2018 – 2019 Mathematics and Statistics Senior Project Topics

For those students looking to complete a senior project during the 2018 – 2019 school year, here is a list of potential topics that MS faculty are interested in advising. Please note that this list is not exhaustive such that you may pick a topic not on this list. Also note that faculty will be limited to advising at most 2 senior projects in any given semester. If you are interested in one of these topics, contact the faculty member.

**Topic:** Weakly nonlinear equatorial Kelvin waves  
**Advisor:** Steven D. London (londons@uhd.edu)

**Project Description:**  
Equatorial Kelvin waves play an important role in the behavior of El Nino. El Nino is a phenomenon where the normally cool waters of the equatorial eastern Pacific ocean periodically become warm. It plays a major role in the global climate system. Most of the studies of equatorial Kelvin waves have been on the linearized governing equations (ie. the nonlinear terms are ignored by assuming that the wave amplitudes are small). We propose to study the governing equations assuming that the wave amplitudes are still small but with the nonlinear terms included.

**Pre-requisite:** differential equations (I could probably take someone who has had just Calculus 2)

**Topic:** Complex Ordinary Differential Equations: Analytic and Algebraic Aspects  
**Advisor:** Dr. Cesar Garza (garzace@uhd.edu)

**Project Description:** In this project we’ll study complex ODEs with singularities. This subject combines many areas in mathematics and has a very rich theory. We will concentrate on its algebraic (Differential Fields, Picard-Vessiot Extensions, Galois Theory of these ODEs, etc.) and analytic (Monodromy, Formal expansions, Analytic Transformations and Asymptotic Expansions) sides.

**Pre-requisite:** For the Analysis student: MATH 4305. For the Algebra student: 4306

**Topic:** ODEs and Dynamical Systems  
**Advisor:** Dr. Cesar Garza (garzace@uhd.edu)

**Project Description:** This is a deeper study of real ODEs focused on systems of linear differential equations. Dynamical Systems is a very active field of Applied Mathematics with applications into Chaos Theory, Economics and Physics. We will study the behavior of autonomous and nonautonomous dynamical systems. We will also study Periodicity of solutions, stability and asymptotic behavior of systems.

**Pre-requisite:** MATH 2307 and 3301. MATH 4303 is desirable but not required.

**Topic:** An overview of Algebraic Topology
Advisor: Dr. Cesar Garza (garzace@uhd.edu)

Project Description: Is a sphere really different from a torus? Can a sphere be continuously deformed to a point? Algebraic Topology concerns itself with the classification and study of topological spaces via algebraic methods. The key question is this: How do we really know when two spaces are different and in what senses can we claim they are the same? In this project we will develop several notions of "equality", starting with the existence of homeomorphisms between spaces. We will then explore several weakenings of this notion, such as homotopy equivalence, having isomorphic homology or fundamental groups, and having homeomorphic universal covers.

Prerequisites: MATH 4303 and 3306

Topic: Introduction to Measure Theory

Advisor: Dr. Cesar Garza (garzace@uhd.edu)

Project Description: Measure theory and theory of the integral developed by Lebesgue at the beginning of the last century found numerous applications in other branches of pure and applied mathematics, for example in the theory of (partial) differential equations, functional analysis and fractal geometry; it is used to give mathematical foundation to probability theory and statistics, and on the real line it gives a natural extension of the Riemann integral which allows for better understanding of the fundamental relations between differentiation and integration. We will discover the essential foundations of this important aspect of mathematical analysis.

Prerequisites: MATH 4307, or at least 3307.

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Topic: Mathematical modeling of some biological/physical systems

Advisor: Dr. Vlad Hryniv (hrynivv@uhd.edu)

Project Description: Brief description of project: We can consider, for example, a biological population (or possibly populations) and how its growth/decay can be modeled by using differential equations (or partial differential equations), difference equations, etc. The same idea applies to a physical system, that is, it would be a model that has some applications in physics.

Pre-requisite: Ideally, students will have taken by that time a course like differential equations or even partial differential equations, although Calculus II and or III is enough.

