

DIFFEDGE

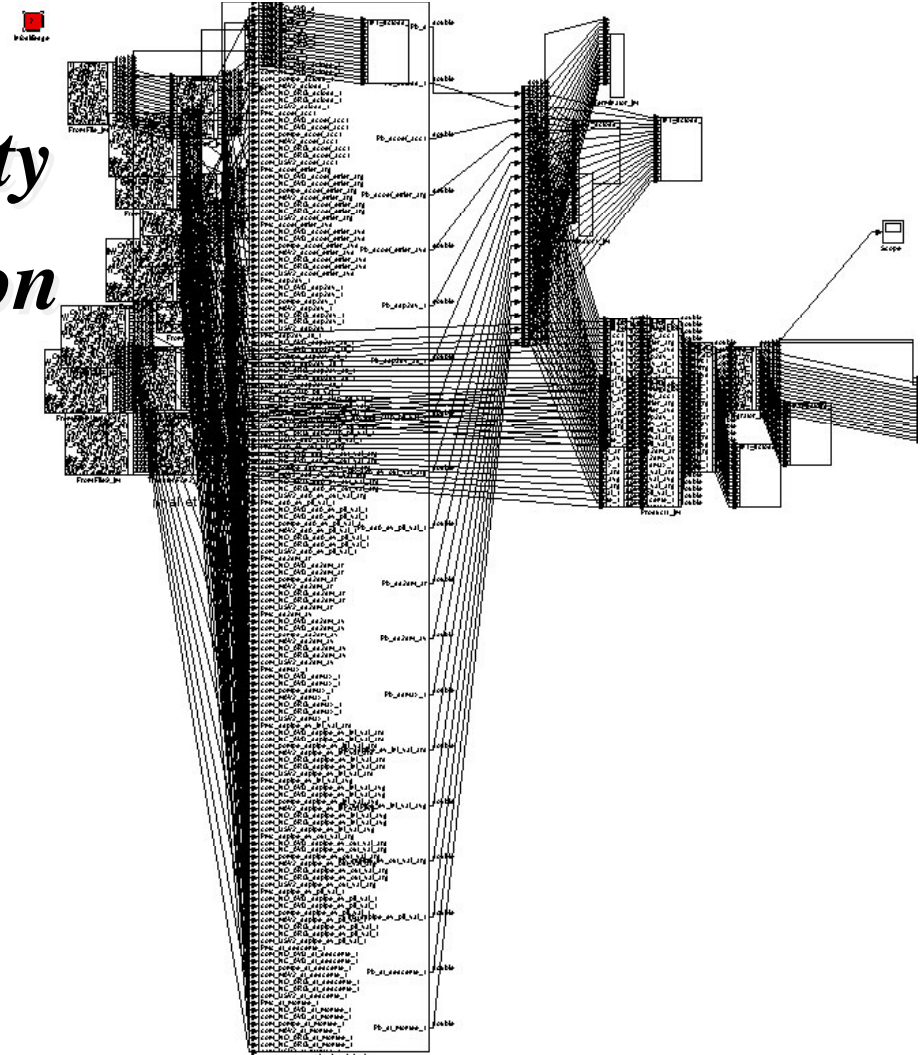
Differentiation, sensitivity analysis and identification of hybrid Models

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Diffedge : Motivation

- Although advances in computer speed as well as numerical simulation algorithms are allowing much larger and more complex calculations to be performed.
- Using state-of-the-art numerical algorithms requires substantially more information other than a subroutine returning the model residuals.
- This additional information is, in general, very difficult to obtain, models are often treated as “black-boxes” and less sophisticated algorithms are used.
- *Diffedge eliminates the drawbacks of finite-difference approximations and the complexity to use the automatic differentiation*

Diffedge : Derivative methodology

It combines the powerful of computer algebra system and block diagram structures for computing the derivative of a Simulink model with respect to the independent parameters. The derivative of objective function and constraints can be also computed and inside the Simulink model.

