PARAMETRIC ANALYSIS OF MECHATRONIC SYSTEM PERFORMANCE USING SYSML MODELS: A CASE STUDY

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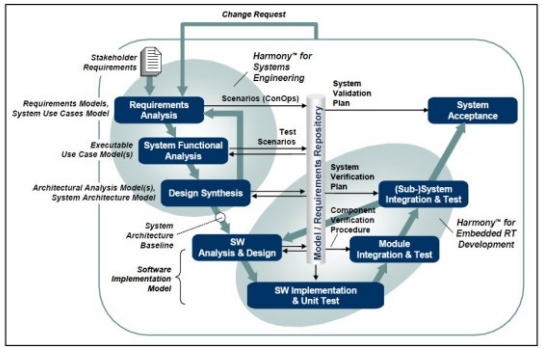
Why am I here ?

- Collegium Project :
  - **SUPMECA** (Paris) : mechanical engineering
  - ENSEA (Cergy) : electrical engineering
  - EISTI (Cergy) : computer engineering

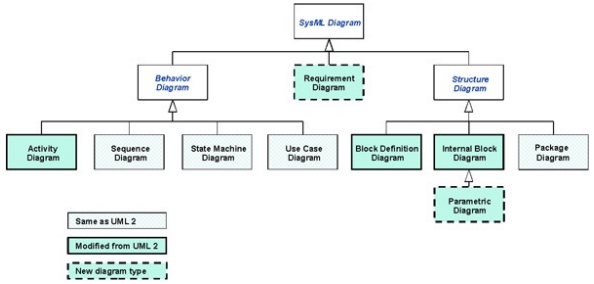
What is SysML ?

- OMG Systems Modeling Language
- De-facto language for Systems Engineering :
  - supporting specification, analysis, design, verification and validation
  - integrating different disciplines (mechatronics)
- Model-Based Systems Engineering
- Methodology and tool independent

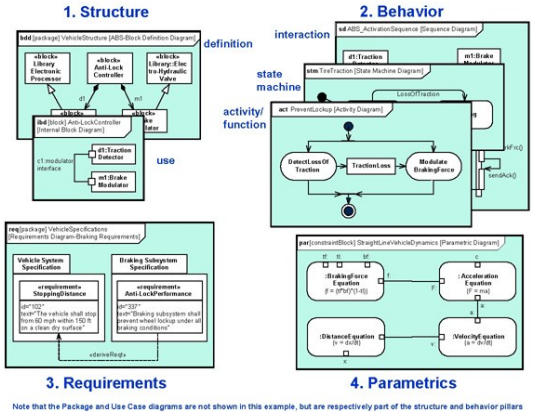
Why SysML ?



SysML Diagram Types



The Four Pillars of SysML



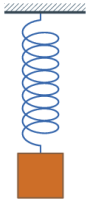
Parametrics

- Express constraints between system property values :
  - Provide support to engineering analysis (performance, reliability, trade-off, …)
  - Expression language (equations) can be formal (MathML, OCL, …) or informal : constraint blocks
- Parametric diagram represents the usage of the constraints in an analysis context

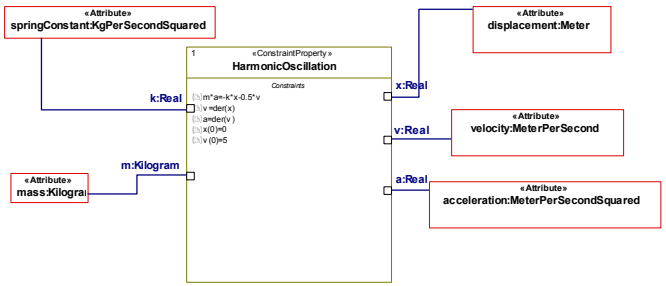
A Parametric Diagram Example (1)

