

Ph.D. Brainstorming Day

DIEEI, University of Catania, Catania, Italy

Time delays Systems

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1# A Numerical procedure to obtain the pseudo-polynomial characteristic equation of a commensurate time-delay system

Objective:

The proposed method is a numerical procedure to obtain the coefficients of the pseudo-polynomial characteristic equation of a commensurate time-delay system. The method is formulated in term of an interpolation problem and it is based on the generation of a suitable set of random numbers.

Method description:

The characteristic equation of a commensurate Time Delay System can be written in term of coefficients as:

$$a(s; z) = a_0(s) + \sum_{k=1}^m a_k(s) z^k \quad \tau \geq 0, k = 1, \dots, m$$

Where: $a_0(s) = s^n + \sum_{i=0}^{n-1} a_{0i} s^i$; $a_k(s) = \sum_{i=0}^{n-1} a_{ki} s^i$, $k = 1, 2, \dots, m$

The coefficients depends only on the number of delays and the matrices sizes.

The equation has r unknown coefficients, a_{0i}, a_{ki} , with r is:

$$r = r_0 + \sum_{i=1}^n (m * i), \quad r_0 = n + 1$$

In order to find the unknown coefficients, the following system of r linear equations should be solved:

$$C = H(s, \tau) \cdot M$$

- $C = [c_1, \dots, c_r]$
- $c_i = \det(s_i I - A_0 - \sum_{k=1}^m A_k z_i^k)$
- $M = [a_{0n}, \dots, a_{00}, a_{1n}, \dots, a_{11}, \dots, a_{kn}]$
- $H_i = \begin{pmatrix} s_1^{n-i} z_1^i & s_1^{n-i-1} z_1^i & \dots & z_1^i \\ s_2^{n-i} z_1^i & s_2^{n-i-1} z_1^i & \dots & z_2^i \\ \vdots & \vdots & \ddots & \vdots \\ s_r^{n-i} z_r^i & s_r^{n-i-1} z_r^i & \dots & z_r^i \end{pmatrix}$
- $H = (H_0 | H_1 | \dots | H_q) \quad i=0, \dots, qc$

$$M = H^{-1}(s, \tau) \cdot C$$

M is the coefficients of the pseudo-characteristic equation

Method advantage:

The procedure is suitable for the stability analysis of commensurate TDSs with many delays, where the symbolic computation of the pseudo-polynomial cannot be adopted.

2# Linear dynamic coupling in the synchronization of hyperchaotic systems

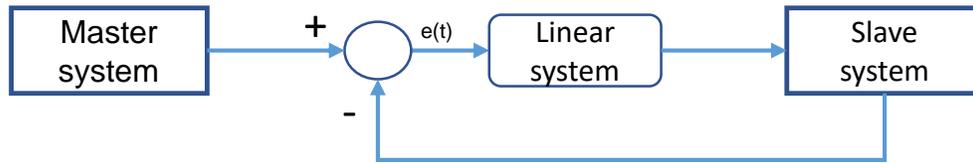
Objective:

A novel coupling scheme is applied to the synchronization of hyperchaotic systems. The coupling scheme is based on a simple linear dynamical system driven by a suitable signal, accounting for the synchronization error.

Method description:

The coupling scheme is based on the definition of a suitable error signal and using such signal to drive a second-order linear dynamic system. The output of such linear dynamic coupling is then used to synchronize the slave system.