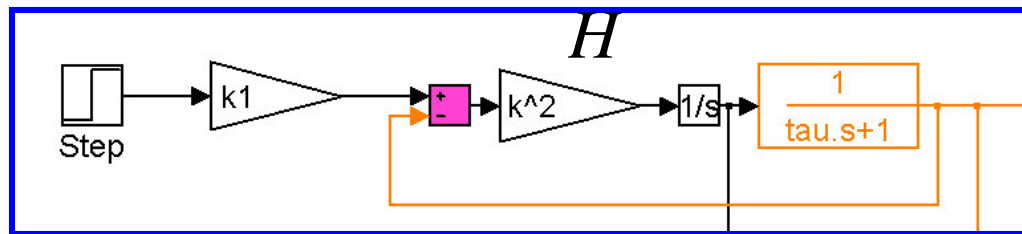
➤ The benefits

- By remaining in the environment of simulation, it is possible to obtain the second or higher order derivatives by applying *Diffedge* again on the derivative model.
- *No additional* programming is required and modification of the model (mdl file and the list of the parameters).
- The visualisation of the partial derivatives is possible for any coordinate of the model.
- Possibilities to use several optimisation algorithms requiring gradient, hessian or none (***Diffedge is an automatic tool for optimisation problems.***)
- *no information can escape the modeller's attention about of the structure of its mathematical model*

➤ The fields :

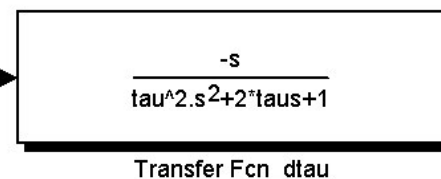
- Analytical sensitivity and statistical analysis
- Optimisation and identification
- Fault detection for system monitoring, in real-time.
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Diffedge : Méthodology: JM'rules

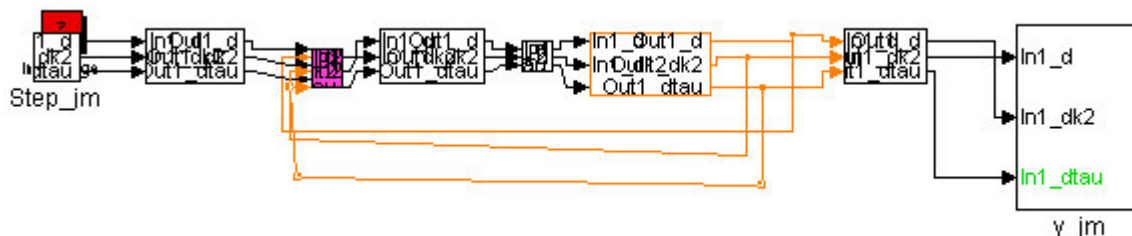
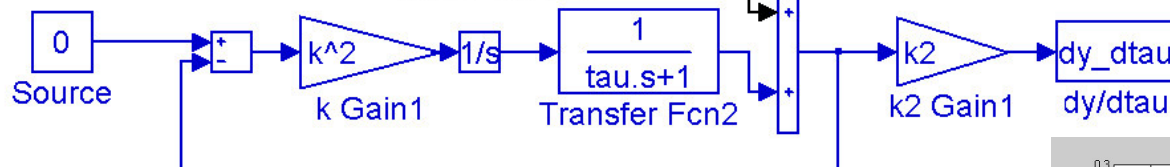


Rule JM 2 : all input of block no touched by the derivative flow can be considered as a nul source.

Original block is increased of derivative flow.



Symbolic derivative of the TF



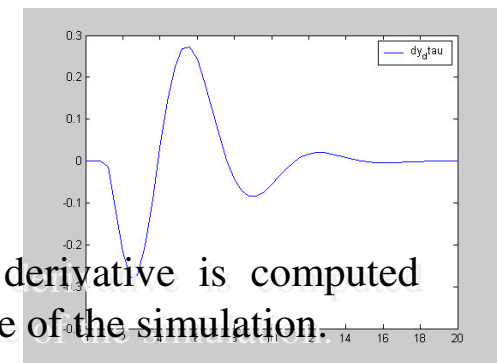
Derivative of gain k2.

$$Y = K2 * H * U$$

dy_dk2
dy/dk2

dy_dk2_dk2
dy/dk2/dk2

The derivative is computed inside of the simulation.