- A simple harmonic osillator :
  - m : mass of the point
  - k : spring constant
  - x : relative position of the point mass
  - t : time
- Equation of motion :

$$m\frac{d^2x}{dt^2} = -kx$$

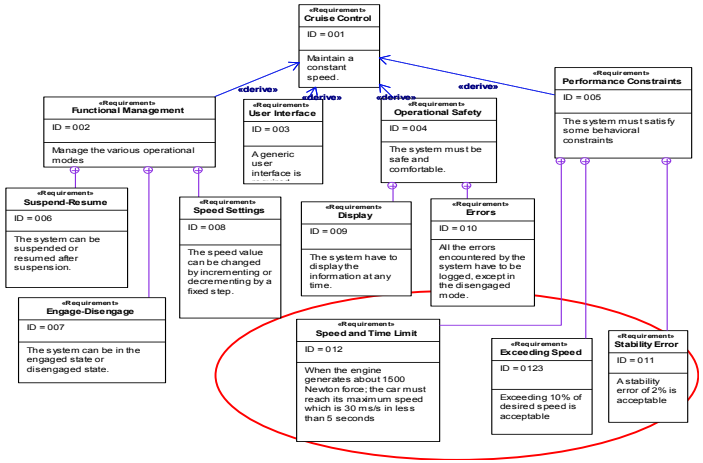


A Parametric Diagram Example (2)

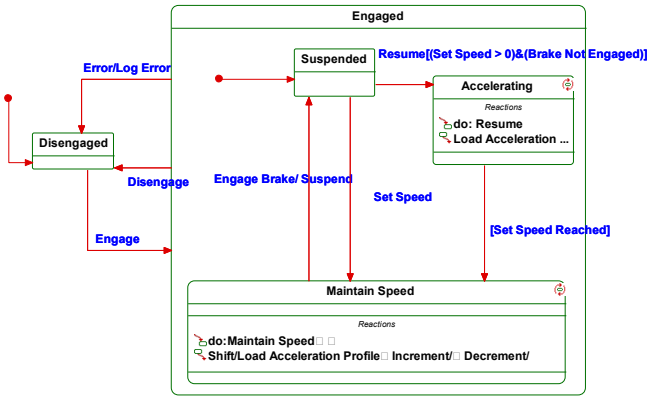


Case Study : **Cruise Control System**

Requirement Diagram

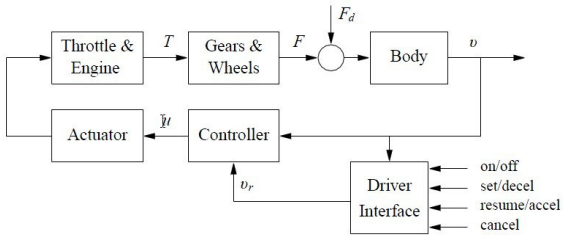


State machine diagram

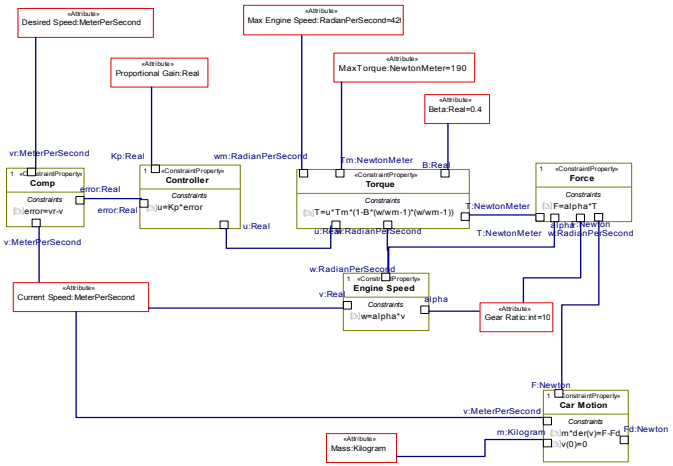


A Dynamic Model

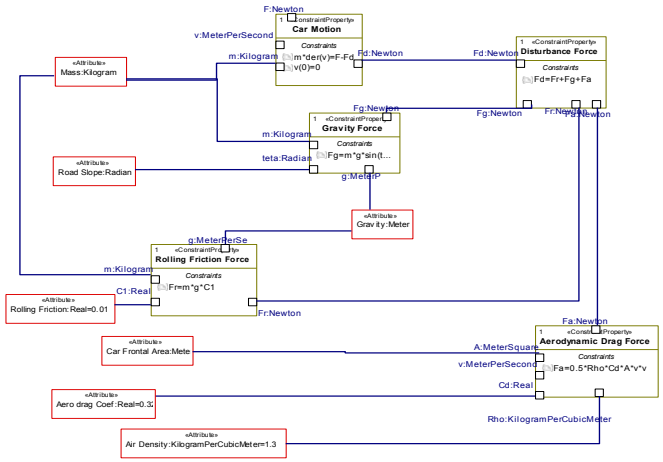
- Closed–loop control system (Astrom and Murray 2010):



