmaceutical Interventions to manage the epidemic. The spread of a disease in a specific population is a function, in part, of the population's movements from one city to another. In order to know how COVID-19 disease is spreading in a particular population affected by the daily mobility of the population in a specific region of Puerto Rico, we need to consider the disease's biological factors and metapopulation analysis. Using a mathematical model, we aim to analyze the actions taken to mitigate the virus's spread based on data behavior and understand how mobility in the island works. Preliminary results indicate that there is an increase in new cases by applying less restrictive measures in the executive orders. After running the simulations with different parameters on the protective measures, when used, the effective reproductive number decreases. Other mitigation strategies like mask usage, physical distancing, border closure, and contact-tracing are interventions whose effectiveness is about to be tested in our model using the Puerto Rican data.

Acknowledgments: Thanks to the Interdisciplinary Research Institute, the UPR-IPERT program and the Puerto Rico Louis Stokes Alliance for Minority Participation (PRLSAMP) for the funding (NSF-HRD 2008186) and support on this research work.

Keywords: COVID-19, metapopulation, epidemiological model

An Implementation of McEliece Public Key Cryptosystems for Post-Quantum Cryptography Using AG Codes and Analysis

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Current public key cryptography standards recommended by the National Institute of Standards and Technology (NIST) and heavily used in commerce, such as: RSA (Rivest et al. 1978) and several Elliptic Curve Cryptosystems rely on the fact that the problem of factorizing and finding discrete logarithm factor numbers using a quantum computer fast (Shor 1997), rendering these cryptosystems non-viable. One of the cryptosystems that is highly promising in the Post-Quantum world, is the McEliece (1978) public-key cryptosystem, based on the theory of error-correcting codes. The system uses the generator matrix of an error correcting code with good rate, error correction capability, and a fast decoding algorithm to encrypt and decrypt data. The original system uses a class of codes known as Goppa Codes, with a large number of in-equivalent systems, and a good decoding algorithm with complexity O(n log n) (Shor 1997). Because the problem of decoding a general linear code is known to be NP-Complete (Johansson et al. (2002)), and brute force attacks have been show to have a large work factor, these public key cryptosystems are so far regarded as safe, even from attack by quantum computers. In this talk, we will present an implementation of the McEliece Cryptosystem using different families of Algebraic Geometry (AG) codes, and we compare and analyze the resulting encryption/decryption methods, their running times and their parameters. We will demonstrate implementiaons in functional field arithmetic in SAGE involving Berlekamp-Massey and Patterson algorithms.

Acknowledgements: Andres Arroyo was supported by the Bridge to Doctorate Fellowship of UPRrp supported by NSF.

Keywords: McEliece public key cryptography; post-quantum cryptosystems; function fields; AG codes

High-frequency dynamics of magnetic antivortex states

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Grant Riley, National Institute of Standards and Technology.
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Non-uniform magnetic spin textures, such as skyrmions and vortices among others, are attracting increasing interest due to their unique topological properties as well as their potential for applications. However, only a few investigations have been conducted on magnetic antivortices (AV), in part due to the difficulty in creating stable AV compared to other magnetic states. The AV is

predicted to have similar properties to its physical counterpart, the magnetic vortex, such as an in-plane spin distribution and a nanometer-scale core region which is magnetized perpendicular to the plane. In addition, an AV is predicted to have a rich dynamic response, similar to what has been observed for vortices, including a sub-GHz gyrotropic mode and a number of higher frequency modes.

This work discusses the high frequency dynamics of an AV state confined at the intersection of 37-nm thick Permalloy microstrips that are part of a pound-key like shape structure. The main methodology was based on micromagnetic simulations, however comparison with the experimental results is also discussed. Both in-plane (30-ps duration to suppress the gyrotropic mode) and out-of-plane excitations were considered. Spatial mode maps obtained by Fourier analysis show pairs of azimuthal modes that travel around the AV center with opposite handedness in response to an in-plane field, while for an out-of-plane excitation modes with standing radial-like character, with strong, quantized excitations along the structure diagonal, are found instead. For the higher order modes, propagating spin waves are observed in the long rectangular legs for both excitation directions. The spin waves in the legs are sensitive to the spin state at the intersection and the dominant wavelength is correlated with the wavelength in the AV region.

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Keywords: physics, micromagnetic, spin-waves, dynamics, ferromagnetism, nanotechnology, magnonics.

La Uña Taptana como recurso didáctico para el desarrollo del pensamiento numérico en la primera infancia

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Joana Abad Calle, Universidad Nacional de Educación, Ecuador.

El sentido numérico y en particular la comprensión del número en la educación inicial en Ecuador es un aspecto que ha sido obviado en el currículo. Green (1991) caracteriza esto en tres aspectos: capacidad de hacer cómputos con fluidez, de hacer estimados y juicios e inferencias. El objetivo de la investigación fue desarrollar el sentido numérico en niños de educación inicial a partir del material concreto Uña Taptana1 con el proceso etnomatemático del contar y aspectos determinantes para la comprensión del número de Van Luit y Van Rijt (1997). Se ha realizado una investigación de estudio de caso con 29 docentes de educación inicial. Para ello, se ha desarrollado un taller de tres días con los docentes de manera virtual sobre el uso de la Uña Taptana para desarrollar el sentido numérico en la primera infancia. La información fue recolectada a través de un cuestionario y tareas de ejecución desarrollado por los docentes como parte de la evaluación del taller.

Los resultados señalan que el 79% de los docentes participantes del taller entienden que el material concreto Una Taptana desarrolla el pensamiento numérico y provoca el razonamiento lógico en los niños de 3 y 4 años. Incluso, los docentes afirman en un 100% que el uso de este recurso didáctico desarrolla actitudes favorables hacia la comprensión del número – concepto abstracto de la matemática en los inicios de la formación académica del niño. El 89.7% afirma que los niños en este nivel aprenden las matemáticas de forma concreta a través del recurso didáctico, en la

que el proceso del contar se da a través del ordenar, seriar, clasificar, correspondencia biunívoca, conteo estructurado y no estructurado. No obstante, los docentes señalan que desarrollar el sentido número en este nivel educativo en la edad de 3 años esta 'En Proceso' (ordenar, clasificar y secuenciar), a diferencia de los de 4 que están en nivel 'Alcanzado'. Sin embargo, en las destrezas de correspondencia biunívoca, conteo estructurado y no estructurado están en nivel 'Inicio' y 'En Proceso' respectivamente.

Reconocimiento: Esta investigación es parte de los resultados del proyecto de investigación 'El sentido numérico en la educación inicial y básica elemental: proceso etnomatemático del conteo' de la Universidad Nacional de Educación – 2019-2020.

Palabras clave: sentido numérico, Uña Taptana, proceso del contar, niños, enseñanza de matemáticas

Regularity theory for nonlocal space-time master equations

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Marta de Leòn-Contreras, University of Reading.
Pablo Raúl Stinga, Iowa State University.