Diffedge : an example strongly nonlinear with discontinuity (successful optimization)

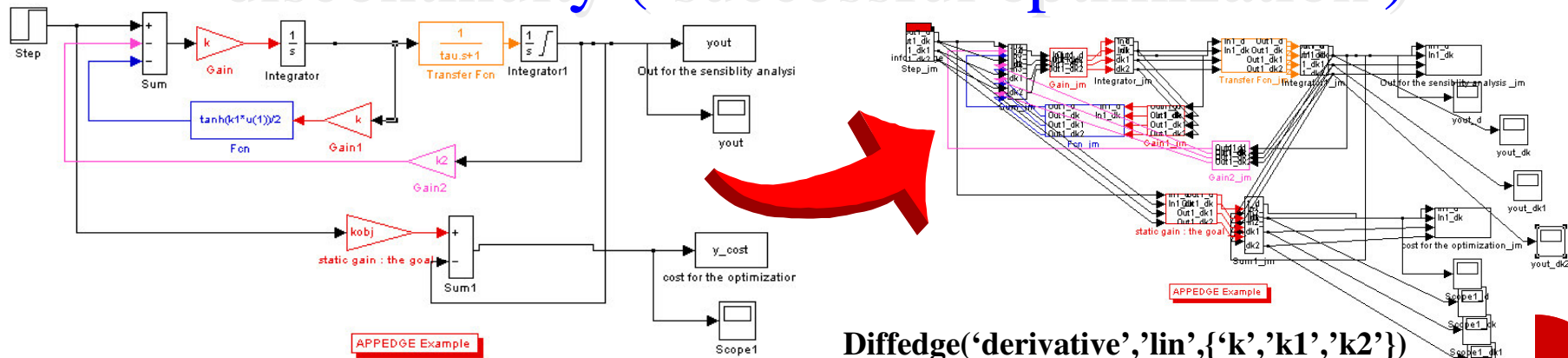
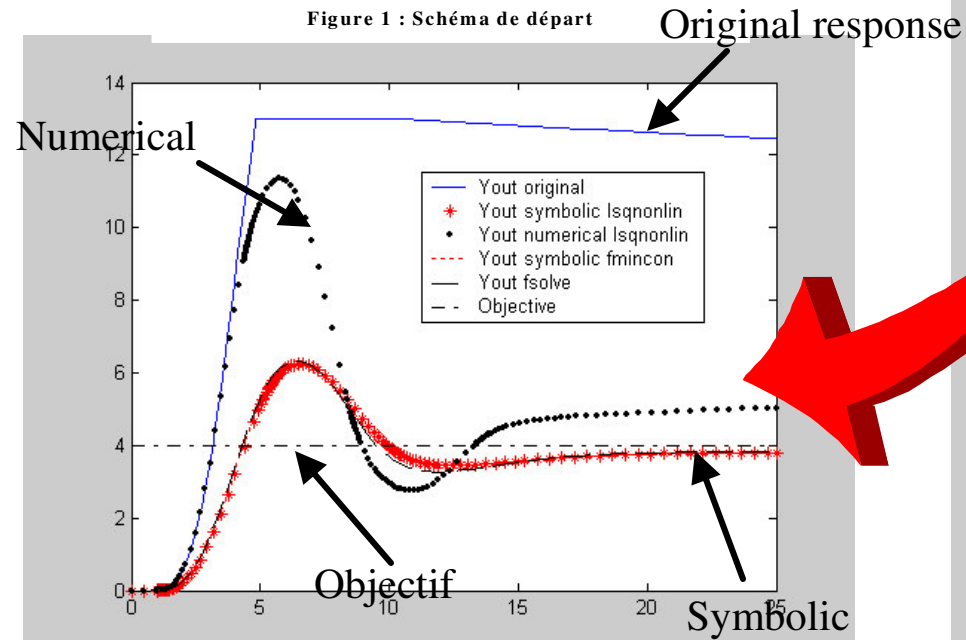
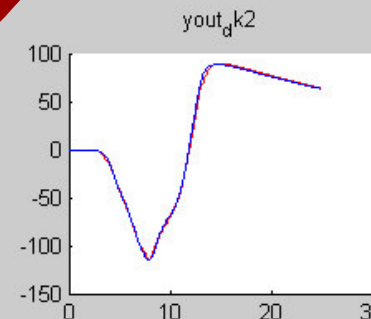
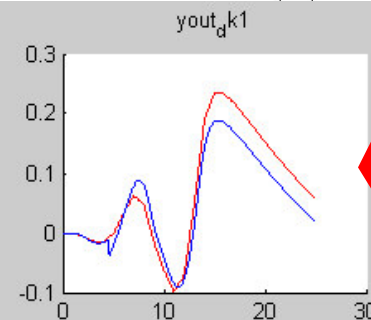
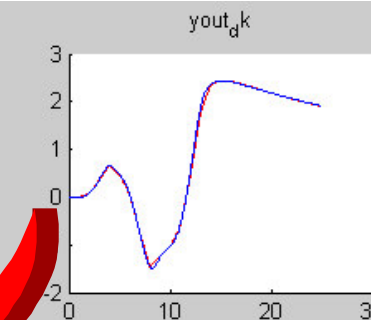


