The Blackwell-Tapia Conference and Awards Ceremony

October 28-29, 2016

The University of Tennessee Conference Center
600 Henley Street, Knoxville, TN

Friday, October 28, 2016

1:00-1:10 Welcome by Suzanne Lenhart, NIMBioS Associate Director for Education & Outreach

1:10-2:00 Joaquin Bustoz, Jr. Lecture: Abdul-Aziz Yakubu, Howard University
Mathematical Models for Malaria with Applications to Mali and USA
Introduced by Suzanne Lenhart, NIMBioS

2:10-2:50 Federico Ardila, San Fransisco State University
Using High-Dimensional Geometry to Move Robots Quickly
Introduced by Brendan Hassett, ICERM

2:50-3:10 Break

3:10-3:50 Cristina Villalobos, The University of Texas-Rio Grande Valley
Becoming Agents of Change: Building Diverse Communities and Lessons Learned from Mathematical Modelling of Eye Disease
Introduced by Kelly Sturner, NIMBioS

4:00-4:40 Edray Goins, Purdue University
Toroidal Belyi Pairs, Toroidal Graphs, and their Monodromy Groups
Introduced by Abdul-Aziz Yakubu, Howard University

4:50-5:00 Introduction to NIMBioS by Colleen Jonsson, Director of NIMBioS

5:00-6:00 Poster session and reception

Dinner on your own

Saturday, October 29, 2016

8:45 Continental Breakfast Available at the Conference Center

9:15-9:55 Jose Perea, Michigan State University
The Shape of Data
Introduced by David Eisenbud, MSRI

10:05-10:45 Overtoun Jenda, Auburn University
Generalized Baer's Criterion
Introduced by Suzanne Lenhart, NIMBioS

10:45-11:10 Group Photo & Break

11:10-11:50 Monica Jackson, American University
Correlation Induced by Missing Spatial Covariates
Introduced by Louis Gross, NIMBioS

Noon-1:30 Lunch in 404A

- Career Advice Panel Discussion for graduate students - bring your lunch to 403
  - Panelists: Joan Lind (moderator), University of Tennessee-Knoxville; Michael Kelly, Transylvania University; Johnny Guzman; and Cristina Villalobos
- Networking lunch for other participants in 404A
  - Tables:
    1. Mariel Vazquez and De Witt Sumners
    2. Abdul-Aziz Yakubu
    3. Carolyn Morgan
    4. Monica Jackson
    5. Jose Perea
    6. Edray Goins
    7. Federico Ardila
    8. David Eisenbud, Brendan Hassett, and Suzanne Lenhart
    9. Richard Tapia and Carlos Castillo-Chavez
    10. Overtoun Jenda

1:30-2:10 Johnny Guzman, Brown University
Some Numerical Methods for Steady State Interface Problems
Introduced by Arlie Petters, Duke University

2:20-3:00 Carolyn Morgan, MECK Limited LLC
Statistical Reasearch - Industrial, Governmental, and Academic
Introduced by Louis Gross, NIMBioS

3:00-3:20 Break

3:20-4:00 De Witt Sumners, Florida State University
The Work of Mariel Vazquez
Introduced by Carlos Castillo-Chavez, Arizona State University

4:15-5:15 Prize Winner Lecture: Mariel Vazquez, University of California, Davis
Using Topology, Geometry and Computer Simulations to Understand the Molecule of Life
Introduced by Carlos Castillo-Chavez, Arizona State University

Holiday Inn - Knoxville, Downtown
Windows on the Park Pavillion - Tennessee Ballroom
525 Henley Street, Knoxville, TN

6:00-9:00 Reception followed by Blackwell-Tapia Banquet

Remarks by Richard Tapia, Rice University
Introduced by Arlie Petters

Award Presentation

Speaker Abstracts

Federico Ardila (San Francisco State University) ***Using High-Dimensional Geometry to Move Robots Quickly***

How do we move a robot quickly from one position to another? To answer this question, we need to understand the "configuration space" containing all possible positions of the robot. Unfortunately, these spaces can be very high dimensional and intricate. Fortunately, combinatorialists and geometric group theorists have encountered and studied these kinds of spaces before. Thanks to the tools they've developed, we can build "remote controls" to navigate these configuration spaces, and move (some) robots optimally.

