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Research Experiences at All Levels: From K-12 Through Ph.D. and Beyond

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Abstract— **This presentation will focus on vertical and horizontal research on stochastic theory and control. In ten poster presentations, the importance of the vertical and horizontal teaching and research will be shown. Through those ten posters prepared by undergraduate, graduate, K-12 students and established researchers the development of complexity of control problems and their solutions will be presented.**

I. FOCUS ON EDUCATION AND OUTREACH

Stochastic theory and control is traditionally taught within the various mathematics, engineering, sciences, medicine, economics and business disciplines that make use of their tools, allowing a tight coupling between the methods of stochastic theory and control and their applications in a given domain. Epilepsy has been a domain for Kansas Stochastic Control group for the last ten years. An interdisciplinary research program will be illustrated with *Math and Epilepsy* as an educational study-case.

Lectures, workshops, science fair projects, master theses have served as a platform for mathematics and control education. More students in biology, computer science, environmental science, physics, mathematics and other disciplines seek to learn and apply the mathematical methods. To meet their expectations we have provided new exciting ways of providing motivation for studying complicated concepts of mathematics starting from freshman years of calculus. Through this project we will invest in new approaches to education and outreach for the dissemination of stochastic theory and control concepts and tools to non-traditional audiences as K-12 students and K-12 teachers.

As a first step toward implementing this recommendation, new courses and workshops will be discussed for both undergraduates and graduates. Additional steps to be taken include development of new teaching materials that can be used to broadly educate the public about mathematics and epilepsy. This might include a multimedia CD that describes the complexity of epilepsy and mathematical tools that have been used. The benefits of reaching out to broader students' communities will be increased awareness of the usefulness of mathematics and control and acceleration of the benefits of mathematics and control through broader use of its principles and tools.

The power of the educational component of the proposed project lies in providing practical experience in applying calculus to freshmen to stimulate future interest. This project emphasizes the integration of mathematics education and research at all levels of instruction from elementary to graduate school. The proposed project emphasizes the importance of collaborative effort, provides a cross-disciplinary set of examples and demonstrations that illustrate mathematics principles across the entire spectrum of biology and medicine. It shows strongly the fundamental importance of mathematics, in particular, importance of control systems in the day-to-day lives of people. The goal of increasing public awareness of usefulness of mathematics is and control an educational one and can best be undertaken by mathematicians and medical doctors, users of mathematics.

We strongly believed that the success of the Research Experiences for Undergraduates (REU) Program at the University of Kansas, in stochastic area, has been achieved because of the involvement and strong commitment of Dr. Osorio and Dr. Frei. Both of them gave lectures every semester to students, undergraduate and graduate, in every class that was taught by Bozenna Pasik-Duncan and Tyrone Duncan. They were presenters at every workshop for 5-6th graders during the Math Awareness Month (MAM), and at the First NSF Workshop for High School Teachers of Mathematics and Science on "Ideas and Technology of Control Systems" in Chicago, 2000. The purpose of that workshop was to enhance the cooperation among various control groups and high school teachers of mathematics and science throughout the United States and the world, to give attention to control and systems ideas and technology, and to increase the general awareness of the importance of control and systems technology and its cross-disciplinary nature among high school teachers and students. The workshop was organized by Bozenna Pasik-Duncan and was held in conjunction with the American Control Conference (ACC).

Out of 20 undergraduates working as REU program members, 2 finished with master theses on epilepsy; 4 of them became NSF Graduate Fellows in mathematics, physics and astronomy, engineering, and philosophy of sciences. All four of them participated in Math and Epilepsy collaboration. This shows how important and successful the program has been.

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For mathematics professors there is nothing more powerful than bringing real-life problems to the classroom, present them to talented students no matter which level and challenging them to solve them. Kansas Stochastic Control group has been lucky having real-life problem collaborators. We plan to make this program more constructive and permanent. We would make our presentations available on-line. More students, teachers, and colleagues could benefit from our collaboration.

