

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

Nga NGUYEN, Hubert KADIMA
LARIS, EISTI, France
REM 2011, September 15-16, Kocaeli, Turkey

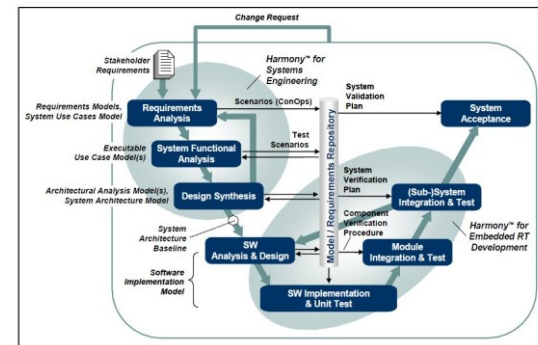
Why am I here ?

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

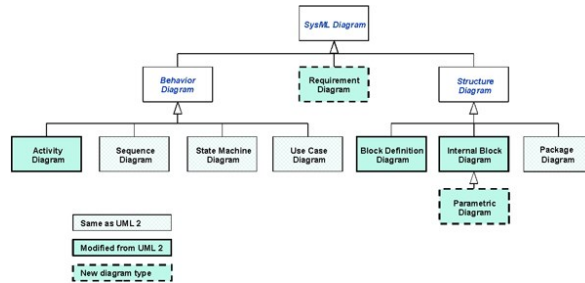
What is SysML ?

- 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**

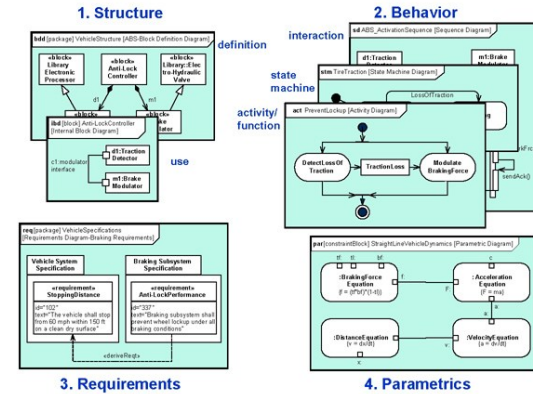
Why SysML ?



SysML Diagram Types



The Four Pillars of SysML



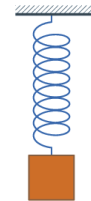
Parametrics

- 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

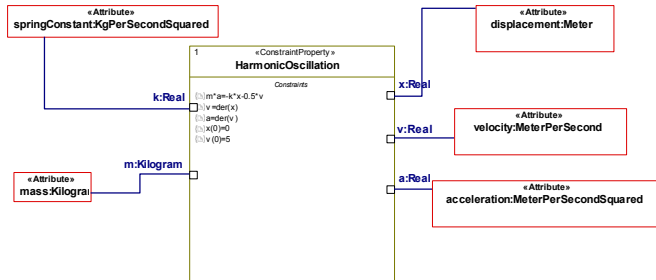
A Parametric Diagram Example (1)

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

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

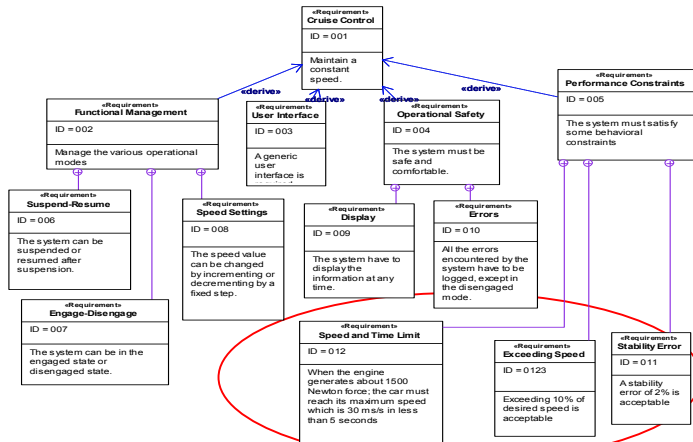


A Parametric Diagram Example (2)