Edray Goins (Purdue University) ***Toroidal Belyi Pairs, Toroidal Graphs, and their Monodromy Groups***

A Belyi map $\beta : \mathbb{P}^1(\mathbb{C}) \to \mathbb{P}^1(\mathbb{C})$ is a rational function with at most three critical values; we may assume these values are $\{0, 1, \infty\}$. A Dessin d'Enfant is a planar bipartite graph obtained by considering the preimage of a path between two of these critical values, usually taken to be the line segment from 0 to 1. Such graphs can be drawn on the sphere by composing the stereographic projection: $\beta^{-1}([0, 1]) \subseteq \mathbb{P}^1(\mathbb{C}) \backsimeq S^2(\mathbb{R})$. Replacing $\mathbb{P}^1$ with an elliptic curve E, there is a similar definition of a Belyi map $\beta : E(\mathbb{C}) \to \mathbb{P}^1(\mathbb{C})$. Since $E(\mathbb{C}) \backsimeq \mathbb{T}^2(\mathbb{R})$ is a torus, we call (E, β) a toroidal Belyi pair. The corresponding Dessin d'Enfant can be drawn on the torus by composing with an elliptic logarithm: $\beta^{-1}([0, 1]) \subseteq E(\mathbb{C}) \backsimeq \mathbb{T}^2(\mathbb{R})$
This project seeks to create a database of such Belyi pairs, their corresponding Dessins d'Enfant, and their monodromy groups. For each positive integer N, there are only finitely many toroidal Belyi pairs (E, β) with deg $\beta = N$. Using Hurwitz Genus formula, we can begin this database by considering all possible degree sequences $\mathcal{D}$ on the ramification indices as multisets on three partitions of N. For each degree sequence, we compute all possible monodromy groups $G =$ im $[\pi_1(\mathbb{P}^1(\mathbb{C}) - \{0, 1, \infty\}) \to S_N]$; they are the "Galois closure" of the group of automorphisms of the graph. Finally, for each possible monodromy group, we compute explicit curve
$E : y^2 = x^3 + Ax + B$. We will discuss some of the challenges of determining the structure of these groups, and present visualizations of group action on the torus.
This work is a part of PRiME (Purdue Research in Mathematics Experience) with Gabriel Ngwe, Caitlin Leinkaemper, Dionel Jaime, Ivan Gonzalez, and Baiming Qiao with assistance by Mark Pengitore.

Johnny Guzman (Brown University) ***Some Numerical Methods for Steady State Interface Problems***

We discuss several numerical methods for simple interface problems. We show the basic principles in deriving finite element methods with high accuracy and that are stable with respect to physical constants. Numerical experiments are provided illustrating the effectiveness of the numerical methods.

Monica Jackson (American University) ***Correlation Induced by Missing Spatial Covariates***

Residual spatial correlation in linear models of environmental data is often attributed to spatial patterns in related covariates omitted from the fitted model. We connect the nonunique decomposition of error in geostatistical models into trend and covariance components to the similarly non-unique decomposition of mixed models into fixed and random effects. We specify spatial correlation induced by missing spatial covariates as a function of the strength of association and (spatial) covariation of the missing covariates. The connection with variance components models provides insight into estimation procedures.

Overtoun Jenda (Auburn University) ***Generalized Baer's Criterion***

In 1940, Baer proved that an R-module M is injective if and only if any homomorphism from an ideal to M can be extended to a homomorphism from the ring R to the module M. One can check that the following are equivalent,

1. M is an injective R-module
2. $Ext^i_R(N, M) = 0$ for all modules N and for all i.
3. $Ext^1_R(R/I, M) = 0$ for all ideals I of R.