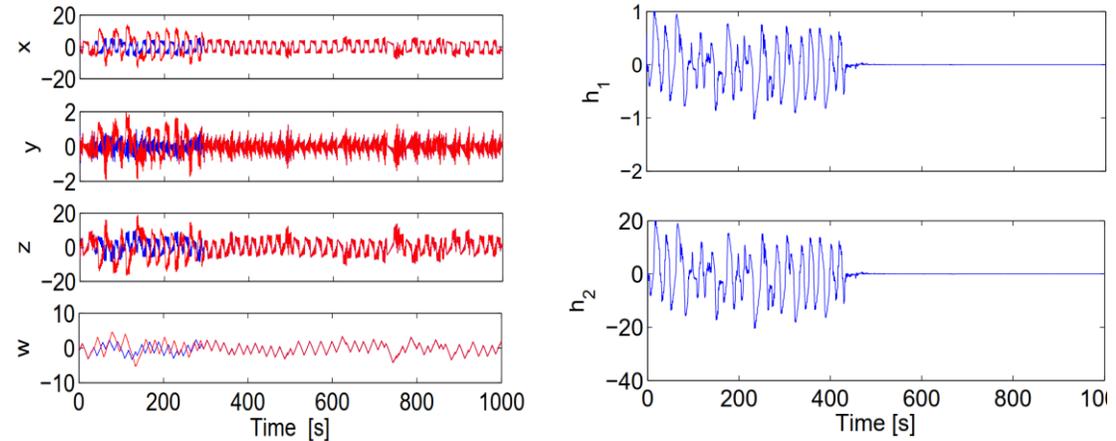
Master /Slave systems coupling:



The synchronization scheme can be represented by:

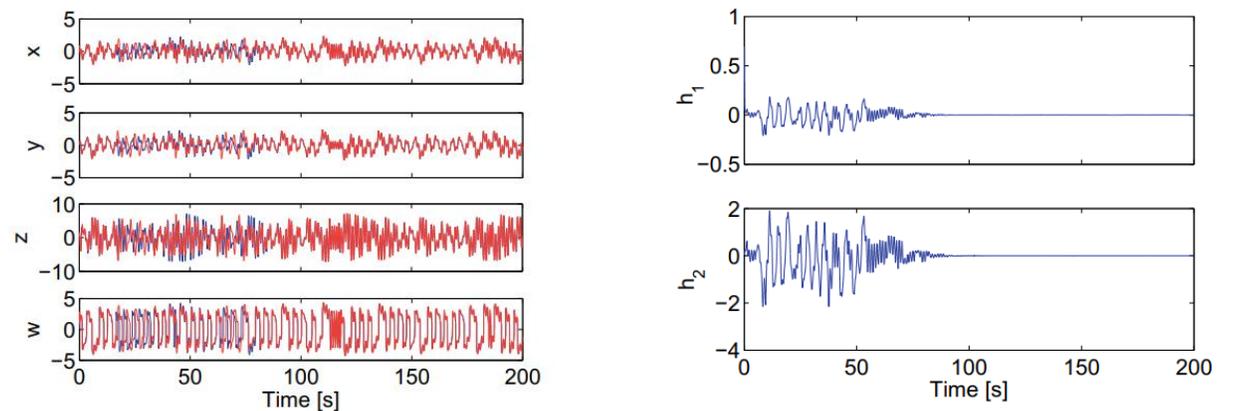
$$\begin{aligned} \dot{x}_M &= F(x_M) \\ \dot{x}_S &= F(x_S) - B_1 h \\ \dot{h} &= Gh - KB_2(x_M - x_S) \end{aligned}$$

Synchronization of two hyperchaotic Chua's circuit using a linear dynamic coupling



(a) trends of the master (blue) and slave (red) state variables; (b) trends of the state variables of the linear coupling system.

Synchronization of two hyperchaotic Saito oscillator using a linear dynamic coupling

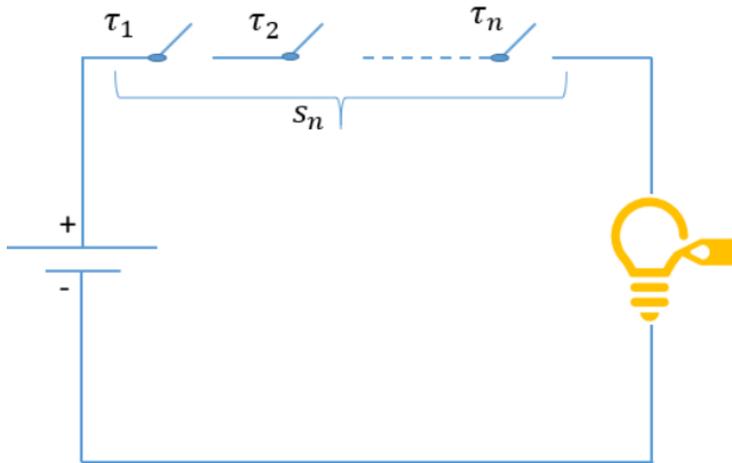


3# Modeling a population of switches via chaotic dynamics

Objective:

A new method to model switching mechanisms using a deterministic switches. The study takes into account two cases the logistic map and the time recurrence of chua's circuit. The main objectif is to explain how the serie connecting mode of switches affects the behavior of the entire switch population and in particular the degree of synchronization and how these connections can be used to reduce the random variability (i.e., the CV), thus increasing the synchronization level.

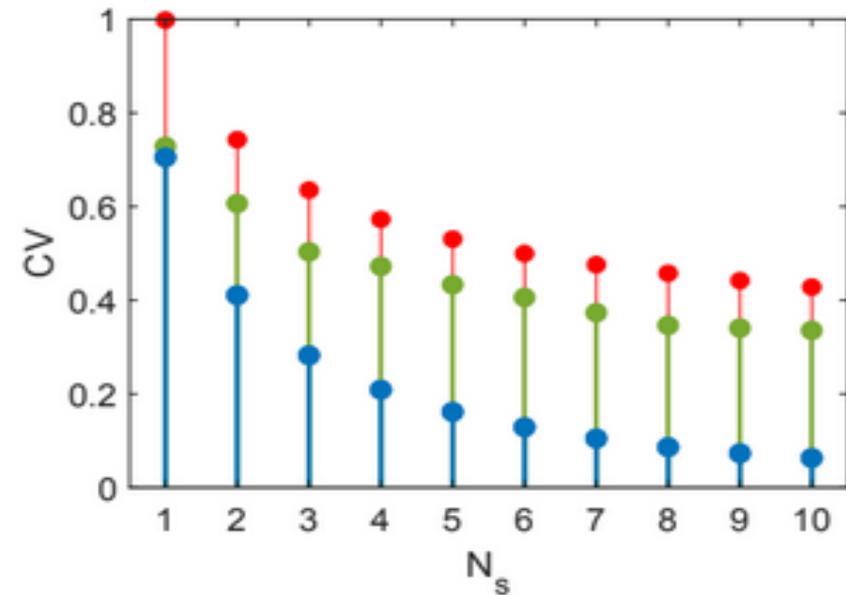
Method description:



A composite switch, made of n independent irreversible switches connected in series, denoted sn-switch.

The coefficient of variaion is:

$$CV = \frac{\sigma_{on}}{\bar{\tau}_s}$$



The Coefficient of variation calculated for N_s irreversible switches: stochastic switches (red), chaotic switches (blue: logistic map; green: Chua's circuit).

4# Graphical Method for the Stability Analysis of Commensurate Multiple Time Delay Imperfect Systems

Objective:

A graphical method to analyze the stability of LTI systems, with multiple commensurate time delays, is proposed. It is based on the determination of the purely imaginary roots of the pseudo-polynomial characteristic equation of the system.

Method description:

The characteristic equation of TDS can be represented as bivariate polynomial:

$$a(s, z) = \sum_{k=0}^q a_k(s) z^k; z = e^{-\tau s}$$

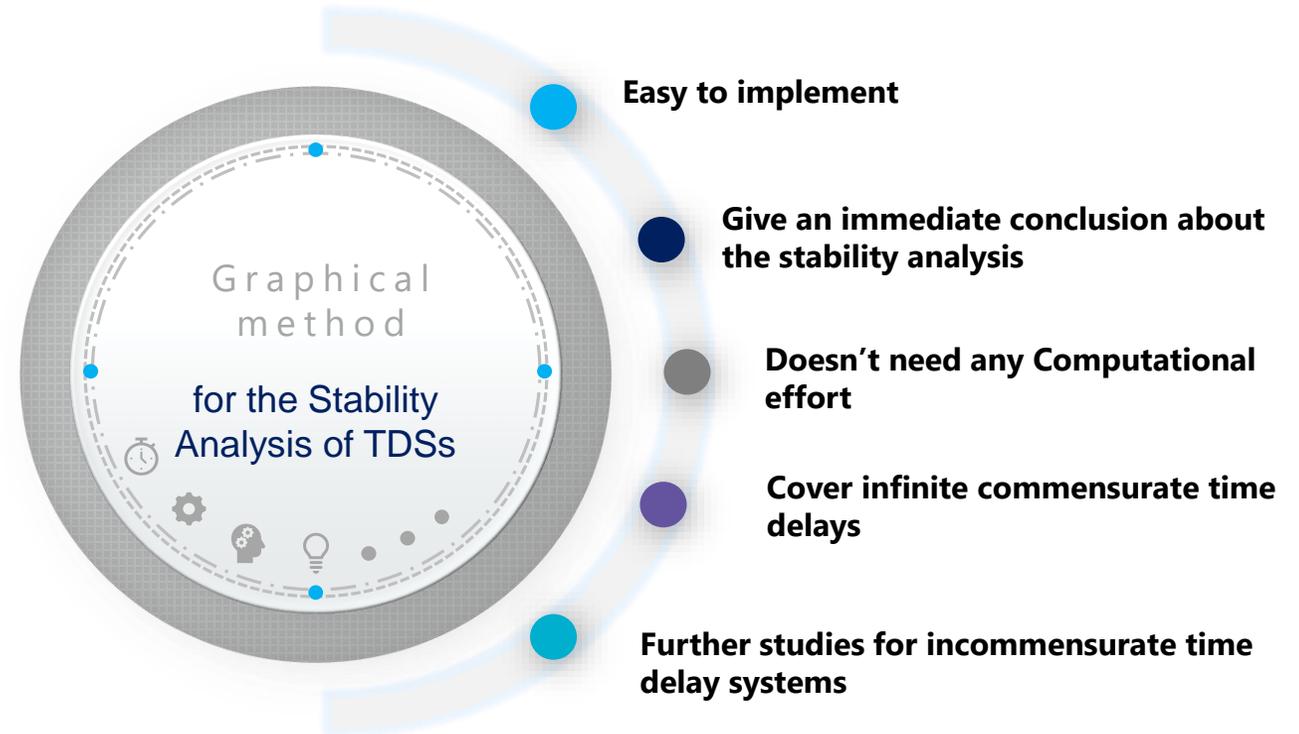
To determine the system if delay dependent or independent, we consider $s = \pm j\omega$ in order to find if the characteristic equation has roots on the imaginary axis

$$\det\left(j\omega I - A_0 - \sum_{k=1}^m A_k z^k\right) = \det(\lambda I - A) = 0$$

$$A = A_0 + \sum_{k=1}^m A_k z^k; z = e^{-j\theta}$$

In order to obtain the imaginary roots, we consider $\lambda = \pm j\omega$, $z = e^{-j\theta}$, where $\omega > 0$, and $\theta \in [0, 2\pi]$.

Method Advantages:

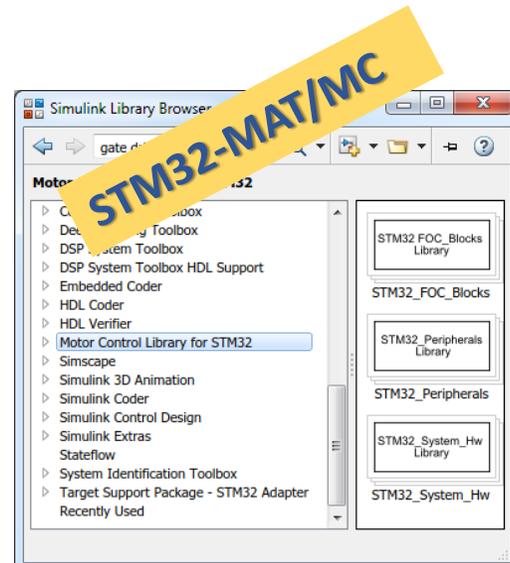
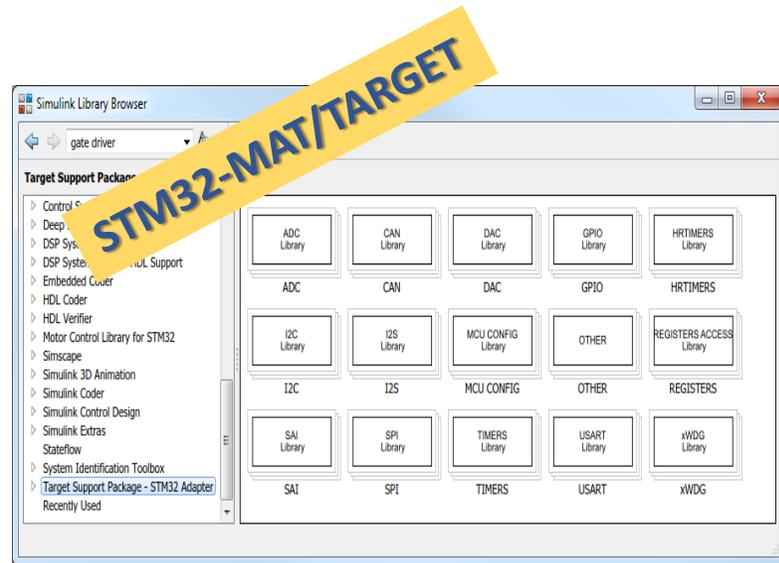


5# A Model-Based Design approach for embedded system development on STM32 microcontrollers

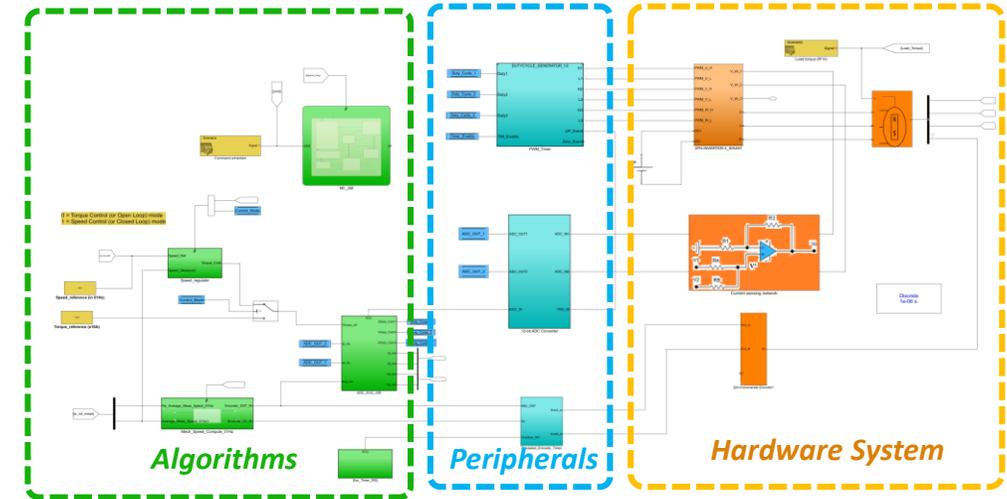
Objective:

A new software tool is presented that allows exploiting Model-based design (MBD). It is suitable for running Simulink® application models for STM32 MCUs. A first Simulink® blockset library for STM32 peripherals allows us to implement Processor In the Loop (PIL) configuration and automatic code generation. A second Simulink® blockset includes extensive Math and Motor control functions that have been developed based on the STM32 Motor control library

