Stability analysis of a LTI-TDS dynamics with four independent delays

Dynamics with the following 2 by 2 state space representation is studied for stability:

x_dot(t) = A x(t) + B1 x(t-tau1) + B2 x(t-tau2) + B3 x(t-tau3) + B4 x(t-tau4)

where

A = [0 1 ; -2 -4]   , B1 = [-6 0 ; 1 0],   B2 = [0 4 ; 0 -2],

B3 = [3 -4 ; -2 1],   B4 = [-9.45 -9.1 ; 5.5 2.55]

When tau3 = tau4 = 0, the problem reduces to the one solved in [Sipahi, Olgac, 2006, Systems and Control Letters] (see the stability picture with boundaries in black) with the technique CTCR [Sipahi, Olgac, 2005 Automatica].

When tau3 and tau4 are *non-zero*, a 4-D stability picture has an interesting formation. With non-trivial extensions of CTCR, corresponding stability picture can still be extracted. For ease of display and for comparison with tau3 = tau4 = 0 case, tau3 and tau4 are chosen as 10 msec, and the boundaries of the stability picture are depicted by blue curves.

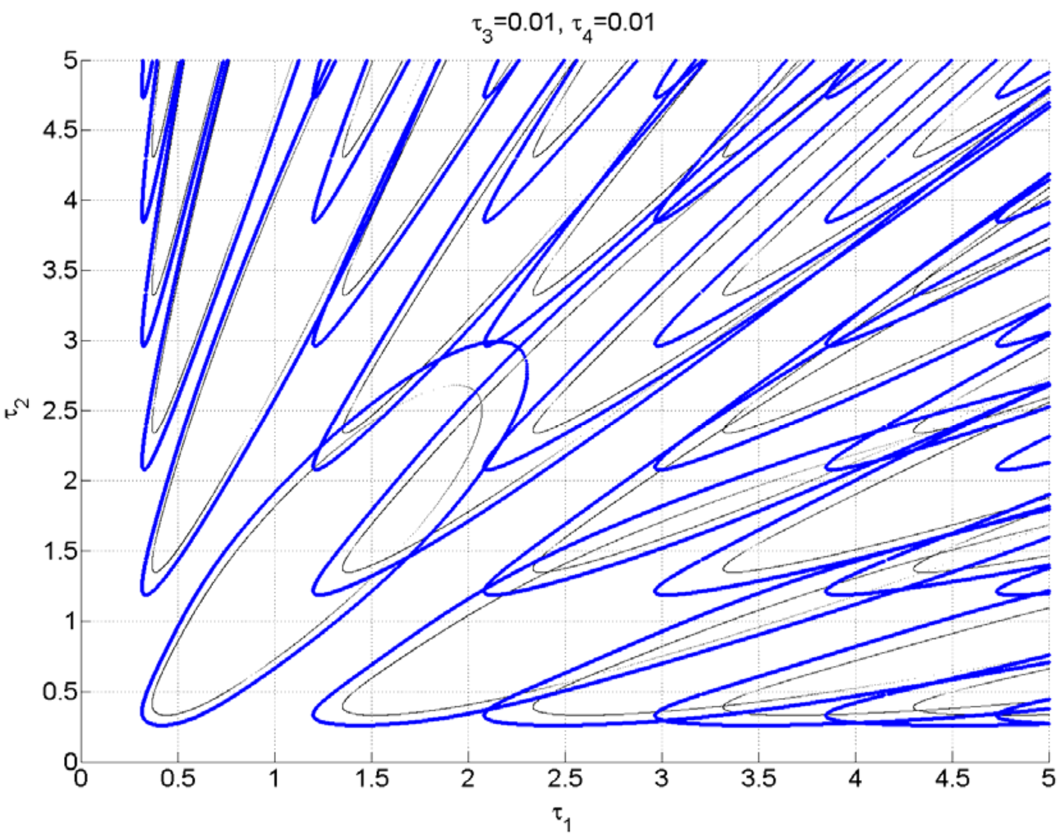

Figure obtained by non-trivial extensions of CTCR

For cross-validation, two different techniques (one based on detection of imaginary axis crossings by [Elias Jarlebring], and the other on the distribution of right most roots by [Dimitri Breda]) are presented below.

