Noise induced large fluctuations in delay-coupled mixed reality systems

Ira B. Schwartz[1], **Klimka Szwaykowska**[1], **Thomas W. Carr**[2], **Jason Hindes**[1,3]

[1] *US Naval Research Laboratory, Code6792, Washington, DC 20275, USA (e-mail: Ira. Schwartz@nrl.navy.mil, klementyna.szwaykowska.ctr@nrl.navy.mil, jason.hindes.ctr@nrl.navy.mil)*
[2] *Southern Methodist University, Department of Mathematics, Dallas, Texas 75275, USA (e-mail: tcarr@smu.edu)*
[3] *JH is currently National Research Council fellow.*

With the availability of ever more cheap and powerful computing, interest in the use of augmented and mixed-reality experiments has grown considerably in the engineering and physical sciences. Broadly speaking, these experiments consist of a simulated, or virtual model coupled directly to a physical experiment. Within the physical experiment, it is typical to find a good deal of uncertainty and noise since it is connected to the real world, and thus subjected to random perturbations. In contrast, the virtual part of the coupled system represents a somewhat idealized version of reality in which noise can be eliminated entirely, or at least well characterized. Thus, mixed-reality systems have very skewed sources of uncertainty spread through the entire system.

In this talk, we consider the pattern formation of delay - coupled swarms theoretically and experimentally to illustrate the idea of mixed-reality. Motivated by mixed-reality experiments, we then consider a generic model of a mixed-reality system, and show how noise in the physical part of the system can influence the virtual dynamics through a large fluctuation, even when there is no noise in the virtual components. The virtual large fluctuation happens while the real dynamics exhibits only small random oscillations. We quantify the effects of uncertainty by showing how characteristic timescales of noise induced switching scale as a function of the coupling between the real and virtual parts of the experiment. Our results show that the probability of switching in the virtual world scales inversely as the square of reduced noise intensity amplitude, rendering the virtual probability of switching to be an extremely rare event. Our results are also confirmed through simulations, which agree quite well with analytic theory.