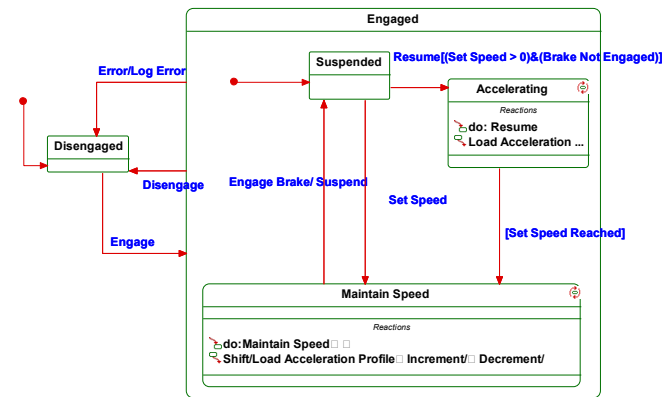


Case Study : Cruise Control System

Requirement Diagram

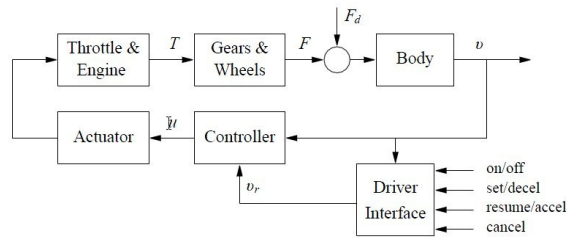


State machine diagram

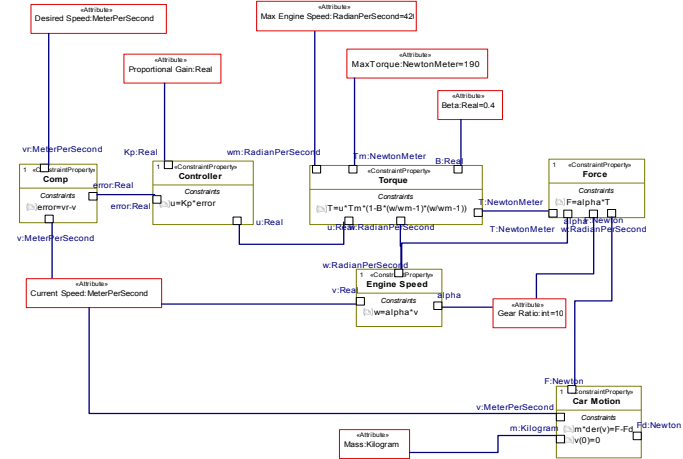


A Dynamic Model

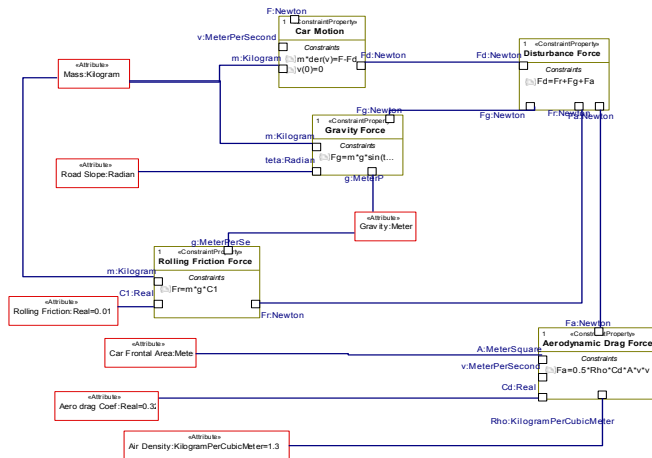
- Closed-loop control system (Astrom and Murray 2010):



Parametric Diagram (part 1)



Parametric Diagram (part 2)



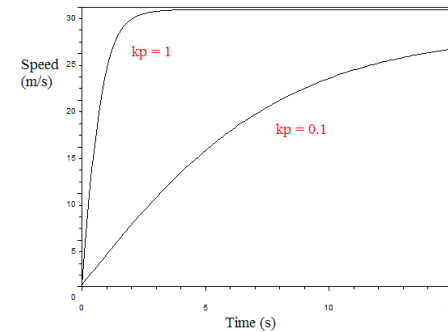
Rhapsody Constraint View

Evaluate	Name	Type	Original Value	Value	Min.	Max.
	CruiseControlParametricDiagram	Parametric Diagram				
	Current Speed	MeterPerSecond				
	Max Torque	NewtonMeter	190	190		
	Max Engine Speed	RadianPerSecond	420	420		
	Beta	Real	0.4	0.4		
	Gravity	MeterPerSecond	9.8	9.8		
	Mass	Kilogram		1000		
	Road Slope	Radian		0		
	Rolling Friction	Real	0.01	0.01		
	Car Frontal Area	MeterSquare	2.4	2.4		
	Aero drag Coef	Real	0.32	0.32		
	Air Density	KilogramPerCubicMeter	1.3	1.3		
	Desired Speed	MeterPerSecond		30		
	Proportional Gain	Real		1		
	Gear Ratio	int	10	10		
	Engine Speed	Engine Speed				
	Torque	Torque				
	Gravity Force	Gravity Force				
	Rolling Friction Force	Rolling Friction Force				
	Aerodynamic Drag Force	Aerodynamic Drag Force				
	Disturbance Force	Disturbance Force				
	Car Motion	Car Motion				
	m	Kilogram				
	v	MeterPerSecond				
	F	Newton				
	Fd	Newton				
	constraint_8	Constraint	m * der(v) = F - Fd	m * der(v) = F - Fd		
	constraint_16	Constraint	v(0) = 0	v(0) = 0		
	Force	Force				
	Comp	Comp				
	Controller	Controller				

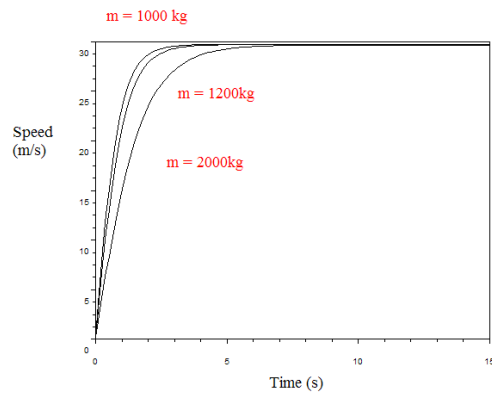
But problems ?

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

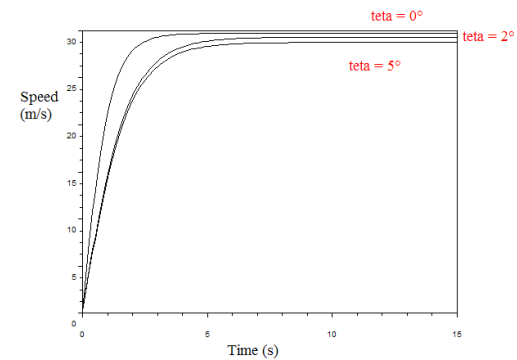
Experimental Results (1)



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