In relative homological algebra, we define an analogous notion which is called a *Gorenstein Injective* module. Suppose R is n-Gorenstein (that is a ring with $inj\ dim(R) \leq n$), then M is called a Gorenstein injective module if there exists an exact sequence,

$$E_n \to E_{n-1} \to \cdots \to E_0 \to M \to 0$$

where each E_i is injective and the sequence if $Hom(E, -)$ exact for any choice of injective module E. It is not difficult to see that then every injective module is Gorenstein injective. Our goal has been to find a similar criterion to that of Baer's for the Gorenstein injectives. Our starting point was to look at a simple case where R is a local, Gorenstein ring where $dimR = 1$. Then we proved that M is Gorenstein injective if and only if $Ext^1_R(R/ < r >, M) = 0$ for all $R-$ regular elements r. We want to generalize this result to $n-$ dimensional Gorenstein rings.

Carolyn B. Morgan (MECK Limited LLC) ***Statistical Research - Industrial, Governmental and Academic***

Statistics is an all-encompassing discipline. During her professional career, the author has conducted statistical research directed at a large number of real-world applications in governmental, industrial and academic settings. In this talk she will explore the extraordinary power of mathematical and statistical methods to address problems ranging from product reliability to biomedical engineering research as it relates to anterior cruciate ligament (ACL) injuries. Additionally, she will highlight how the use of the Weibull distribution and principal component analysis statistical methods were used in her research. The discussion will also emphasize the importance of interdisciplinary teams

of mathematicians, statisticians, engineers and computer scientists to solving these and other challenging technical problems.

Jose Perea (Michigan State University) ***The Shape of Data***

Topology, and particularly algebraic topology, has been used for decades to study the shape of mathematical objects – from surfaces to categories and spaces of functions. Recently some of these same ideas have been adapted to the study of data. I will show in this talk how one can use algebraic topology to probe the shape of data, and provide some examples of applications to computer vision and biology.

De Witt Sumners (Florida State University) ***The Work of Mariel Vazquez***

Mariel Vazquez epitomizes excellence in research, teaching and service at the interface between mathematics and biology. Mariel is strongly motivated by the biological importance of her research, and has enjoyed great success in her collaborations with experimental scientists. She is a world leader in a generation of mathematical scientists with outstanding theoretical and computational skills, matched by success in experimental research in a molecular biology laboratory. It will be a great pleasure for me to outline some of the achievements in her amazing career.

Cristina Villalobos (The University of Texas-Rio Grande Valley) ***Becoming Agents of Change: Building Diverse Communities and Lessons Learned from the Mathematical Modeling of Eye Disease***

The mathematical modeling of the photoreceptor interactions in the presence of retinitis pigmentosa will be presented and discussed in this talk. Retinitis pigmentosa is an eye-disease that affects approximately 1 in 4000 individuals and can lead to blindness. Currently, there is no treatment to halt the degeneration of the photoreceptors. However, the discovery of the RdCVF protein has shed light to possible therapies to slow the degeneration. Existence of an optimal control along with numerical results will be presented that show the experimentally observed rescue effect that RdCVF has on the cones. Based on some of the lessons learned from the mathematical model, the speaker will transition and discuss her invitation to students and faculty to become agents of change in their own communities. With that purpose in mind, the presenter will share her own career path to her present position and her efforts in becoming an agent of change in mentoring faculty and students which has led to the creation of a Center of Excellence in STEM Education that has allowed her to inspire and to help Latino students to enroll and obtain PhD degrees.

Abdul-Aziz Yakubu (Howard University) ***Mathematical Models of Malaria with Applications to Mali and USA***

In this talk, we will introduce a deterministic malaria model for determining the drug administration protocol that leads to the smallest first malaria episodes during the wet season. To explore the effects of administering the malaria drug on different days during the wet season while minimizing the

potential harmful effects of drug overdose, we will define 40 drug administration protocols. Our results fit well with the clinical studies of Coulibaly *et al.* at a site in Mali. In addition, we will provide protocols that lead to smaller number of first malaria episodes during the wet season than the protocol of Coulibaly *et al.* In the second part of the talk, we will use our malaria model to "capture" the 2016 Centers for Disease Control and Prevention (CDC) reported data on the 2013 number of imported malaria cases in the US. Furthermore, we will use our "fitted" malaria models for the top 20 countries of malaria acquisition by US residents to study the impact of protecting US residents from malaria infection when they travel to malaria endemic areas, the impact of protecting residents of malaria endemic regions from mosquito bites and the impact of killing mosquitoes in those endemic areas on the 2016 CDC malaria surveillance data.