Figure 1 : Schéma de départ

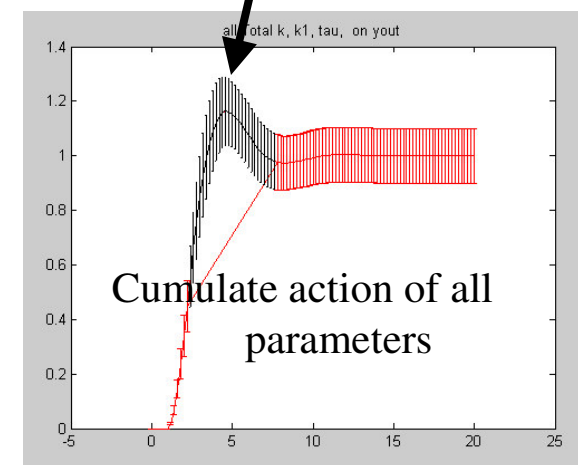
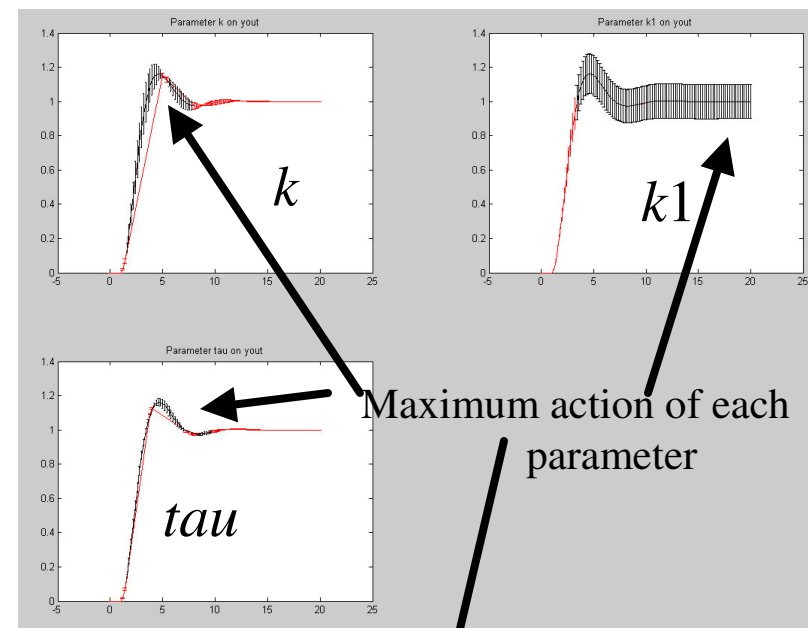
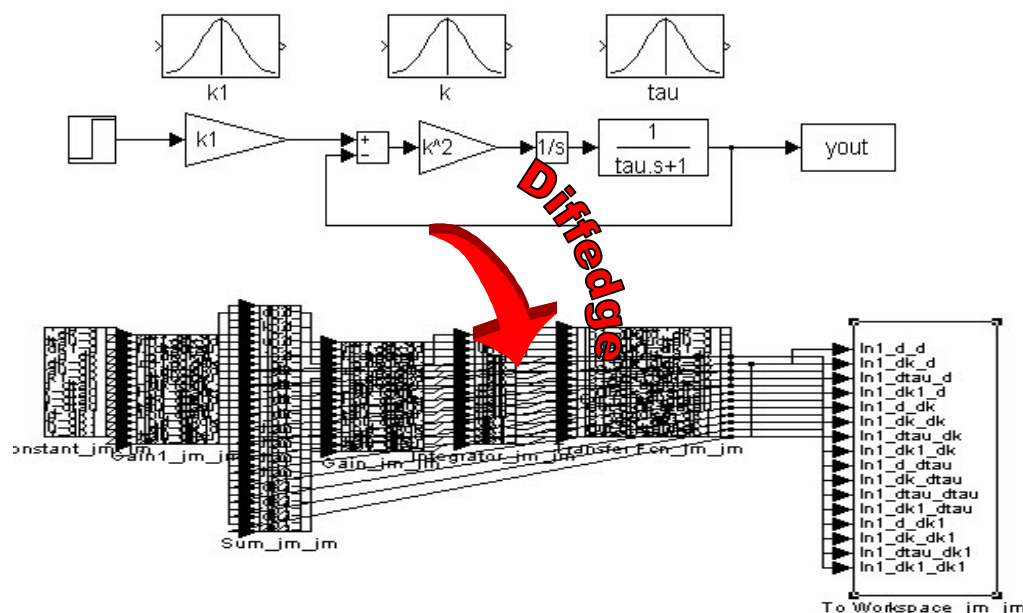