We analyze regularity estimates for solutions to nonlocal space time equations driven by fractional powers of parabolic operators in divergence form. These equations are fundamental in semipermeable membrane problems, biological invasion models and they also appear as generalized Master equations. We develop a parabolic method of semigroups that allows us to prove a local extension problem characterization for these nonlocal problems. As a consequence, we obtain interior and boundary Harnack inequalities and sharp interior and global parabolic Schauder estimates for solutions. For the latter, we also prove a characterization of the correct intermediate parabolic Holder spaces in the spirit of Sergio Campanato.

Re-identification Approaches for a Markerless Animal Monitoring System in Open Space Setup

Jeffrey Chan, Department of Mathematics, University of Puerto Rico at Río Piedras.
Rémi Mégret, Department of Computer Sciences, University of Puerto Rico at Rio Piedras.
José Agosto, Department of Biology, University of Puerto Rico at Rio Piedras.
Tugrul Giray, Department of Biology, University of Puerto Rico at Rio Piedras.

Recent advances in deep neural networks have transformed various areas in science and industry by enabling the automatic analysis of complex data with accuracy at times matching those of humans. In particular, Convolutional Neural Networks have achieved excellent performance in face recognition and person re-identification from image and video. Performance for re-identification in the animal domain is currently not at the same level. One important factor is the lack of large well-annotated image datasets, which are an important step to achieve high performance. Human datasets from many sources including social media can be leveraged to obtain annotated data. In

contrast creating datasets for specific animals generally requires extra data acquisition and expert annotation. In some cases, even experts cannot provide a good identity annotation of individual animals, such as in honeybees, without tagging them with markers. This talk reviews exciting and novel ideas towards animal identification in open space setup that do not require manual identity annotations nor markers. The discussion focuses on exploiting tracking information to learn discriminative features and self-supervised learning to achieve robust representations for re-identification. Developing an animal identification system without the need of manual identity annotations will enable the monitoring of animal behavior at finer grain and larger scale than currently possible. In complex animal societies such as honeybees, this information will be crucial to obtain new insights into their biology and their interaction with environmental factors while reducing to a minimum the need for the manipulation of the individuals or for more intrusive monitoring setups.

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Keywords: animal identification, deep learning, self-supervised learning, discriminative features

Genus integration, abelianization and differential characters

Iván Contreras, Amherst College, Massachusetts, USA.
Rui Fernandes, University of Illinois, Urbana-Champaign, Illinois, USA.

The genus integration of a Lie algebroid was introduced in joint work with Rui Fernandes as the quotient space of A-paths by A-homologies. We prove that such integration is the abelianization of the Weinstein groupoid, and we also show that the obstructions to smoothness of the genus integration are controlled by the extended monodromy groups. In this talk we will survey the integration problem of Lie algebroids and these new results, which can be seen as a generalization of the Hurewicz theorem in algebraic topology. We will also present an ongoing work on the particular case of the prequantization Lie algebroid associated with a closed 2-form. In particular our results recover the prequantization condition as well as the usual description of principal circle bundles with connection via differential characters.

Acknowledgments: This project was partially supported by the NSF grants DMS-1405671, DMS-1710884, and a Simons Fellowship in Mathematics.

Keywords: Lie algebroids, monodromy, genus integration, Hurewicz theorem, abelianization, differential characters.

A generalization of a theorem of Bartoli and Schmidt on the existence of an absolutely irreducible component of a hypersurface over a finite field and its applications and ramifications

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Carlos A. Agrinsoni Santiago, Department of Mathematics, University of Puerto Rico at Rio Piedras.
Heeralal Janwa, Department of Mathematics, University of Puerto Rico at Rio Piedras.

Many applications of algebraic geometry and coding theory require the existence of an absolute irreducible factor of a hypersurface. Finding a criterion to determine the existence of an absolute irreducible factor is rare. Finding absolutely irreducible factors is related to determining the properties of the corresponding multivariate polynomial. A few authors have authors have formulated diverse criteria based on different properties of the polynomials.

In 2019 Bartoli and Schmidt provided a criterion for polynomials in two variables to guarantee the existence of an absolute irreducible factor given the tangent cone of the polynomial satisfy certain conditions. We generalized this criterion to apply to several a polynomial in variables and to apply to other situations apart from the tangent cone. We present an application of this new criterion to the exceptional almost perfect nonlinear conjecture.

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Keywords: exceptional APN conjecture, absolute irreducibility testing

AMS Classification: 94B, 11T

Qualitative and numerical results for a PDE model for chemotaxis with logistic growth

Padi Fuster Aguilera, Department of Mathematics, Tulane University.
Vincent R. Martinez, Department of Mathematics, Tulane University.
Kyle K. Zhao, Department of Mathematics, Tulane University.

In this talk, we will discuss a particular one-dimensional PDE model for chemotaxis with logarithmic sensitivity and logistic growth for the organism population density. For the initial boundary value problem with Neumann boundary conditions, we will present analytic results on the long-time behaviour of the solution which converges to a constant state: its carrying capacity. This is in contrast with results obtained by Zhao et al for the model without logistic growth, in which the solution converges towards its initial average. Moreover, we will present data from numerical simulations that show a separation of scale phenomenon and provide a detailed short time behaviour of the solution.

Acknowledgements: This research was partially supported by the PSC-CUNY Research Award Program under grant PSC-CUNY 62239-00 50, and the Simons Foundation Collaboration Grant for Mathematicians No. 413028.

Keywords: PDE, chemotaxis, global existence

The Expected Number of Distinct Consecutive Patterns in a Random Permutation

Anant Godbole et al., East Tennessee State University.

Let π_n be a uniformly chosen random permutation on $[n]$. Using an analysis of the probability that two overlapping consecutive k-permutations are order isomorphic, we show that the expected number of distinct consecutive patterns in π_n is $\frac{n^2}{2}(1 - o(1))$. This exhibits the fact that random permutations pack consecutive patterns near-perfectly.

Acknowledgments: This is joint work with Austin Allen, Carnegie Mellon University; Dylan Cruz Fonseca, University of Puerto Rico, Río Piedras; Veronica Dobbs, Marquette University; Egypt Downs, Virginia State University; Evelyn Fokuoh, East Tennessee State University; Sebastián Papanikolaou Costa, Universidad Ana G. Méndez; Christopher Soto, Queens College, CUNY; Lino Yoshikawa, University of Hawaii at Hilo.

P-recursivity of some families of Boolean functions under biased Walsh transforms

Axel O. Gómez-Flores, Department of Mathematics, University of Puerto Rico at Río Piedras.
Luis A. Medina, Department of Mathematics, University of Puerto Rico at Rio Piedras.