Blackwell-Tapia Prize Winner Lecture
Mariel Vazquez
University of California, Davis
Using Topology, Geometry and Computer Simulations to Understand the Molecule of Life

DNA topology addresses changes in topology and geometry of DNA molecules. For the last 25 years we have studied the topological mechanism of DNA-binding enzymes and the effects of DNA packaging in highly confined environments. We use knot theory to describe the different topological forms adopted by circular DNA. The unique geometry involved in a DNA binding reaction is entrapped in a 2-string tangle and its effect on the topology of the substrate DNA is investigated using tangle calculus. Tools from low-dimensional topology are helpful to characterize the tangles involved in the reaction. We also use computer simulations and visualization tools to determine enzymatic pathways of topology simplification and assign relative probabilities to help discriminate between them. In this talk I will give an overview of the methods used in our group.

Poster Abstracts

1. **Sarder Mohammed Asaduzzaman (University of Victoria)** ***The Coexistence or Replacement of Two Suptypes of Influenza***
   A pandemic subtype of influenza A sometimes replaces (e.g., in 1918, 1957, 1968) the previous seasonal subtype. However, the reintroduced subtype H1N1 in 1977 has been co-circulating with H3N2 since then. To understand these alternatives, we formulate a hybrid model for the dynamics of influenza A epidemics. Our model takes into account the cross-immunity between seasonal strains and the cross-immunity between seasonal and pandemic subtypes. A combination of theoretical and numerical analyses shows that for very strong cross-immunity between seasonal and pandemic subtypes, the pandemic cannot invade, whereas for strong and weak cross-immunity there is coexistence, and for intermediate levels of cross-immunity the pandemic may replace the seasonal subtype.

2. **Ghanshayam Bhatt (Tennessee State University)** ***Incoherent Matrices for Compressed Sensing***

3. **Ariel Cintron-Arias (East Tennessee State University)** ***Post-Secondary Enrollment: model Validation and Student Life Tables***

4. **Moussa Doumbia (Howard University)** ***Malaria Incidence and Anopheles Mosquito Density in Irrigated and Adjacent Non-Irrigated Villages of Niono in Mali***
   In this poster, we extend the mathematical model framework of Dembele et al. (2009), and use it to study malaria disease transmission dynamics and control in irrigated and non-irrigated villages of Niono in Mali. In case studies, we use our "fitted" models to show that in support of the survey studies of Dolo et al., the female mosquito density in irrigated villages of Niono is much higher than that of the adjacent non-irrigated villages. Many parasitological surveys have observed higher incidence of malaria in non-irrigated villages than in adjacent irrigated areas. Our "fitted" models support these observations. That is, there are more malaria cases in non-irrigated areas than the adjacent irrigated villages of Niono. As in Citinis et al., we use the sensitivity analysis on R0 to study the impact of the model parameters on malaria control in both irrigated and non-irrigated villages of Niono.

5. **Kossi Edoh (North Carolina A&T University)** ***Encryption Schemes for Cloud Data Security***
   The emergence of cloud computing and its increasing demand in recent years incentivizes the need to study cloud data security. New cryptographic tools are needed to provide security for cloud data because of the complexity. The project analyzes cutting edge topics such as homomorphic encryption, functional encryption, multi-party computation, verifiable computation, and secure scientific computing in providing cloud data security.

6. **Michelle Guinn (Belmont University)** ***Image Processing and Interpolations***
   The objective of my research is to design an algorithm to enhance stereoscopic imagery so that it adapts to the viewing distance of the observer, with seamless transitions among stereo and hyperstereo levels. The algorithm will use image smoothing, blending edge detection techniques to provide this enhancement.