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Topic: Triangular norms (norms)

Advisor: Dr. Jean Nganou (nganouj@uhd.edu)
Project Description: A t-norm is an operation on the unit interval subject to some additional properties. These are used in probabilistic metric spaces to replace the standard distance for metric spaces. These play a key role in fuzzy logic, and in many-value logic in particular. Scholar will explore t-norms, and study some of the important classes of t-norms such as continuous, monotonic, archimedian, nilpotent. Examples of each type will be considered as well as applications of t-norms in general.

Prerequisites: Multivariable calculus should be enough, but the introduction to analysis is preferred.

Topic: On the number of groups of a given order
Advisor: Dr. Jean Nganou (nganouj@uhd.edu)

Project Description: Given a position integer $n$, we denote by $k(n)$ the number of groups (up to isomorphism) of order $n$. For example, $k(1) = 1, k(2) = 1, k(3) = 1, k(4) = 2$, .... Scholar will study the function $k$ and find some of its properties. Compute $k(n)$ for some nice classes of integers like primes, square of primes...In addition characterize all the integers $n$ such that $k(n) = 1$, and all the integers $n$ such that $k(n) = 2$.

Prerequisites: An introduction to modern algebra.

Topic: The Jordan normal form (JNF) of a matrix.
Advisor: Dr. Jean Nganou (nganouj@uhd.edu)

Project Description: Matrices play a significant role in solving (systems of) differential equations. However the operation needed on matrices in representing solutions can be extremelly difficult to compute in general. On the other hand, some matrices (for example diagonal, or diagonalizable) workout much easily. The JNF is a standard way to replace a given matrix with a nicer one that would work better with the operations stated above. Scholar will study the method of computing the JNF of matrices and apply it on a number of matrices.

Prerequisites: An introduction to linear algebra.

Topic: The Golden ratio and applications.
Advisor: Dr. Jean Nganou (nganouj@uhd.edu)

Project Description: The golden ratio is the positive solution $\varphi$ of the equation $x^2 - x + 1 = 0$. This number shows up in various contexts and areas of mathematics, and is closely related to some constructability problems in geometry. Scholar will explore various famous areas where the Golden ratio appears. A special attention will be given to applications in geometry.

Prerequisites: Minimal background beyond calculus. Geometry for teachers is desirable.

Topic: The method of residues for computing integrals
Advisor: Dr. Jean Nganou (nganouj@uhd.edu)
**Project Description:** In Calculus, students learn to compute definite integrals using the usual techniques of integration. However, there are many nice functions (for instance rational functions) where the techniques covered seem hopeless. Remarkably, one can compute a good class of such integrals using residues from complex analysis. Scholar will study the theorem and understand its proofs. More importantly, scholar will apply the theorem to compute integrals that seem very complicated to apply the usual technique from calculus.

**Prerequisites:** Complex variables

**Topic:** The (Hamilton) quaternions

**Advisor:** Dr. Jean Nganou (nganouj@uhd.edu)

**Project Description:** The complex numbers system extends the real numbers system and the quaternion numbers system extends the complex numbers system. They have very interesting algebraic and geometric properties and are used significantly in Physics. Scholar will define the quaternion numbers and study some of their main properties. He/she would also cover few connections/applications in Physics.

**Prerequisites:** It is desirable to have taken modern algebra and/or linear algebra.

**Advisor:** Dr. Sergiy Koshkin (koshkins@uhd.edu)

**Topics:** Patterns in plant growth: Fibonacci spirals and optimal packing; Number theoretic methods in cryptography: golden cryptography and generalizations; Finding winning game strategy by Monte-Carlo search: the game of Chomp; Plane curves and relativity: adding velocities on a cubic; Geometry in painting: golden spirals, quasicrystal tilings, inversions, impossible objects; Actuarial mathematics: survival modeling and optimization of insurance premiums; Image processing with linear algebra, fuzzy logic and clustering algorithms; Voting patterns at the US Supreme Court revealed by spectral decompositions; Geometry of bicycle tracks: when does the back wheel retrace the front wheel track?; Solving large linear systems on a quantum computer, much faster

**Project Description:** Individual projects are based on background skills and general areas they want to pursue in the future.

