From SYSTEMS to ELECTRONIC CIRCUIT : a CAE flow strategy

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Motivations

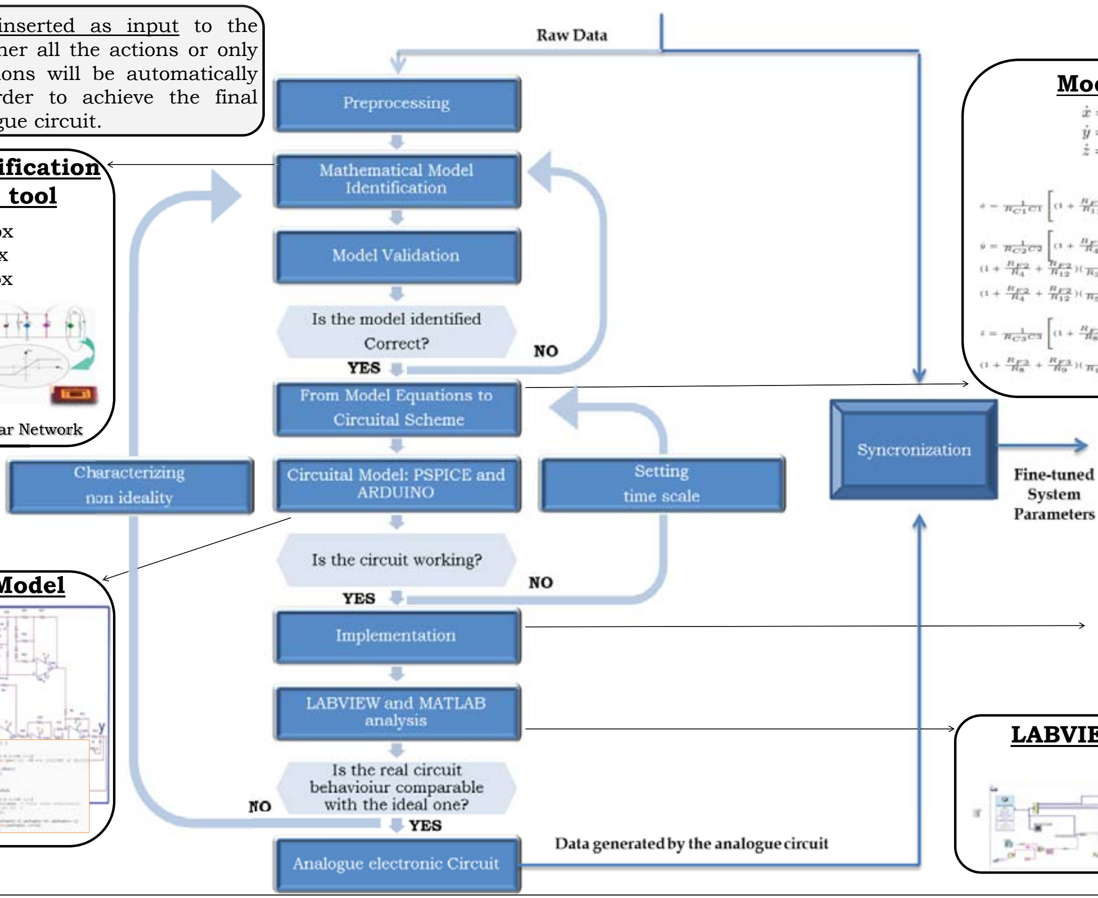
Data-driven model identification is essential for real system investigation and control strategies design.
Moreover, mathematical models able to reproduce systems dynamical behaviors do not fully describe all their properties that may rather be caught by exploiting analogies with hydraulic , mechanical, or electronic systems whose models resembles the mathematical one.
Physical analogues may be easily designed and implemented, as a consequence, performing experiments on these allows to fine-tune system parameters of the mathematical model in order to fit real data accounting for non-ideal effects.
This approach si adopted in many industrial and research fields such as in nuclear fusion area where physical analogues of ideal models have been formulated to reproduce the main non linear dynamics characterizing critical events such as plasma instabilities occurrences.

Goal

In this work, a CAE flow strategy able to automatically identify, design and implement a model from raw data is proposed. The overall process follows a batch approach where a sequence of actions are automatically performed; each one, except from the circuit implementation phase, is characterized by software tools able to provide as output the required input for the following step. During the overall CAE flow, testing phases are also performed and the required conditional actions initiated. CAE flow will result in the mutual interaction of CAE tools capable to deal with all the challenges related to the identification, design, implementation, analysis and characterization of the final electronic analog system. It is important to highlight the possibility to use selected actions instead of the whole set. In order to show the effectiveness of the adopted approach a case of study related to plasma instabilities is discussed.

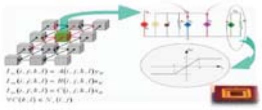
Platform Architecture: Methods and Implementation

Raw Data are inserted as input to the platform and either all the actions or only the selected actions will be automatically performed in order to achieve the final Electronic Analogue circuit.