7. **David Kotval (University of Tennessee - Chattanooga)** ***Optimal Design of the Spectrum of a Sturm-Liouville Problem with the Spectral Parameter Appearing in the Boundary Conditions***
   Optimal forms are of great interest to many applications in engineering. This poster investigates the optimal form, with respect to cross-sectional area, of a rod of given mass such that it most efficiently resists destructive mechanical resonance. To carry out the optimization, we use the calculus of variations to maximize the principle eigenvalue of the corresponding the SturmLiouville problem with generalized boundary conditions that contain the spectral parameter.

8. **Andrew Marchese and Vasileios Maroulas (University of Tennessee - Knoxville)** ***Signal Classification with a Point Process Distance on the Space of Persistance Diagrams***
We consider the problem of signal classification. Through the use of delay-embedding and persistent homology, the signal classification problem is transformed into a persistence diagram classification problem. We propose a new distance on the space of persistence diagrams and introduce a classification scheme utilizing it. This distance takes into consideration the different cardinalities among persistence diagrams. Classification using this distance in benchmarked in both synthetic data and real acoustic signals, and outperforms current signal classification techniques. The work is joint with V. Maroulas.

9. **Reginald McGee (Mathematical Biosciences Institute)** ***Uncovering Functional Relationships in Leukemia***
Mass cytometers can record tens of features for millions of cells in a sample, and in particular, for leukemic cells. Many methods consider how to cluster or identify populations of phenotypically similar cells within cytometry data, but there has yet to be a connection between cell activity and other features and these groups or clusters. We use differential geometric ideas to consider how cell cycle and signaling features vary as a function of the cell populations. This consideration leads to a better understanding of the nonlinear relationships that exist in the cytometry data.

10. **Francis Patricia Medina (Worchester Polytechnic Institute)** ***Hybrid Modeling and Analysis of Multicomponent Absorption with Applications to Coalbed Mehtan***
We consider non-standard models of multi-component adsorption with applications to gas adsorption processes in coalbeds. In particular we follow thermodynamically consistent approaches, both at macroscale, via the Ideal Adsorbate Solution (IAS) theory, as well as at the pore-scale. The models we consider do not have a simple algebraic form, and therefore their analyses and numerical simulation have challenges. We present several mathematical analysis results and numerical solutions to illustrate the issues

11. **Josh Mike and Vasileios Maroulas (University of Tennessee - Knoxville)** ***Combinatorial Hodge Theory for Equitable Kidney Paired Donation***
The problem of Kidney Paired Donation (KPD) has traditionally been approached within an integer programming framework. Here we adopt computational topology methods to find kidney exchange cycles. Employing Hodge theory, we decompose the edge flow describing the KPD pool into three parts. The curl portion of the flow represents local cycles and is trivial here. The gradient portion creates a scoring that we use to measure inequity in the kidney exchange. This scoring measures typical cases of disparity within a KPD pool, specifically that under demanded pairs and highly sensitized patients have lower scores than typical patient-donor pairs. The last portion of the decomposition is used to guide our search for kidney exchange cycles by capturing the 1-cohomology of the kidney exchange graph and investigating the tendency of the donations to occur in cycles. Further results demonstrate that PD pair score and the chance to obtain a kidney are positively correlated when using top

trading cycles and chains; in contrast, we show that our method eliminates disparity in a KPD pool, i.e. the chance to obtain a kidney through our method is independent of score. The work is joint with V. Maroulas.