**Prerequisites:** Based on project.

**Topic:** R package development

**Advisor:** Dr. Dexter Cahoy (cahoyd@uhd.edu)

**Project Description:** The student/s will create R packages of the statistical methods/procedures that I have developed. The student/s will acquire more R programming skills, etc. The student/s will also gain co-authorship.

**Prerequisites:** Any course pre-requisites required: R/R Studio proficiency and some statistics knowledge.

**Topic/Project Description:** Study the combinatorial problem of counting number of perfect matchings in a multiset (sets of objects of different types or colors) with or without weights attached to the edges.
The applications are related to solving: Graduation type problems, Hitchcock transport problems, optimal allocation of resources problems, and others. We will use some known formulas for these counting numbers and explore various cases and specific applications.

**Advisor:** Dr. Plamen Simeonov (simeonovp@uhd.edu)

**Prerequisites:** Requires basic Calculus I and II, and Discrete Math; MAPLE or Mathlab or computer programming skills are recommended

**Topic/Project Description:** Design and implement algorithms for Boolean networks that are used to model genomic networks and state transition functions with prescribed properties. There are many open problems and project topics in this area. These networks are used in bioinformatics and biomathematics.

**Advisor:** Dr. Plamen Simeonov (simeonovp@uhd.edu)

**Prerequisites:** Discrete Math and Linear Algebra; MAPLE or Mathlab or computer programming skills are recommended

**Topic/Project Description:** I recently developed a new type of polynomial blossom with Ron Goldman from Rice University. We have the formulas, but we would like to perform some modeling and computational work for Bezier curves and surfaces for this so-called Askey—Wilson blossom. This theory has applications in geometric modeling and computer-aided design.

**Advisor:** Dr. Plamen Simeonov (simeonovp@uhd.edu)

**Prerequisites:** Requires basic Calculus I and II, and Numerical Analysis; MAPLE or Mathlab or computer programming skills are recommended

**Topic:** New Mathematics Teacher Retention in Houston-Area Schools

**Advisor:** Dr. Judith Quander (quanderr@uhd.edu)

**Project Description:** Collecting mostly qualitative data (interview, survey, and classroom observations) to better understand what new high school mathematics teachers struggle with during their first few years in the classroom.

**Prerequisites:** Math 3303 (Geometry for Teachers) or Math 3313 (Mathematics Topics for Secondary Teachers); students should be interested in mathematics teaching or mathematics education research; however, this is not for BA Math w/ Secondary Teacher Certification students who will complete their senior projects as part of Professional Block 2 in Urban Education.

**Topic:** High resolution scheme for conservation laws

**Advisor:** Dr. Xinyu Li (lix@uhd.edu)

**Project Description:** Computational methods for partial differential equations arising in biology with particular emphasis on finite difference and finite element methods and convergence analysis for these methods. Parameter estimation techniques with particular emphasis on identifying parameters in ordinary/partial differential equations arising in biology
**Prerequisites:** Numerical analysis, Differential equation

**Topic:** Statistical Data Analysis

**Advisor:** Dr. Shishen Xie (XieS@uhd.edu)

**Project Description:** Depends on student’s interest.

**Prerequisite:** At least one junior-level statistical course

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**Topic:** Any topic related to the history of math

**Advisor:** Dr. Linda Becerra (BecerraL@uhd.edu)

**Project Description:** Depends on student’s interest.

**Prerequisite:** None

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**Topic:** Any topic related to modern algebra.

**Advisor:** Dr. Linda Becerra (BecerraL@uhd.edu)

**Project Description:** Depends on student’s interest.

**Prerequisite:** Math 3306

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**Topics:** Decision analysis and game theory; Linear, integer, and binary programming; Network optimization; Project management; Analysis of sports statistics; Probabilities in games, sports, and gambling

**Advisor:** Dr. Timothy Redl (redlt@uhd.edu)

**Project Description:** Individual projects will be determined based on student’s background skills and mathematical or statistical interests in the above topics.

**Prerequisites:** Depends on the topic... discuss with project advisor.