We showed that, under certain conditions, restricted and biased exponential sums and Walsh transforms of symmetric and rotation symmetric Boolean functions are, as in the case of the non-biased domain, C-finite sequences. We also showed that under other conditions, these sequences are P-recursive, which is somewhat different behavior than their non-biased counterparts. We also show that exponential sums and Walsh transforms of a family of rotation symmetric monomials over the restricted domain $E_{n,j} = \{\mathbf{x} \in \mathbb{F}_2^n : wt(\mathbf{x}) = j\}$ ($wt(\mathbf{x})$ is the Hamming weight of the vector $\mathbf{x}$) are given by polynomials of degree at most j, and so, they are also C-finite sequences. Finally, we also present a study of the behavior of symmetric Boolean functions under these biased transforms.

Involutions of $\mathbb{F}_q$ obtained from binomials of the form $x^m(x^{\frac{q-1}{2}}+a)$

Lillian González Albino, Department of Mathematics, University of Puerto Rico at Río Piedras.
Ivelisse Rubio, Department of Computer Sciences, University of Puerto Rico at Rio Piedras.
Ariane Masuda, Department of Mathematics, New York City College of Technology of The City University of New York.

Permutations over finite fields have many applications ranging from cryptography and combinatorics to theory of computation. For many of these applications it is important to find permutations with a small memory footprint that are easy to implement. A good option is to use permutations generated by polynomials that are their own inverse, called *involutions*. In 2017, Castro et al. gave explicit formulas for monomial involutions over $\mathbb{F}_q$ and their fixed points. The number of fixed points is important in applications in cryptography since it is related to the non-linearity of a permutation. In 2018, Zheng et al. characterized involutions of the form $x^m h(x^s)$ over $\mathbb{F}_q$, but an explicit formula for m and the amount of fixed points were not given. In this talk we present results on explicit formulas for binomial involutions $x^m(x^{\frac{q-1}{2}}+a)$ over $\mathbb{F}_q$, and their fixed points.

Acknowledgements: This research was sponsored in part by Puerto Rico Louis Stokes Alliance For Minority Participation (PR-LSAMP).

Keywords: permutation polynomials, involutions, fixed points, finite fields

Proyecto: Developing Technological Pedagogical Content Knowledge of Pre-Service Math Teachers

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Wanda Villafañe Cepeda, Universidad de Puerto Rico en Río Piedras.
Gloriana González, Universidad de Illinois.

Presentamos los hallazgos y logros del proyecto interinstitucional **Developing Technological Pedagogical Content Knowledge of Pre-Service Math Teachers (ELICIT-Math)** en su primer año de implantación. ELICIT-Math tiene como meta el **establecimiento de prácticas** para ayudar a los futuros maestros de matemáticas del nivel secundario a diseñar lecciones incorporando tecnología que permite la interconectividad en el salón de clases.

El objetivo principal es desarrollar el conocimiento del contenido pedagógico tecnológico (TPACK, por sus iniciales en inglés) para mejorar las capacidades de los estudiantes en cuanto a la compresión matemática, la fluidez en los procesos, la capacidad estratégica, el razonamiento adaptativo y la disposición productiva.

Se describirán los cambios que se realizaron al curso de métodos **EDPE 4030 – Manipulativos y tecnología en matemáticas secundaria** para integrar las estrategias de "Lesson Study", el TPACK, la orquestación instrumental y los espacios híbridos. Incluiremos las iniciativas de colaboración con el centro de prácticas, las estrategias para mejorar la transición de los cursos de métodos a los de prácticas clínicas, los métodos de investigación utilizados para contestar las preguntas de investigación1 y las dificultades causadas por el cierre debido a la pandemia. Final-

mente, describiremos los cambios que realizamos para adaptarnos a las restricciones impuestas por la emergencia sanitaria, en especial, lo relacionado con el aprendizaje en línea.

Agradecimientos: Proyecto sufragado con fondos de la National Science Foundation, Division of Undergraduate Education (#1930950 & #1930971).

Nota: Las preguntas de investigación son: ¿De qué manera los futuros maestros aprenden a aplicar los principios de planificación de orquestaciones instrumentales e implantar lecciones de matemáticas para promover la proficiencia matemática de los estudiantes? ¿Qué apoyos de los maestros cooperadores permiten a los futuros maestros a aplicar la orquestación instrumental en sus lecciones?, ¿Cómo el modelo modificado de "Lesson Study" brinda oportunidades para crear espacios híbridos que conectan los cursos de métodos y las experiencias clínicas?

Regressions viewed as projections

Alvaro Lecompte Montes, Inter American University, San Germán Campus.

With large data samples, the use of vectors and matrices is becoming common in statistics. We use here that means and OLS regressions can be viewed as orthogonal projections and apply geometrical concepts such as angles and distances to evaluate them. This allows new insight for the examination of set of data. As an example, this analysis is applied to one variable distributions, which are viewed as more detailed projections than the projection to the constant vector. Similarly, stepwise regressions using dummy variables arise naturally as better suited projections when there is non-linear or heteroskedastic dependent behavior.

Computation of optimal time for application of fungal pathogen to control coffee berry borer infestation

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Amitabha Bose, Department of Mathematical Sciences, New Jersey Institute of Technology, Newark, NJ.
Paul Bayman, Department of Biology, University of Puerto Rico at Río Piedras.

The coffee berry borer (CBB) is a small insect that penetrates the coffee berry, eats its seed and reproduces inside it. The CBB causes considerable loss to coffee production worldwide. In this talk we present a mathematical model of coffee berry infestation by the CBB over multiple seasons. The model consists of a system of nonlinear ordinary differential equations for the interaction dynamics of the coffee berry and the CBB along a coffee season, which includes the effect of coffee harvesting, in conjunction with a one-dimensional map to extend the population dynamics over multiple coffee seasons. The map has three fixed points; two are stable and one is unstable. The stable fixed points correspond to either CBB elimination or complete infestation by the CBB. The unstable fixed point acts as a threshold that separates initial CBB population values that are attracted to one of these stable solutions. We use two parameters to control the threshold value: coffee harvest-

ing percentage over multiple seasons and the initial time at which to apply the fungus (which kills the CBB) each year. For a prescribed percentage of harvesting we compute the time at which the fungus must be introduced such that the threshold value is maximized. We found that the starting day to apply the fungus depends on the percentage of coffee harvested each year and that day is within one month after the coffee berry is formed.

Acknowledgements: This project was supported by USDA Specific Cooperative Agreement, USA 58-1245-4-083 and a grant from the Puerto Rico Science and Technology Research Trust.

Keywords: coffee berry borer, mathematical modeling, one-dimensional map, pest control management, fungal pathogen

Walsh-Hadamard transforms of generalized p-ary functions and C-finite sequences

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Leonid B. Sepúlveda, Department of Mathematics, University of Puerto Rico at Rio Piedras.
César Serna-Rapello, Department of Mathematics, University of Puerto Rico at Rio Piedras.