Diffedge('derivative','lin',{ 'k','k1','k2' })



The numerical derivative (blue) is wrong and we have an artefact at the discontinuity because we compute the derivative outside of the simulation and the epsilon of $f(k1+\epsilon)$ is difficult to choose

Diffedge : Statistical analysis in one simulation



For each instant we obtain the confidence interval of the output

$$L(P_i) = N(m_{pi}; \sigma_{pi}) \xrightarrow{\text{approximation}} L(Y_i) = N(m_{yi}, \sigma_{yi})$$

yout order	parameters	nominal values	rms max	variation in %	résidu	dy/dk max	time max
1	Total k, k1, tau,		0,0153968	1,55	9,01E-05	1,16631	3,4
2	k	1	0,0120105	1,29	5,03E-05	1,20105	3,2
3	k1	1	0,0116297	1,00	0	0,416067	4,6
4	tau	1	0,00282104	0,43	6,45E-06	1,0677	2,6

Demonstration of Diffedge

- ◆ We use Diffedge on examples of Simulink and Appedge and we will show
 - ◆ the difficulties to compute the derivative by finite differences (choice of epsilon)
 - ◆ The powerful of diffedge when we have discontinuity, events, state machine, scalar, bus and vector signals
- ◆ F14 aircraft : noise generator, variable step solver, block time numerical derivative
- ◆ Gear (A real hybrid system with stateflow, look-up table 2D, logical events ...)
- ◆ Bioreactor: fault detection when two parameters are moving. We use the derivative nonlinear observer inside of the monitor.(<http://www.appedge.com>)
- ◆ Optimisation of nonlinear model.
- ◆ Linear model : shows that the second order of partial derivatives are equals
- ◆ Industrial case (more than 600 blocs, 53 subsystems, 60 parameters)