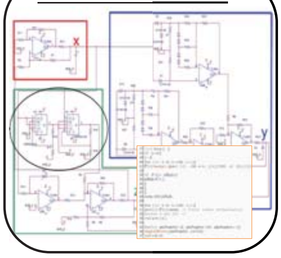
Model Identification Software tool

- White Box
- Grey Box
- Black Box



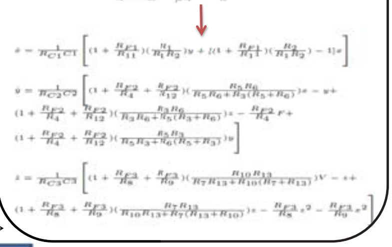
Cellular Nonlinear Network

Circuital Model

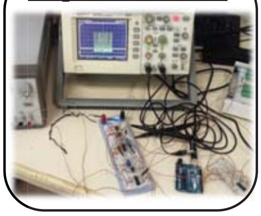


Model2Circuit tool

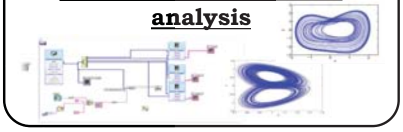
$$\dot{x} = y - ax$$
$$\dot{y} = \gamma x - Rx^3 + Kz - by$$
$$\dot{z} = \alpha - \beta z^2 - x^2$$



Implementation



LABVIEW and MATLAB analysis



Case of study

Identified Model

During nuclear fusion experiments, different types of plasma instabilities occurs. Plasma behavior during plasma instabilities has been qualitatively described by means of a low-dimensional model (1) formalized in [1].

$$\dot{x} = -\{1 - (z + P(t))\}y - \delta x$$
$$\dot{y} = x$$
$$\dot{z} = \eta(h - z - y^2 z) \quad (1)$$

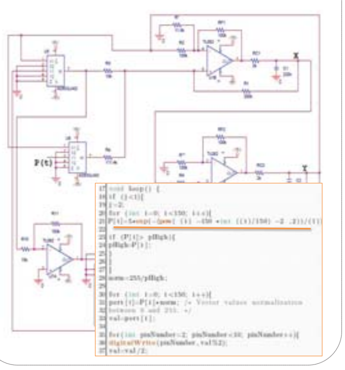
Model2Circuit tool

$$\dot{x} = -\{1 - (z + P(t))\}y - \delta x$$
$$\downarrow$$
$$\dot{x} = \frac{1}{R_{C1}C_1}\left[\left(\frac{R_{F1}}{R_1} - 1\right)x - \frac{R_{F1}}{R_2}y + \frac{R_{F1}}{R_3}V^* + \frac{R_{F1}}{R_P}\frac{P(t)y}{10}\right]$$

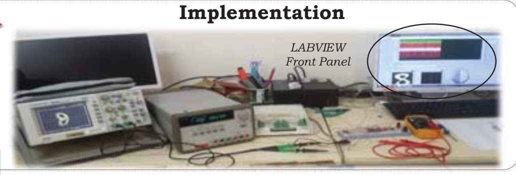
$$\dot{y} = x$$
$$\downarrow$$
$$\dot{y} = \frac{1}{R_{C2}C_2}\left[\left(\frac{R_{F2}}{R_5} - 1\right)y + \frac{R_{F2}}{R_4}x\right]$$

$$\dot{z} = \eta(h - z - y^2 z)$$
$$\downarrow$$
$$\dot{z} = \frac{1}{R_{C3}C_3}\left[\frac{R_{F3}}{R_7}V - z - \frac{R_{F3}}{R_6}V^{**}\right]$$

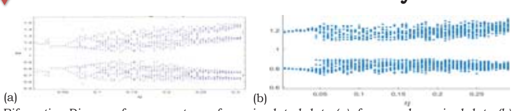
Circuital Model: PSPICE and ARDUINO



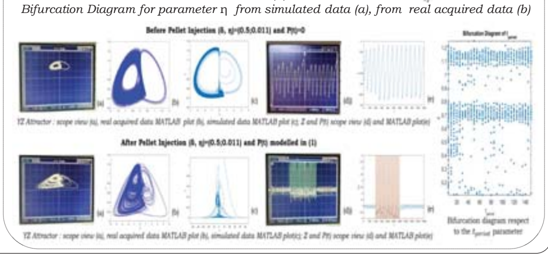
Implementation



LABVIEW and MATLAB analysis



(a) (b)
Bifurcation Diagram for parameter η from simulated data (a), from real acquired data (b)



In this example, the model was already identified by Constantinescu in [1], so that it has been used as starting point to obtain the related electronic model . When running the CAE platform, actions are executed from the « Model2Circuit tool» to the final hybrid circuit realization.
In the case presented, all the testing conditions resulted positive, so no feedback loops have been used.

[1] Constantinescu, D., et al. "A low-dimensional model system for quasi-periodic plasma perturbations." Physics of Plasmas 18.6 (2011): 062307.