In this talk we show that Walsh-Hadamard transformations of generalized p-ary functions whose components are symmetric, rotation symmetric or a combination or concatenation of them are C-finite sequences. This result generalized many of the known results for regular p-ary functions. We also present a study of the roots of the characteristic polynomials related to these sequences and show that properties like balancedness and being bent are not shared by the underline p-ary functions.

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Keywords. Walsh-Hadamard transform, rotation functions, trapezoid functions, symmetric functions, exponential sums, linear recurrence, generalized p-ary functions.

Cavitation of a spherical body under mechanical and self gravitational forces

Pablo V. Negrón-Marrero, Department of Mathematics, University of Puerto Rico at Humacao.
Jeyabal Sivaloganathan, Department of Mathematical Sciences, University of Bath, UK.

In this paper we look for minimizers of the energy functional for isotropic compressible elasticity taking into consideration the effect of a gravitational field induced by the body itself. We consider the displacement problem in which the outer boundary of the body is subjected to a Dirichlet type boundary condition. For a spherically symmetric body occupying the unit ball, the minimization

is done within the class of radially symmetric deformations. We give conditions for the existence of such minimizers, for satisfaction of the Euler-Lagrange equations, and show that for large displacements the minimizer must develop a cavity at the centre. A numerical scheme for approximating these minimizers is given together with some simulations that show the dependence of the cavity radius and minimum energy on the displacement and mass density of the body.

Keywords: nonlinear elasticity, cavitation, self-gravity

A general stochastic maximum principle for mean-field controls with regime switching

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D.T. Nguyen, Department of Applied Mathematics, Ho Chi Minh City University of Technology, Ho Chi Minh City, Vietnam.

Motivated from large-scale controlled systems in random environment with weak dependences of the agents, this talk focuses on regime-switching controlled diffusions with mean-fields interactions. First, the conditional mean-field is used to model the controlled dynamic systems and the optimization process. Then, analysis of variational and adjoint equations using forward and backward stochastic differential equations with regime-switching and conditional mean-field are carried out to solve the control problem. Necessary conditions for optimality are obtained without assuming the convexity of the control space. Finally, an example on conditional mean-variance portfolio selection with regime switching is given to illustrate the sufficient conditions for optimality.

Nonlinear Nonlocal Operators with Comparisons to Classical Nonlinear Diffusion

Mikil Foss, Department of Mathematics, University of Nebraska-Lincoln.
Hayley A. Olson, Department of Mathematics, University of Nebraska-Lincoln.
Petronela Radu, Department of Mathematics, University of Nebraska-Lincoln.

Nonlocal calculus operators were generated to help describe phenomena which cannot be captured by standard partial differential equations – such as super- or sub-diffusion – and have many applications ranging from subsurface transport to image processing to phase transitions. Nonlocal operators are integral operators which act on a small horizon around the point of interest; often, this is a ball of radius δ. There is desire to define nonlocal operators that behave similarly to classical differential operators as this δ-horizon converges to zero.

In this work, we consider a class of nonlocal operators which converge to the classical nonlinear diffusion model as the δ-horizon shrinks. Classical nonlinear diffusion models capture behavior such as temperature or concentration dependent diffusion which can be useful in the nonlocal framework. This work includes the convergence of the actions of the nonlocal and classical operators as well as convergence of solutions to analogous systems of equations in the nonlocal and classical settings.

Implementation of the ECS curriculum in spanish: experiences and results from a teacher-centered researcher-practitioner partnership

Edusmildo Orozco et al., College of Natural Sciences, University of Puerto Rico at Río Piedras.

To address the need for integration of Computer Science Education in Puerto Rico's high schools, a group of educators from the Department of Computer Science teamed with the College of Education of the UPR-RP. Since 2017, the National Science Foundation (NSF) has funded the project Exploring Computer Science (ECS4PR). ECS4PR is facilitating the implementation of the Exploring Computer Science (ECS) curriculum in Spanish through the Professional Development (PD) of high school teachers. Two key aspects in this process are: First, the establishment of a researcher-practitioner partnership (RPP). Second, beyond a simple translation of the ECS curriculum, the cultural and linguistic adaptation of it.

In this work, we share the results and experiences regarding the two year implementation of the last teacher cohort and discuss the development of the RPP and the ECS PD workshops. We also present our approach for the cultural and linguistic adaptation of the ECS curriculum and its challenges. Finally, we share our preliminary data from (1) pre/post-survey assessments of the ECS-PD for teacher participants; (2) students' assessment developed by SRI International; and (3) other instruments that assess teachers' perceptions about the translated curriculum, and their efforts to implement the ECS curriculum.

At present, we have a stable RPP community that has evolved to address teachers' needs through peer-coaching and teacher-led workshops. In addition, we have almost completed the adaptation of ECS v9.0. We are revising our research instruments to improve data acquisition in order to scale up our efforts to reach more schools in Puerto Rico. This goal will require the commitment from the Puerto Rico Department of Education and a broader community of educators.

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Keywords: exploring computer science, ecs, professional development, computer science education, researcher-practitioner partnership.

Minimum Rank of Regular Bipartite Graphs

Sebastian Papanikolaou-Costa, Universidad Ana G. Mendez.

The rank of a graph G is defined as the rank of its adjacency matrix A. The smallest rank among all the matrices with the same pattern of non-zeros entries as A, over the field $\mathbb{F}$, is called the minimum rank of A over $\mathbb{F}$. The smallest among all the minimum ranks of A (considering all the fields) is called the minimum rank of G. In this work, we study regular bipartite graphs. Specifically, we used linear recursions with linear complexity 2 and zero forcing sets to prove that the minimum rank of a $(n-1)$-regular bipartite graph, with n vertices on each side, is 4. The matrix that attains the minimum rank of G is an extended parity check matrix for the graph code of G, which has the highest dimension possible (depending on the component code to be used).

Acknowledgements: This is joint work with an L. Carrasquillo-López, Axel O. Gómez-Flores, Lucy Martinez, Heidi D. Pérez-Diana, Lino Yoshikawa, and Fernando L. Piñero González (advisor).

Hermitian lifted codes

Fernando L. Piñero González et al., University of Puerto Rico at Ponce.

We construct codes for local recovery of erasures with high availability and constant-bounded rate from the Hermitian curve. These new codes, called Hermitian-lifted codes, are evaluation codes with evaluation set being the set of $\mathbb{F}_{q^2}$-rational points on the affine curve. The novelty is in terms of the functions to be evaluated; they are a special set of monomials which restrict to low degree polynomials on lines intersected with the Hermitian curve. As a result, the positions corresponding to points on any line through a given point act as a recovery set for the position corresponding to that point.

Acknowledgements: This is joint work with Hiram H. López, Beth Malmskog, Gretchen L Matthews, and Mary Wootters.

