The Texas A&M University System and Los Alamos National Laboratory partner to design robust networks

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By The Texas A&M System National Laboratories Office

Researchers are developing innovative solutions to improve performance and robustness of complex networks, like power grids and multi-robot networks, through a collaborative research effort established by the Texas A&M University System (TAMUS) National Laboratories Office and Los Alamos National Laboratory (LANL).

Swaroop Darbha, Ph.D. from TAMUS and Harsha Nagarajan, Ph.D. from LANL have teamed up to improve robust complex networks, specifically power grids. Their research lies at the intersection of control theory, discrete optimization and complex networks. They are basically developing a solution strategy for Mixed-Integer Semi-Definite Programs (MISDPs) appearing in complex network applications.

There are a lot of design and operation decisions that need to be made in developing a networked system. One decision a designer needs to make is whether to place a sensor or an actuator in a specific location. A sensor is a component that turns a physical attribute into an electronic signal and an actuator takes an electronic signal and turns it into a physical action. This concept explains the "mixed-integer" part of an MISDP. It is called a mixed-integer because when there is a physical component that either provides electrical signals or physical actions or not, these are restricted to integers in the computer program. However, it is mixed because these integers are mixed with the other actions throughout the network, which may be continuous variables in the program.

The "semi-definite program" part of an MISDP relates to optimization. In multi-robot networking applications, robots gather information by communicating with each other to establish the state of the system. Since it is expensive to establish communication among robots, the designer needs to decide which robots really need to communicate in order to minimize estimation errors and keep the overall cost within a reasonable budget. In this aspect of the network, "definiteness" relates to connectedness of the robots via communication.

Nagarajan explained, "This project not only focuses on the theoretical aspects of mathematical modeling but also on the development of computational methods and algorithms which address a hard, open problem in the discrete system realization aspect of control theory. The developed methods are fundamental enough which can be applied on a myriad of applications such as advanced manufacturing networks, robot localization, unmanned aerial vehicle routing and power grids."

Power grids motivated this research because they require networks that are reliable and resilient. Issues with system stability arise due to brief interruptions and random disturbances from fluctuating renewable energy sources and uncertain demands. This research would help to stabilize the networks and optimize energy expenditure of the system by strategically locating the control devices and responding to the dynamic status of the system.

The research has applications beyond power grids. Darbha explained, "In manufacturing networks, such as in roll-to-roll manufacturing applications, an error in the location of the web relative to the roller can propagate through the network and affect the quality of the product at the downstream end. In such applications, there arises a problem of determining 'where' to place actuated rollers to minimize the disturbance propagation and enhance quality of the product."

The methods developed in this project towards solving MISDPs also can be used towards developing open-source tools that can be utilized in a variety of fields and applications in the future. This partnership between the TAMUS and LANL will provide new insights and innovations in future systems improvement.

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