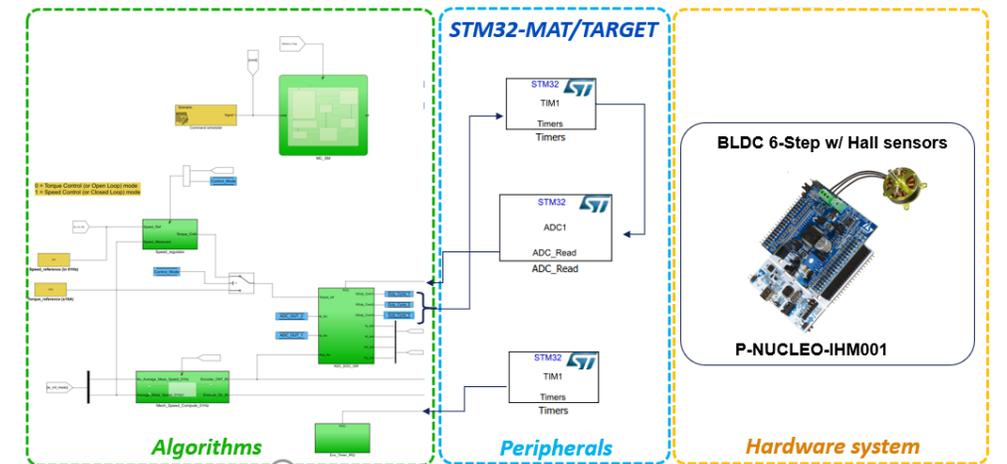
MBD tools for STM32 MCUs and FOC Motor Control



STM32 FOC MC – Model for simulation



STM32 FOC MC – Model for Code generation



Publications:

«A numerical Procedure to Obtain the pseudo-polynomial characteristic equation of a commensurate time-delay system»

L. Belhamel, L. Fortuna, M. G. Xibilia

In: ISSCS, Technical University of Iasi, Romania, luglio 11 – 12 / 2019.

«Linear dynamic coupling in the synchronization of hyperchaotic systems»

L. Belhamel, A. Buscarino, L. Fortuna, M. G. Xibilia

In: ISSCS, Technical University of Iasi, Romania, luglio 11 – 12 / 2019.

«Graphical method for the stability analysis of Commensurate multiple Time delay Imperfect Systems»

L. Belhamel, M. G. Xibilia

In: IEEE SMC 2019 - Industry 4.0, Nicolaus Hotel, Bari italia, ottobre 6 - 9/ 2019.

«Modeling a population of switches via chaotic dynamics»

A. Buscarino, L. Belhamel, C. Manes, P. Palumbo

In : convegno Automatica.it 13/09/2019

«A numerical Procedure to Obtain the pseudo-polynomial characteristic equation of a commensurate time-delay system»

L. Belhamel, L. Fortuna, M. G. Xibilia

In: ISSCS, Technical University of Iasi, Romania, luglio 11 – 12 / 2019.

«A Model-Based Design approach for embedded system development on STM32 microcontrollers»

Loubna Belhamel, Arturo Buscarino, Luigi Fortuna, Gaetano Rascona

In: CAE, Vicenza italy, 28-29/2019.

«Delay Independent Stability for multiple commensurate time delay systems»

L. Belhamel, L. Fortuna, M. G. Xibilia

In: Not published yet

Other Activity:

- Qualified tutoring activities for bachelor students in the University of Catania. *01/10/2019 – present*
- Invent: « An hybrid electronic platform to emulate dynamical complex switching systems»
Marco Maria BRANCIFORTE, Luigi Fortuna, Arturo Buscarino, Maide Bucolo, Carlo Famoso, Loubna Belhamel
STMicroelectronics *25/10/2019*
- Temporary as an Intern In STMicroelectronics *07/01/2019 – 07/07/2019*:
« Development of MATLAB models for microcontroller systems and their industrial applications for motor control»
- Research scholarship entitled: "Reduced order models with finite delay" in the University of Catania *01/02/2019 – 01/05/2019*
- BCD DAYS 3.0 – 2019, Catania In STM32Microelectronics « Model Based design » *07/05/2019- 09/05/2019*

- MATLAB Attestations: *08/2019*
 - MATLAB Onramp
 - Introduction to Statistical Methods with Matlab
 - Introduction to machine learning
- Seminar “Graphene THz Wireless Communications for Networks-on-Chip and Programmable Metasurfaces”, Lecturer: Prof. Sergi Abadal, Universitat Politècnica de Catalunya (UPC). *06/09/2019*
- Ph.D Days 2018