Keywords: hermitian codes, locally recoverable codes, AG codes

Connections between 2-dimensional and multidimensional Costas Arrays

Andrés Ramos, University of Puerto Rico at Río Piedras.
Ivelisse Rubio, University of Puerto Rico at Río Piedras.

A Costas Array is a $n \times n$ grid that has one dot per column and row with the property that all vectors between two dots are distinct. We represent Costas Arrays as permutation matrices where the dots correspond to a 1's and the empty spaces correspond to 0's. This curious family of permutations arise from applications to sonar engineering. Generalizations to multiple dimensions,

where the array lie on a $n_1 \times n_2 \times \cdots \times n_{m-1} \times n_1 n_2 \cdots n_m$ grid, are useful for new applications. In this work we study properties of these $(m+1)$-dimensional Costas Arrays and their connections to 2-dimensional Costas Arrays.

Keywords: Costas arrays, multidimensional arrays, finite fields

Multivariate fixed rank Gaussian Process Regression for interatomic potentials

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Gaussian Process Regression (GPR) has been implemented for decades in the context of spatial statistics (a field where it's called kriging) and more recently adopted in the machine learning domain, especially as a surrogate model for computer experiments. It is well known that GPR results in the (estimated) best linear unbiased prediction of outputs using inputs while also quantifying uncertainty of such predictions. However, GPR cannot be implemented if the training data size n is too large, since the computational burden is $O(n^3)$, and storage of the input covariance matrix is also expensive. Furthermore, GPR is almost always implemented assuming the input dependence is a stationary process. We propose a fixed rank GPR algorithm that approximates GPR through the use of truncated basis functions. The method is computationally faster than GPR while guaranteeing positive definiteness of the input covariance matrix. Moreover, our method does not require a stationarity assumption. For the objective of modeling interatomic potentials, we derive a multivariate fixed GPR and study its performance.

Acknowledgements: Work was partially supported by NSF Grant OAC-1940179.

Keywords: GPR, kriging, big data, interatomic potentials, emulator, multivariate model

Involution derangement graphs

Vonnie Dobbs, Marquette University.
Lucy Martinez, Stockton University.
Doel Rivera Laboy, Pontifical Catholic University of Puerto Rico.
Thea Rugg, Haverford College.

The derangement graph on all permutations is defined as the graph whose vertex set is the set of all permutations on $[n]$ with two vertices being adjacent if they have no position in common. Much is known about this graph, but specifically as a Cayley Graph whose vertex set is a group. Permutations have plenty of interesting subsets, which makes us question, what happens if we restrict the vertex set to one of these subsets? We examine the involution derangement graph, which is a subgraph of the permutation derangement graph. The involution derangement graph is the derangement graph whose vertex set is the set of all involutions on $[n]$, with an involution being a permutation whose inverse is itself. We study and compare classic graph theory properties between

the two graphs, such as degree, diameter, chromatic number, independence number, and more.

Acknowledgments: This work was conducted under the supervision of Prof. Anant Godbole, of the PR-TN REU in Probabilistic Combinatorics and Algebraic Coding Theory and the support of the PR-LSAMP program.

Los lenguajes de programación como medio para la enseñanza de las matemáticas

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Pedro Arraiza González, Robinson School, PR.

Los lenguajes de programación como herramientas para la enseñanza de las matemáticas han sido considerados desde los años 60s, cuando el Dr. Seymour Papert crea su lenguaje de programación llamado Logo. Como consecuencia se comienza a investigar sobre la efectividad de dichas herramientas en el aprendizaje. Aunque los resultados de las primeras investigaciones fueron mixtos, recientemente se ha comenzado a explorar nuevamente la idea del uso de los lenguajes de programación para la enseñanza de las matemáticas dado a la alta integración de la tecnología en la sociedad actual. Los nuevos resultados son esperanzadores, pero aún siguen siendo inconclusos, dado a la complejidad de los sistemas que componen los procesos educativos y como estos interactúan con los medios por los cuales se llevan a cabo estas investigaciones.

Una de las implicaciones más importantes del uso de los lenguajes de programación en la enseñanza de las matemáticas es poder proveer experiencias de aprendizaje que ayuden a desarrollar los pensamientos concretos al usar, explorar, y jugar con las matemáticas, lo que por consecuencia ayudará a desarrollar los procesos de abstracción que son necesarios para desarrollar estructuras mentales sobre conceptos matemáticos más avanzados. Los grandes matemáticos se conocen, no por su habilidad para llevar a cabo procesos matemáticos, sino por su habilidad para crear matemáticas y pensar sobre problemas complejos – un efecto secundario de la exploración y juego con las matemáticas – siendo esto alusivo al proceso de aprendizaje construccionista que propone que las ideas matemáticas se desarrollen por medio de la construcción activa de objetos tangibles, sean estos objetos físicos o mentales. Presentaremos varios ejemplos de actividades didácticas conducentes a la exploración de ideas matemáticas por medio de la programación para estudiantes de escuela intermedia.

Palabras clave: educación matemática, construccionismo, lenguajes de programación, tecnología educativa

Manifestación de las creencias del maestro de matemáticas de escuela superior, sus prácticas y el discurso en la solución de problemas: Un estudio de caso

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A través de un estudio un estudio de caso, que lo constituyó el proceso pedagógico en la sala de clases de una maestra de Matemáticas de nivel superior del Departamento de Educación de Puerto Rico, se logró explorar y describir las creencias de los maestros de Matemáticas de escuela superior sobre la enseñanza y aprendizaje de las Matemáticas a través de la solución de problemas, los elementos que influyen principalmente en sus prácticas de enseñanza, y la relación de las creencias con el discurso empleado en su práctica. La recopilación de información consistió en entrevistas, observaciones dentro del contexto y el análisis de documentos, proveyendo una descripción de la complejidad idiosincrásica del fenómeno. Para analizar la información utilizamos el modelo de Wolcott, enfatizando en la descripción de los hechos, el análisis de las interrelaciones entre los diferentes elementos del fenómeno y la interpretación de los significados que emergieron del contexto estudiado.

Los hallazgos demostraron que las decisiones e interpretaciones que llevó a cabo la maestra en su contexto escolar exhibían peculiaridades vinculatorias inconfundibles de sus creencias sobre aspectos pedagógicos utilizados para estructurar sus clases, las normas sociales y sociomatemáticas que regularon los patrones discursivos y dialécticos, y el discurso matemático que promovió el aprendizaje de los estudiantes. De la investigación se desprende que la naturaleza del discurso empleado a través de la solución de problemas tuvo su origen en las epistemologías personales, experiencias y expectativas de logro. Esto propició un ambiente de aprendizaje que permitió a sus estudiantes involucrarse en conversaciones académicas donde estos presentaron diversas estrategias a sus pares, dentro de grupos pequeños o la clase entera, mediante la interacción sociocultural y patrones de participación fundamentados en la dinámica de preguntas y respuestas que promovieron la negociación de significados y entendimientos compartidos.

