LSU College of Science Research Summary for Michael Malisoff

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My research area is applied dynamical systems, with a focus on mathematical control theory, with applications to marine robotics, aerospace engineering, and several other engineering domains. My research is largely on improving the performance of dynamical systems by using feedback controls, which are ways to automatically adjust the action of a system in response to information about the system's state and surroundings. An example of a feedback control is a thermostat that turns on air conditioning when the temperature of a room gets too high, and more complex feedback controls are used in many branches of engineering. Typically, feedback controls are applied to a class of dynamical systems called tracking systems, and then the goal is to force the state of the system to track a desired operating mode, such as a flight path for an airplane, or a path for a marine robot. For simple linear systems, it is often easy to design feedbacks that ensure tracking, using linear algebra. However, it can be difficult to achieve tracking for more realistic systems having nonlinearities, time delays, uncertainties, or constraints on the allowable control or state values. To handle these more complex systems, I developed delay compensation and data-driven methods, event-triggered controllers, observer designs, and robust forward invariance methods. Robust forward invariance leads to predictable tolerance and safety bounds that ensure obstacle avoidance, and event-triggered controls have the advantage of only changing the control values when it is essential to do so. My research proves mathematical theorems. However, the theory I develop is geared towards applications. I have collaborated with engineering faculty on control problems for active magnetic bearings, adaptive systems, bioreactors, DC motors, heart rate controllers, hovering helicopters, human-computer interactions, marine robots, microelectromechanical relays, neuromuscular electrical stimulation, and unmanned air vehicles. Some of this work is in my Springer research monograph and journal articles, which are largely in control engineering and mathematical control theory journals and were sponsored in part by my research grants from the US National Science Foundation.

I am always interested in involving students and postodoctoral researchers in my research, and many of my publications are co-authored with students. Students working on my projects must first have a background in undergraduate mathematics that includes differential equations. Then I aim to guide my mathematics student advisees towards an interdisciplinary approach, where the original motivation comes from a specific engineering problem, but where the ultimate goal is to prove general mathematical results that apply to a wider range of control systems. When co-advising students from engineering, I aim to help them develop new feedback control techniques that can guarantee improved performance for control systems in specific engineering systems in engineering labs. I have collaborated with 12 PhD students on my research. One of my PhD advisees, Aleksandra Gruszka, won three awards for her research. She won a finalist plaque for the Best Student Paper Award at the 2011 American Control Conference, where she also won the best presentation award in her session, and she was one of the 12 graduate students from across the US who were chosen to present their research in the Association for Women in Mathematics sessions at the 2012 Joint Mathematics Meetings. I also collaborated with Prof. Fumin Zhang from the Georgia Tech School of Electrical and Computer Engineering on an NSF RAPID project that used marine robots to search for oil pollution from the Deepwater Horizon oil spill. Our RAPID project combined control theory with field work with actual robots at Grand Isle, LA, and it involved 13 graduate and undergraduate students. Marine robots are useful because of the hazards and high costs of having humans working in polluted areas. There were news reports about our marine robotics project, including an article in the LSU College of Science magazine, an NSF highlight at research.gov, and an AP article that appeared in many US newspapers. My more recent projects have used model predictive control to resolve contentions on communication networks, and have studied event-triggered controls under the types of delays that can arise from underwater communication.

Key words: control systems, engineering mathematics, interdisciplinary