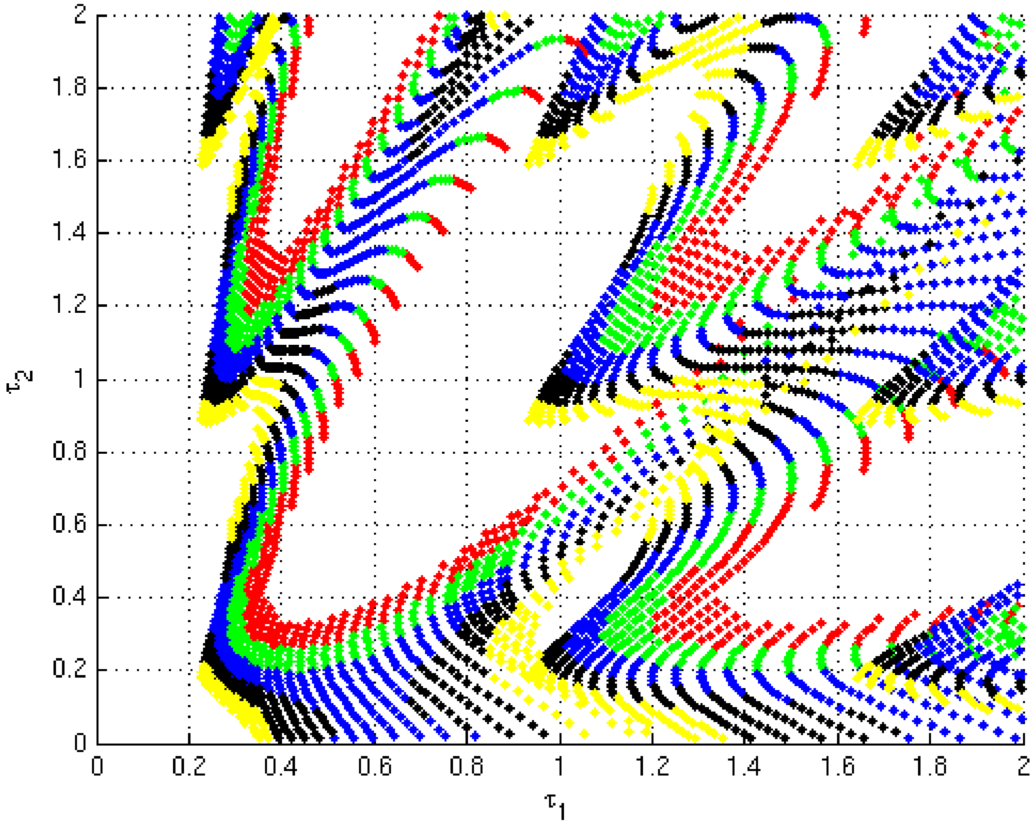

Figure obtained by the technique in [Jarlebring, Computing the Stability Region in Delay-space of a TDS using Polynomial Eigenproblems, 6th IFAC Workshop on Time-Delay Systems, 2006] (tau3=tau4 swept between 0 to 0.01)

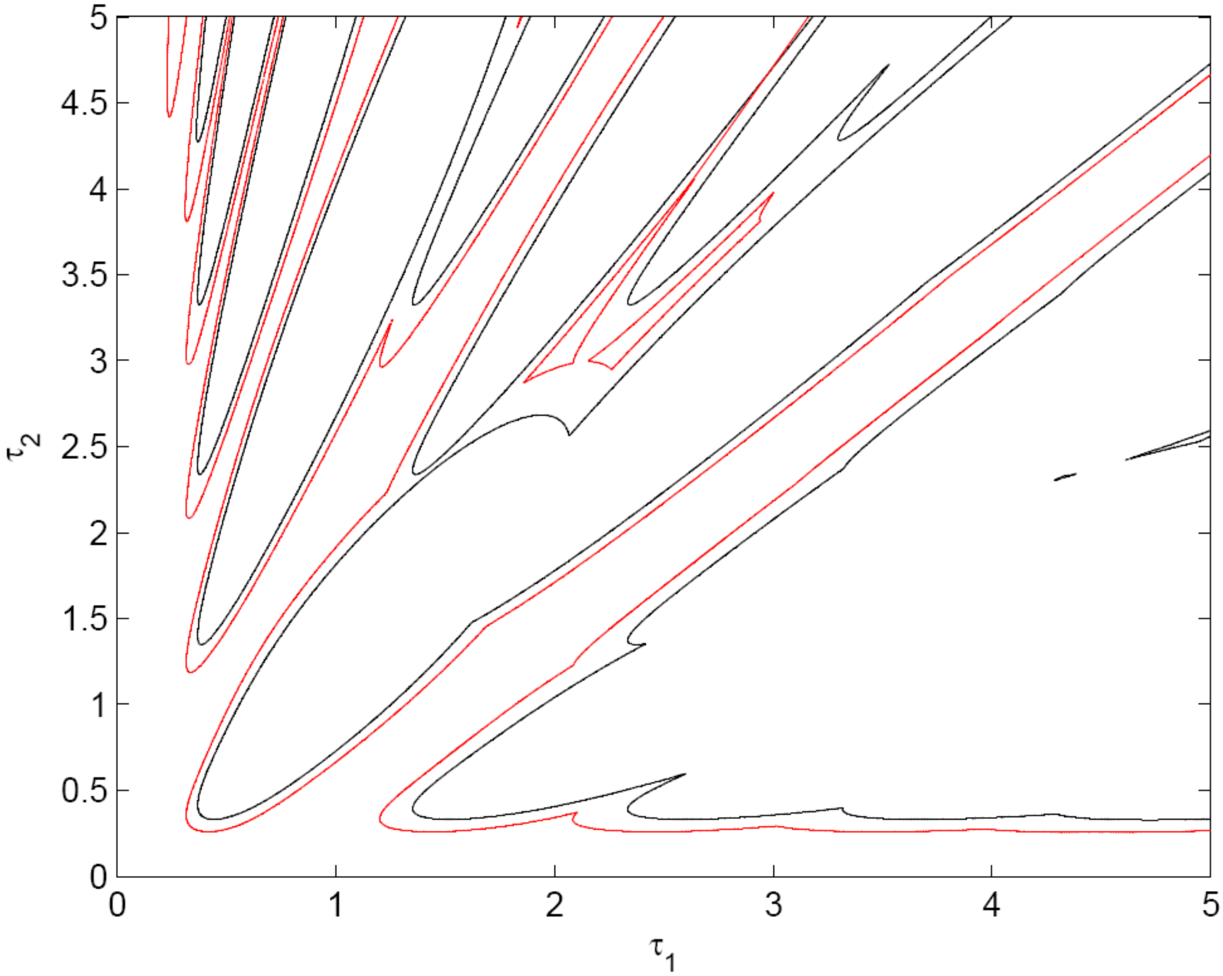

Figure obtained by the technique in [Breda, D., Maset, S., and Vermiglio, R., "Pseudospectral differencing methods for characteristic roots of delay differential equations", SIAM J. Sci. Comput., vol. 27(2), pp. 482-495, 2005.] (black curves -> tau3=tau4=0, red curves tau3=tau4=0.01)