Finalmente, si registramos las creencias de los maestros y sus posturas filosóficas de cómo se enseña y aprende, los patrones discursivos y las normas que regulan dichas dinámicas, podemos comprender profundamente las relaciones complejas que promueven la construcción de entendimientos matemáticos a través de un discurso rico y productivo dentro del contexto cultural de los estudiantes.

Agradecimientos: Al director de disertación, el Dr. Omar A. Hernández Rodríguez y a los miembros de mi comité graduado, la Dra. Claudia X. Alvarez Romero y la Dra. María S. Martínez Miranda, mi agradecimiento por su disposición y colaboración. Además, la colaboración fundamental del Departamento de Estudios Graduados de la Universidad de Chicago y al Departamento de Educación de Puerto Rico.

Palabras claves: creencias, normas sociales, normas sociomatemáticas, discurso

Graph universal cycles of permutations and set partitions

Dorothea Rugg, Haverford College.
Christopher Soto, Queens College, City University of New York.

Universal cycles are cyclic strings of elements which encode various combinatorial objects, such as permutations, in different "windows" along the code. They were first developed by Chung, Diaconis, and Graham in 1992. Previous work has attempted to create universal cycles for permutations and set partitions with varying degrees of success, with some objects unable to be placed in a universal cycle altogether. Graph universal cycles are extensions of universal cycles developed by Brockman, Kay, and Snively in 2010. They use graphs rather than letters or numbers to encode different combinatorial objects within the cycle. Our work shows the existence of graph universal cycles for permutations and set partitions as well as for specific subsets of these objects.

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Explicit Constructions of Finite Groups as Monodromy Groups

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Ra-Zakee Muhammad, Department of Mathematics, Pomona College.
Eyob Tsegaye, Department of Mathematics, Stanford University.

In 1963, Greenberg proved that every finite group appears as the monodromy group of some morphism of Riemann surfaces. In this work, we give two constructive proofs of Greenberg's result. First, we utilize free groups, which given with the universal property and their construction as discrete subgroups of $\mathbb{R}$, yield a very natural realization of finite groups as monodromy groups. We also give a proof of Greenberg's result based on triangle groups $\Delta(m, n, k)$. Given any finite group G, we make use of subgroups of $\Delta(m, n, k)$ in order to explicitly find a morphism π such that $G \simeq \pi$.

Structural Szemerédi–Trotter theorem for lattices

Olivine Silier, Department of Mathematics, California Institute of Technology.
Adam Sheffer, Department of Mathematics, CUNY Baruch College.

Incidence problems provide a framework for characterizing an underlying geometry and find applications beyond discrete geometry, spanning combinatorics, number theory, computer science, and harmonic analysis. A point and a line form an *incidence* if the point is on the line. The Szemerédi–Trotter theorem states that the number of incidences between points from the set P and lines from the set L is $O(n^{4/3})$ where $|P| = |L| = n$. The theorem is tight since there exist configurations with $\Theta(n^{4/3})$ incidences. Only two such configurations were known, one from

Erdős, the other from Elekes. In this work, we find a family of constructions (including these two) that spans all maximum-incidence constructions with a lattice of points. Moreover, while the Szemerédi–Trotter theorem has been known for nearly four decades, hardly anything is known about the *structural problem*: characterizing the configurations with $\Theta(n^{4/3})$ incidences. Here, we use an energy variant to derive a tight point-energy bound which depends on the geometry of the configuration. We also derive a variety of structural properties where the point set is a Cartesian product.

Acknowledgements: This research was sponsored in part by the REU at Baruch College CUNY and by the Lynn A. Booth and Kent Kresa SURF fellowship.

Keywords: incidence, cartesian product, energy (additive combinatorics definition)

Introducing three best known binary Goppa codes

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Axel O. Gómez–Flores, Department of Mathematics, University of Puerto Rico at Río Piedras.
Christopher Soto, Department of Mathematics, Queens College of the City University of New York.
Fernando L. Piñero González, Department of Mathematics, University of Puerto Rico at Ponce.

The current best known $[239, 21]$, $[240, 21]$, and $[241, 21]$ binary linear codes have minimum distance 98, 98, and 99 respectively. In our research, we introduce three binary Goppa codes with Goppa polynomials $(x^{17} + 1)^6, (x^{16} + x)^6$, and $(x^{15} + 1)^6$. The Goppa codes are $[239, 21, 103]$, $[240, 21, 104]$, and $[241, 21, 104]$ binary linear codes respectively. These codes have greater minimum distance than the current best known codes with the respective length and dimension. In addition, with the techniques of puncturing, shortening, and extending, we find more derived codes with a better minimum distance than the current best known codes with the respective length and dimension.

Acknowledgements: This research was conducted in The Puerto-Rico/East Tennessee REU in Combinatorics, Probability, and Algebraic Coding Theory supported by NSF-DMS REU-1852171.

Keywords: binary Goppa codes, linear codes, minimum distance, coding theory

Extreme Value theory and the Re-assessment in the Caribbean: Spatial Modeling of rainfall data and predictions

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Luis R. Pericchi Guerra, Departamento de Matemáticas, Universidad de Puerto Rico en Rio Piedras.

Risk assessment has been the cornerstone in resilient planning during extreme rainfall scenarios. Coles, Pericchi and Sisson (2003) and Sisson, Pericchi and Coles (2006) Conjecture states that stan-

dard Gumbel analyses routinely assign a near-zero probability to subsequently observed disasters and that for San Juan, Puerto Rico, standard 100-year predicted rainfall estimates may routinely underestimate by a factor of two by the Maximum likelihood estimators. Our project is to use precipitation annual maximum series from NOAA stations along Puerto Rico's Archipielago in a Bayesian Network Model framework including Hierarchical Modeling to restate the conjecture with models with more variables. This shows that using Bayesian Analysis models, a more precise results in predicting extreme spatial rainfall distribution can be established.

Keywords: Bayesian statistics, Markov chain Monte Carlo methods, extreme value distribution, hierarchical Bayes, spatial statistics

Ruteate: Un App con enfoque UX para promover el chinchorreo en Puerto Rico

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Edusmildo Orozco, Departamento de Ciencia de Cómputos, Universidad de Puerto Rico en Río Piedras.

Agile es un modelo de desarrollo de software ampliamente usado en la industria del software cuya prioridad es la máxima satisfacción del cliente en el menor tiempo posible. Por otro lado, la metodología de diseño basada en la experiencia del usuario (UX, por sus siglas en inglés) tiene en cuenta la totalidad de las acciones que el usuario ejecuta, sus sensaciones y sus pensamientos a medida que usa un producto o servicio. Un producto/servicio que sea diseñado basado en UX debe ser: encontrable, accesible, usable, deseable, confiable y útil.

