CPS: Small: Random Matrix Recursions and Estimation and Control over Lossy Networks

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Project Details

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Abstract: This award is funded under the American Recovery and Reinvestment Act of 2009 (Public Law 111-5). Many of the future applications of systems and control that will pertain to cyber-physical systems are those related to problems of (possibly) distributed estimation and control of multiple agents (both sensors and actuators) over networks. Examples include areas such as distributed sensor networks, control of distributed autonomous agents, collision avoidance, distributed power systems, etc. Central to the study of such systems is the study of the behavior of random Lyapunov and Riccati recursions (the analogy is to traditional LTI systems where deterministic Lyapunov and Riccati recursions and equations play a prominent role). Unfortunately, to date, the tools for analyzing such systems are woefully lacking, ostensibly because the recursions are both nonlinear and random, and hence intractable if one wants to analyze them exactly. The methodology proposed in this work is to exploit tools from the theory of large random matrices to find the asymptotic eigendistribution of the matrices in the random Riccati recursions when the number of states in the system, n, is large. In many cases, the eigendistribution contains sufficient information about the overall behavior of the system. Stability can be inferred from the eigenanalysis. The mean of the eigenvalues is simply related to the mean of the trace (i.e., the mean-square-error of the system), whereas the support set of the eigendistribution says something about best- and worst-case performances of the system. Furthermore, a general philosophy of this approach is to identify and exhibit the universal behavior of the system, provided such a behavior does exist. Here, "universal" means behavior that does not depend on the microscopic details of the system (where losses occur, what the exact topology of the network or underlying distributions are), but rather on some simple macroscopic properties. A main idea of the approach is to replace a high-dimensional matrix-valued nonlinear and stochastic recursion by a scalar-valued deterministic functional recursion (involving an appropriate transform of the eigendistribution), which is much more amenable to analysis and computation. The project will include course development and the recruitment of women and minority students to research. It will also make use of undergraduate and underrepresented minority student researchers through Caltech's SURF and MURF programs.

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