Mathematics and Statistics Senior Project Topics

For those students looking to complete a senior project, 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. Email addresses are provided below.

Topic: Rapid equatorial winds at the equator of "hot Jupiters".

Advisor: Steven D. London (LondonS@uhd.edu).

Project description: We want to consider some problems associated with the behavior of the atmospheres of "hot Jupiters", which are large, Jupiter-like planets orbiting very close to their stars such that one side of the planet always faces its star, ie. the planet has a dayside and a nightside. In particular, these exoplanets generally (but not always) have a rapid eastward current at the equator. We would like to study the mechanism governing this current.

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: 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: The Mathematics of Classical Mechanics

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

Project Description: This is a deeper study of Newtonian Mechanics from the point of view of ODEs and Geometry. Classical Mechanics give rise to systems of differential equations known as the Euler-Legendre equations which can be transformed into Hamiltonian systems. This can be studied from the point of view of Geometry with the introduction of symplectic manifolds, Poisson structures and Hamiltonian flows. Some examples from planetary motion and rigid body systems will be analyzed.

Pre-requisite: MATH 3301 and 3307

Topic: Problems in Machine Learning

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

Project Description: This is a project about rigorously proving that some hypotheses can be "learned" in the sense of Machine Learning. That is, a learning algorithm can be found returning a hypothesis that is "probably accurately correct". This project focuses on proofs based on Statistical Inference techniques. We will study concepts such as PAC Learning, Uniform Convergence, ERM rule, VC dimension. Some typical Machine Learning problems such as axis aligned rectangles will be worked out formally.

Prerequisites: MATH 3307 and MATH 3302.

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 tnorms, 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, $kk(1)=1, kk(2)=1, kk(3)=1, kk(4)=2,….$ 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 extremely 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 $\varphi\varphi$ of the equation $xx^2 - xx + 1 = 0$. 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 undersntand 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.

Topics: R Package Development, Statistical Data Science, Statistical Computing, Computer-Intensive Methods, Mathematical Statistics, Stochastic Process, Applied Probability
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.   Project topics will be determined depending on the student's interest and background.

Prerequisites: R/RStudio proficiency and some statistics knowledge.

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/RStudio 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 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

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.

Topic/Project description: Regression models; Multivariate models; Time series models (financial data etc, ..). Time series topics (Spectral analysis, State space). Quality and Process control.
Advisor: Dr. Ha Nguyen(nguyenha@uhd.edu)
Prerequisites: Senior level; Proficient in at least one Statistical language.