II. STUDENT PRESENTATIONS

The following undergraduate presentations will be given:

- Dominique Duncan
  Quantitative Analysis and Prediction of Epileptic Seizures
  Advisor: Bozenna Pasik-Duncan
  Historically, seizures have been considered unpredictable. Recent results indicate that the prediction of a clinical onset of seizures is impossible. The existing algorithms quantify important seizure characteristics such as intensity, site of origin, spatio-temporal propagation, and duration, making detailed analysis of seizures possible. To predict a seizure we have investigated the relationship between the arclength of the brain waves and the onset of a seizure. Our results show that the simple calculus method of arclength can predict a seizure a few seconds before it occurs. The ability to rapidly and accurately detect epilectic seizures using scalp-recorded signals was shown to be highly dependent upon the "signal-to-noise ratio" present in the recordings. We focus our attention on the development of innovative methods to enhance the seizure signal and to reduce or remove the noise. Different methods of stochastic analysis and mathematical statistics will be applied. Real data for this project have been provided by Dr. I. Osorio at the KU Medical Comprehensive Epilepsy Center.

- Lindsay Hertzig, Amy Lindsey, and Lainey Ahillen
  Statistical Analysis of an Elementary Model for Control of Semiconductor Etching
  Advisor: Bozenna Pasik-Duncan
  The dynamic model for the thermal chlorine etching of gallium arsenide semiconductors consists of three ordinary differential equations. The first ODE models the chemical reaction, the second models the changing pressure in the etching chamber, and the third models the dynamics of a throttle valve which controls chamber pressure. Various statistical methods will be applied to estimate unknown parameters that appear in the equations for the model for control of a semiconductor etching process.

- Vents Ivanov
  Estimation and Queueing Networks
  Advisor: Bozenna Pasik-Duncan
  A queueing network is an interconnected grid of service facilities called nodes. Each node may have its own service mechanism and queueing discipline. For each node there is a probabilistic mechanism for routing traffic either to other nodes or out of the system. Networks may be either closed or open. A closed network has a fixed number k of nodes and a fixed number m of customers. It is assumed that no traffic either enters into or departs from the system. An open network permits arrivals and departures. The rates of arrivals and departures are assumed to be unknown and they will be estimated using the maximum likelihood estimator. Properties of this estimator will be analyzed. I am also interested in acquiring the probabilistic distribution of the queue length process.

- Ian Lewis
  Simulation of Random Variables, Stochastic Differential Equations, and a Finance Model
  Advisor: Bozenna Pasik-Duncan
  Stochastic (random) processes are used everyday to simulate and predict what will happen in financial systems. It is very helpful to simulate these systems and processes on a computer. In this research, I first familiarized myself by writing programs to simulate simple random variables in the language MATLAB. Then general programs were written for the simulation of stochastic differential equations using various approximation methods. These programs are easily adaptable to different specific stochastic differential equations. Then it was attempted to write a program to simulate a financial model with transaction fees.

- Jason Shea
  On Identification and Simulation of the Stochastic Heat Equation
  Advisor: Bozenna Pasik-Duncan
  The Stochastic variant of the one-dimensional heat equation will be considered utilizing different types of control. The system noise will be modeled using Brownian motion techniques. Simulations of the solution(s) to this equation will be constructed using Matlab software and certain unknown parameters will be estimated through application of the Maximum Likelihood Method.

- Naomi Smith
  Statistical Analysis of Coronary Heart Disease and its Risk Factors
  Advisor: Bozenna Pasik-Duncan
  Coronary heart disease (CHD) is the most prevalent cause of death in the United States. Understanding the effects of suspected risk factors for CHD is therefore essential to the average American in maintaining cardiovascular health. The purpose of this research is to

statistically examine the relationship between certain risk factors and the development of CHD. These factors are selected from gender, age, systolic blood pressure, diastolic blood pressure, serum cholesterol, and the number of cigarettes smoked per day. The different statistical methods used for analysis are testing hypotheses, confidence intervals, regression and correlation analysis, and testing for independence. The data for this research are taken from the Framingham Heart Study.

Additionally, graduate students Shane Haas, graduate student at MIT and a former KU student; Annie Davies, Belinda Pierson, Olga Nemon and Yiannis Zachariou, KU graduate students, will present their projects on the same topics as those undergraduates listed above. Finally, the presentation on *Math and Epilepsy* by Dr. Ivan Osorio, KU Medical Center, and Dr. Mark Frei, president of Flint Hills Scientific and a Ph.D. graduate of KU, will be given. The video presentation prepared by PBS will also be shown.