En este trabajo desarrollamos Ruteate, una aplicación diseñada con la metodología UX para exponer y promover a pequeños y medianos negocios netamente puertorriqueños, especialmente a los llamados chinchorros. Nuestra motivación principal es contribuir con un granito de arena a mejorar la maltrecha economía de Puerto Rico y, a la vez, crear nuestro propio modelo de negocio. Estamos pasando por una de las mayores crisis económicas de la historia de la Isla. El huracán María y la pandemia del COVID-19 son dos ejemplos de fenómenos que han tenido un impacto devastador, especialmente en los pequeños y medianos negocios. Al mes de enero del 2021, la mayoría de estos negocios aún están cerrados y se vislumbra que muchos de ellos se estanquen o desaparezcan.

A principios del 2020 realizamos una encuesta de necesidad de una aplicación móvil a dos potenciales grupos de usuarios, consumidores y dueños de pequeños o medianos negocios. La totalidad de los consumidores dijeron que usarían la aplicación para mejorar su experiencia en el chinchorreo y el 80% de los dueños se mostraron positivos al uso de la misma.

Para la fase de desarrollo de nuestro proyecto, usamos herramientas del modelo Agile. Para la fase de investigación desarrollamos instrumentos que siguen la metodología UX. Todos los instrumentos de investigación están avalados por el Comité Institucional para la protección de los seres humanos en la investigación (CIPSHI). En esta presentación mostramos nuestros resultados preliminares, un prototipo de Ruteate y planes futuros.

Agradecimientos: Agradecemos al doctor Carlos Corrada, a la doctora María Egleé y a la doctora Indira Luciano por sus valiosas recomendaciones. También agradecemos al Centro de Apoyo a la Innovación y Comercialización de la UPR Río Piedras UPR I+C por sus recomendaciones en

ámbito comercial.

Error-correcting codes construction and bent/near-bent functions

Jose W. Velazquez, Department of Mathematics, University of Puerto Rico at Rio Piedras.
Heeralal Janwa, Department of Mathematics, University of Puerto Rico at Rio Piedras.

In this talk we discuss the construction of cyclic codes with 2 roots based on bent and near-bent functions. The second element of the defining set of these codes is important in determining its error-correcting capabilities. The selection of this element is closely related to the selection of exponents that lead to bent and near-bent Boolean functions. We study the values selected trough a cyclotomic coset analysis. We identify functions related to good error-correcting codes and draw conclusions from these results. These results are based on properties of vectorial Boolean bent functions.

A function $f : F_{2^r} \to F_{2^k}$ is called a vectorial Boolean function in r variables. Whenever $k = 1$ we call these functions Boolean functions. The nonlinearity property of these functions is a measure of the distance of these functions to the set of affine functions. Almost Perfect Nonlinear (APN) power functions of the form $f(x) = x^d$ have good cryptographic properties and have been studied by Janwa in 1993 on the construction of 2 error-correcting codes. These functions are found to be APN whenever d corresponds to the Gold or Kasami-Welch exponents under certain conditions. The conditions found are like the conditions for the construction of the Gold and Kasami-Welch bent and near-bent Boolean functions. These bent and near-bent functions are defined as $Tr(\alpha x^d)$, $Tr(x^d)$ respectively, with d corresponding to the Gold or Kasami-Welch exponents and α an element in F_{2^r}. The functions have high nonlinearity and thus are studied for their possible connections to error-correcting codes. In this work, we develop algorithms to construct these functions and their related codes, compare our results to known theorems and expand results by Dillon and Dobbertin on the construction of Gold bent functions. Codes derived from these functions will be used to construct Low-Density-Parity-check (LDPC) codes that will improve current NASA standards.

Acknowledgements: We acknowledge the PR Space Grant Consortium, NASA Cooperative Agreement 80NSSC20M0052.

Keywords: error-correction, boolean functions, bent functions, cyclic-codes

Convergence of solution of nonlocal conservation law to local conservation law

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Anh Vo, Department of Mathematics, University of Nebraska-Lincoln.

In this study, we investigate the convergence of nonlocal operators to local counterparts and the convergence of solutions of nonlocal conservation PDE to the local counterpart. Nonlocal operators are integral operators that account for long-range interactions with other points in a finite neighborhood. In contrast, classical operators only account for interactions in the immediate neighborhood.

It was previously shown that nonlocal operators can be reduced to local operators in the sense of distribution. With chosen scaling factor, we show that the nonlocal operator converges point-wise to the local counterpart, as long as the corresponding flux density function's first order derivative satisfies the Holder condition. In particular, if the flux density is a C^1 function, then the order of convergence is approximately δ, where δ is the horizon. We then show that the solution of nonlocal conservation

Keywords: nonlocal, conservation law, convergence

5 Afiches / Posters

(In alphabetical order using the last name of the presenter.)

La equidad y la diversidad en la enseñanza de las matemáticas y la matemática crítica

Bradly Rivera Muñiz, Departamento de Estudios Graduados en Educación, Universidad de Puerto Rico en Rio Piedras, y Robinson School, PR.

Las matemáticas son producto de procesos de abstracción sobre una realidad concreta que nos permiten comprender nuestro mundo, sus interacciones, y a la vez interactuar con y en el mismo, por lo que la falta de conocimiento matemático promueve la deprivación de oportunidades que pueden ser generadas a través de la matemática misma. Se ha observado que los estudiantes pertenecientes a subgrupos de la población basados en raza, etnia, nivel socioeconómico, de género, entre otros, reflejan una variedad de niveles de aprovechamiento académico matemático. Esto es un producto de las dinámicas sociopolíticas cuyos factores son entes de estratificación social, tales como la brecha digital, la identidad, el currículo oculto, y la intervención de estructuras de poder que de alguna manera se refuerzan a través de amplificación de estos problemas.

La matemática crítica es una de las perspectivas teoréticas que fomenta una mirada sociopolítica a la educación matemática, exaltando el concepto de identidad y poder. La contextualización de las ideas matemáticas de acuerdo con la realidad social de un grupo de estudiantes ayuda a fomentar el desarrollo una identidad matemática por la cual los estudiantes se perciben como capaces de hacer, aprender y utilizar las matemáticas. Por medio de la creación de contenido didáctico y actividades que incorporen el conocimiento clásico, el conocimiento comunitario, y el conocimiento crítico, es posible replantear la manera en que se enseña matemáticas para que se convierta en un proceso que provea un acceso más equitativo a las matemáticas.

Palabras clave: matemática crítica, equidad, diversidad, acceso, educación matemática

Automatic wound detection and size estimation using deep learning algorithms

Héctor Carrión et al., Department of Computer Science, University of Puerto Rico at Río Piedras.