12. **Jami Mulgave (North Carolina State University)** ***Bayesian Inference in Nonparanormal Graphical Models***

13. **Cheryl Murphy (Michigan State University)** ***Using Individual-Based Models to Combat Math Phobia in Undergraduate and Graduate Students***

14. **Germaine Kamleu Ndouma (University of the Western Cape), Loma Holtman (University of the Western Cape), and Bingwen Yan (Cape Peninsula University of Technology)** ***Analytical Model for Assessing the Knowledge of Statistical Procedure Amongst Postgraduate Students in Western Cape Institutions***
Over the past decades, university students experienced considerable difficulties in applying the knowledge of statistical concepts that they learned in their previous courses. In this study, we work with the South African Higher Education system. In this context, many strategies were developed to redress issues of reparation and social imbalances inherited from apartheid and to reconstruct a comprehensive educational quality framework. This study proposes an analytical model to assess the knowledge of statistical procedure amongst postgraduate students in academic research environment with the new Higher Education (HE) system. The results indicate that confusion and frustration characterised the attitude of students during the selection of suitable statistical test.

15. **Kamaldeen Okuney and Abba B. Gumel (Arizone State University)** ***Analysis of a Temperature-and Rainfall-dependent Model for Malaria Transmission Dynamics***
A new non-autonomous model is designed and used to assess the impact of variability in temperature and rainfall on the transmission dynamics of malaria in a population. In addition to adding age-structure in the host population and the dynamics of immature malaria mosquitoes, a notable feature of the new model is that recovered individuals do not revert to wholly-susceptible class (that is, recovered individuals enjoy reduced susceptibility to new malaria infection). Detailed uncertainty and sensitivity analysis, using mean monthly temperature and rainfall data from KwaZulu-Natal province of South Africa, shows that the top three parameters of the model that have the most influence on the disease transmission dynamics are the mosquito carrying capacity, transmission probability per contact for susceptible mosquitoes and human recovery rate. Numerical simulations of the model show that, for the KwaZulu-Natal province, malaria burden increases with increasing mean monthly temperature and rainfall in the ranges ([17 – 25]°C and [32 – 110] mm), respectively (and decreases with decreasing mean monthly temperature and rainfall values). In particular, transmission is maximized for mean monthly temperature and rainfall in the ranges [21 – 25]°C and [95 – 125] mm. This occurs for a six-month period in KwaZulu-Natal (hence, this study suggests that anti-malaria control efforts should be intensified during this period). It is

shown, for the fixed mean monthly temperature of KwaZulu-Natal, that malaria burden decreases whenever the amount of rainfall exceeds a certain threshold value.

16. **Robert Stolz (University of California - Davis), Reuben Brasher (Microsoft Corporation), Koya Shimokawa (Univeristy of Saitama), and Mariel Vazquez (University of California - Davis)** ***Modeling Pathways of DNA Unlinking by Site-Specific Recombination***
In Escherichia Coli, replication of circular chromosomes yields topologically linked DNA molecules. Topo IV, one of the type-II topoisomerases in E. coli, plays a major role in the decatenation of the newly replicated chromosomes. It has been shown that in the absence of Topo IV, site-specific recombinases XerC/D, in cooperation with the translocase FtsK, can also unlink the replication links. The goal of this research is to explore the possible topological pathways of stepwise unlinking by XerCD-FtsK. We use computational methods to exhibit the recombination pathways and assign transition probabilities to each recombination step. Our results give strong support to the analytically identified minimal unlinking pathway.

17. **Yiyuan Wang (York University)** ***The Impact of Stormwater Management Ponds on the Transmission of the West Nile Virus***
By investigating the data from larvae surveillance program launched by Toronto and Region Conservation Authority (TRCA), Canada, we establish a basic model to study the impact of Stormwater Management Ponds (SWMP) as well as weather factors on the mosquito abundance and transmission of West Nile virus (WNV). The numerical results show that moderate temperature, rainfall and aquatic intraspecific competition of mosquito development in the SWMP will increase the basic reproduction number, consequently the risk of WNV. We further develop an improved compartmental model and study the dynamics of the transmission, including the existence of a backward bifurcation of the model which allows to develop threshold conditions to evaluate the risk of human infection of WNV in one area. This is a joint work with Pons Wendy, Jessica Fang and Huaiping Zhu.

18. **Shawn Witte (University of California - Davis)** ***Randomly Sampling Grid Diagram of Knots***