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ON STABILITY MARGIN OF A LQR-BASED VEHICLE NETWORK

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Abstract

A classical controller can be designed for a stable single vehicle to guarantee a certain stability margin. For aerospace applications, the stability margin is an important measure whose desirable values are explicitly found in military specifications such as MIL-STL-1797. It is well-known that a LQR (linear quadratic regulator) control-based vehicle has a guaranteed stability margin of 6 dB (gain margin) and 60 degrees (phase margin), and it thus has a desired stability margin according to MIL-STL-1797. Here, the LQR control 'u' is given as a state feedback control, i.e. u = Fx, where 'F' is a LQR gain and 'x' is the state vector. But then, what will happen to the guaranteed stability margin if multiple LQR control-based vehicles are connected according to a certain network topology for some purpose such as formation flight? For the purpose of formation flight, the same LQR control gain as for a single aircraft can be used but multiplied with the relative state vector being calculated based on each aircraft's neighbours; the LQR control u this time is given as u = FL(x-h), where 'F' is the same LQR gain as before, 'L' is an augmented version of the Laplacian matrix corresponding to the network topology, and 'h' is a desired state vector. In this case, it can be shown that (1) the stability margin after the interconnection cannot exceed the guaranteed stability margin of LQR control before the interconnection; (2) when each of the vehicles has a single integrator, the stability margin becomes the Laplacian matrix's zero eigenvalue sensitivity's inverse with a high chance when the sensitivity is large; and (3) there exists a computationally effective upper bound that estimates the stability margin to high accuracy. In addition, a generalized Laplacian matrix (still reflecting the network topology) can be designed for a (not necessarily symmetric) directed network, in a way to maximize the stability margin of the networked system via a LMI (linear matrix inequality) technique.

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