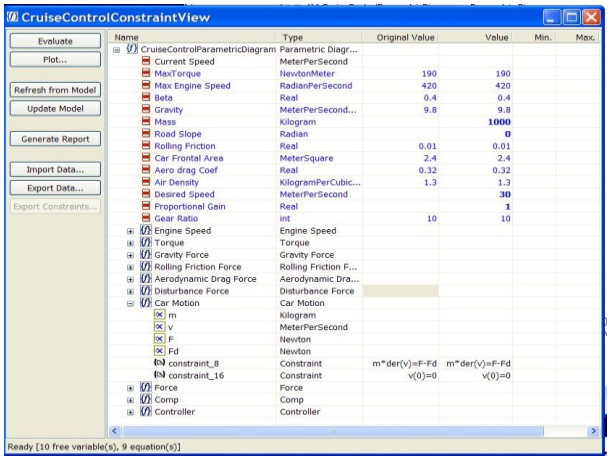
Parametric Diagram (part 1)



Parametric Diagram (part 2)



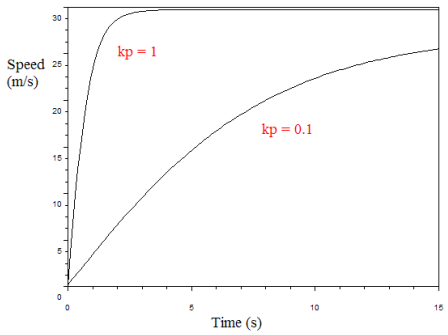
Rhapsody Constraint View



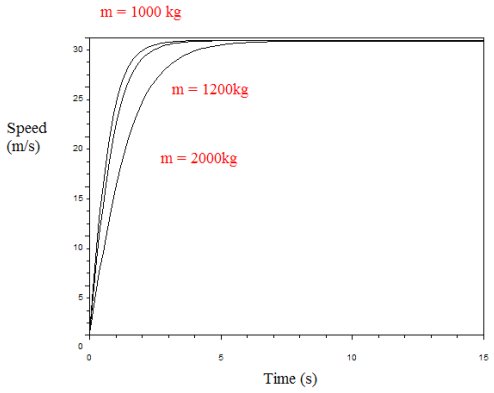
But problems ?

- Rhapsody Parametric Constraints Evaluator (**PCE**) via Computer Algebra System :
  - MATLAB
  - MAXIMA :
    - nonlinear differential equation
    - analytical solution with default option
- SCILAB

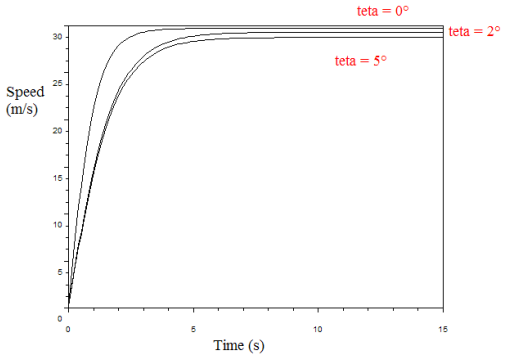
Experimental Results (1)



Experimental Results (2)



Experimental Results (3)



Conclusions

- More experiments must be run !
- But :
  - Lightweight systems => similar results as specialized tools
  - Possibility to combine structural and behavioral specifications with requirement constraints in the same tool => validate the design process

Related work

- SysML parametrics tools:
  - ParaMagic (InterCAX) (Mathematica, OpenModelica solver)
- Simulation tools :
  - Simulink (Matlab), Scicos (Scilab)
  - CATIA Systems, OpenModelica, …
- Combined modeling languages :
  - ModelicaML, SysML4Modelica, …

Future work

- Open source : Topcased, Scilab, …
- Formal verification