Evaluating and tracking wound size is a fundamental metric for the wound assessment process. Good location and size estimates can enable proper diagnosis and effective treatment. Traditionally, laboratory wound healing studies include a collection of images at uniform time intervals exhibiting the wounded area and the healing process in the test animal, often a mouse. These images are then manually observed to determine key metrics —such as wound size progress— relevant to the study. However, this task is a time-consuming and laborious process. In addition, defining the wound edge could be subjective and can vary from one individual to another even among experts. Furthermore, as our understanding of the healing process grows, so does our need to efficiently and accurately track these key factors for high throughput (e.g., over large-scale and long term experiments). Thus, in this study, we develop a deep learning-based image analysis

pipeline that aims to intake non-uniform wound images and extract relevant information such as the location of interest, wound only image crops, and wound periphery size over-time metrics. Our work focuses on images of wounded laboratory mice that are used widely for translationally relevant wound studies. We compare results to that of expert measurements and demonstrate preservation of information relevant to predicting wound closure despite variability from machine-to-expert and even expert-to-expert. The proposed system resulted in high fidelity results on unseen data with minimal human intervention.

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Keywords: machine learning, object detection, semantic segmentation

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An introduction to parking functions

Kimberly P. Hadaway, Department of Mathematics and Statistics, Williams College.
Pamela E. Harris, Department of Mathematics and Statistics, Williams College.

In 1966, Alan G. Konheim and Benjamin Weiss defined "parking functions" as follows: We have a one-way, one-lane street with n parking spaces, numbered in consecutive order from 1 to n, and we have n cars in line waiting to park. Each driver has a favorite (not necessarily distinct) parking spot, which we call its *preference*. We order these preferences in a *preference vector*. As each car parks, it drives to its preferred spot. If that spot is open, the car parks there; if not, it parks in the next available spot. If a preference vector allows all cars to park, we call it a parking function. In 1974, Henry O. Pollak proved the total number of parking functions of length n, meaning there are n parking spots and n cars, to be $(n+1)^(n-1)$. In this presentation, we describe a recursive formula, expound Pollak's succinct six-sentence proof of an explicit formula, and conclude with a discussion of other parking function generalizations.

Acknowledgements: This research was conducted through the Undergraduate Honors Thesis

program at Williams College.

Keywords: combinatorics, parking functions

A rebalancing methodology for a dockless-mode scooters rental system

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We propose the development of an integrated methodology for a scooter rental system. In this dockless-scooter sharing system, GPS tracking and mobile payment are consolidated to provide pickup and drop-off service of scooters; therefore, a customer can park a scooter in any place without having to look for a space in a docking station. Although this system provides a convenient travel service, it brings complex management problems such as exaggerated scooters in a few popular locations.

The research integrates a clustering model, demand prediction with a regression model, an optimization model for the routing of the scooters pickup, and a policy for dynamic rebalancing during each day. First, we collected and preprocessed the scooter company's GPS data operating in the city of Mayaguez, Puerto Rico, and cluster the scooters' locations into several groups. A non-linear regression model is then proposed according to a statistical analysis of the patterns identified according to the day, time, location, and season of the year. Finally, a vehicle routing problem is proposed along with a policy to define the times to rebalance. This policy will be based on deciding the shortest route and the largest number of scooters to be relocated to meet the demand. To test the model's effectiveness, we will show preliminary results with the rebalancing model compared to the scenario without rebalancing during the day. Historical data will be used to simulate these scenarios and demonstrate increased utilization of the system.

Keywords: dockless system, dynamic rebalancing, clustering, optimization model

Assessing the impact of a vaccine in the COVID-19 pandemic

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The aim of this research is to understand the role played by vaccination in the control and management of the coronavirus pandemic. We shall attempt to answer the following queries: i) How long will take Covid-19 vaccines to stop the spread of the coronavirus pandemic? ii) What is the basic and effective reproduction number when a percentage of the susceptible population is vaccinated?, iii) For a given country, what is the optimal vaccine in terms of efficacy, cover rate, and cost?

The proposed mathematical model has eight compartments. Namely, susceptible (S), vaccinated (V), exposed (E, infected but not yet infectious), symptomatic infectious (I_s), asymptomatic infectious (I_a), quarantine (Q), recovered (R), and dead by coronavirus (D). The compartmental model

(SEILQRVD) is described by eight coupled first order differential equations. A computational code was developed to solve and plot the different compartments' populations on function of time.

We have first obtained analytical expressions for the disease free and endemic equilibrium points. Next, a stability analysis was carried out. A close form expression for the basic reproductive number (R_V) was also found. Moreover, a sensitivity analysis of R_V allowed us to identify its more relevant parameters (Recruitment, birth rate, cover rate, and vaccine failure). As a way to test our model, we have used for New York State (NYS) COVID-19 data published by the U. S. Health Department. Preliminary results of our research suggest that equations describing the proposed model for NYS are locally unstable or stable when $R_V > 1$ or $R_V < 1$, respectively. The proposed model satisfied a necessary although not sufficient condition, which is to predict the number of deaths by Covid-19 in New York state between 3/8/2020 and 1/2/2021.

This research will help to choose the optimal vaccine for a given country, in terms of efficacy, cover rate, and cost.

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Keywords: compartmental model, COVID-19 pandemic, basic reproductive number

Automatic piano fingering detection from videos using open source computer vision and machine learning libraries

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Research on predictive models to recommend piano fingerings from written music is an area of ongoing development in Machine Learning (ML). However, these models generally depend on vast amounts of data sets in order to produce an accurate model. Most of the research teams have to produce their own data sets due to the scarcity of datasets for developing these models. We are designing a simple yet effective method for automatically creating datasets for training fingering prediction models. The input to our system is a video/audio file of a pianist's hand recording of a musical piece, such as can be downloaded from YouTube. After capturing the video we extract the sound by using the ffmpeg tool and then deduce a MIDI file using Magenta (an ML library for manipulating sound). Information from the MIDI file, which essentially contains a sequence of (note, time) pairs, is used for extracting the video frames corresponding to the keys being played.

Previous work on this project achieved the detection of the piano keys using OpenCV, an open-source computer vision library. We've managed to identify the piano keys based on their visual pattern. We analyzed the audio to identify when keys were pressed. With the time of the keypresses, we then managed to take the corresponding frame when the key press occurred and identified which finger was near the key with the use of a simple hand model to detect its bounding box using a neural network model on Tensorflow, followed by the use of the OpenPose library to detect the desired hand's keypoints. Thanks to the modifications we made to the algorithm that detects the hand's bounding box, we were able to improve the detection of the pianist's right hand, which is currently our objective. This change to the heuristics allowed us to achieve a 98% detection rate of the desired hand on the 728 scanned frames of the recording of a piano piece by Bach.

Combinatorial constructions of rank metric codes

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We study codes under the rank metric and the subspace distance instead of the traditional Hamming metric. Code words in in network codes are matrices or vector spaces rather than vectors as in the classical coding sense. We'll consider combinatorial constructions of these codes. Specifically, we use De Bruijn sequences (a well known instance of a *universal cycle*) to find collections of matrices or subspaces with a prescribed rank or subspace distance. In this way we generalize the orbit construction of constant dimension codes.

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