Extension: Model-based development at DRiV

Joan Vazquez Molina

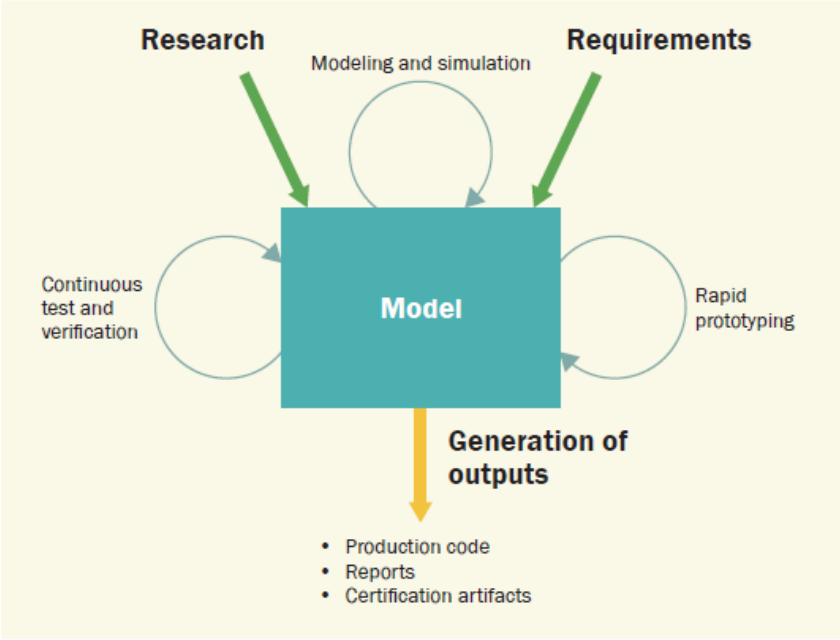
2019-10-21

Course: Mathematical Modeling in the Industry
MSc in Mathematical Research
Universitat Politècnica de València

JVazquezMolina@driv.com

Model-based development (or design)
In a nutshell

- “Model-Based Design (MBD) is a mathematical and visual method of addressing problems associated with designing complex control, signal processing and communication systems. It is used in many motion control, industrial equipment, aerospace, and automotive applications.” (Wikipedia)



Why Model-Based Design?

Model-Based Design provides a path to streamlining many aspects of development. For example, organizations report that Model-Based Design enables them to:

- Manage complex systems
- Automate time-consuming and error-prone tasks
- Quickly explore new ideas
- Create a common language that fosters communication and collaboration
- Capture and retain intellectual property
- Increase product quality
- Reduce risk

Roger Aarenstrup, *Managing Model-Based Design*, The Mathworks, 2015

Towards model-based development

Elements of the previous model

Element	Previous choice
Suspension	Linear springs, dampers, ideal actuator
Vehicle	Quarter car
Road	Step input
Controller	PID

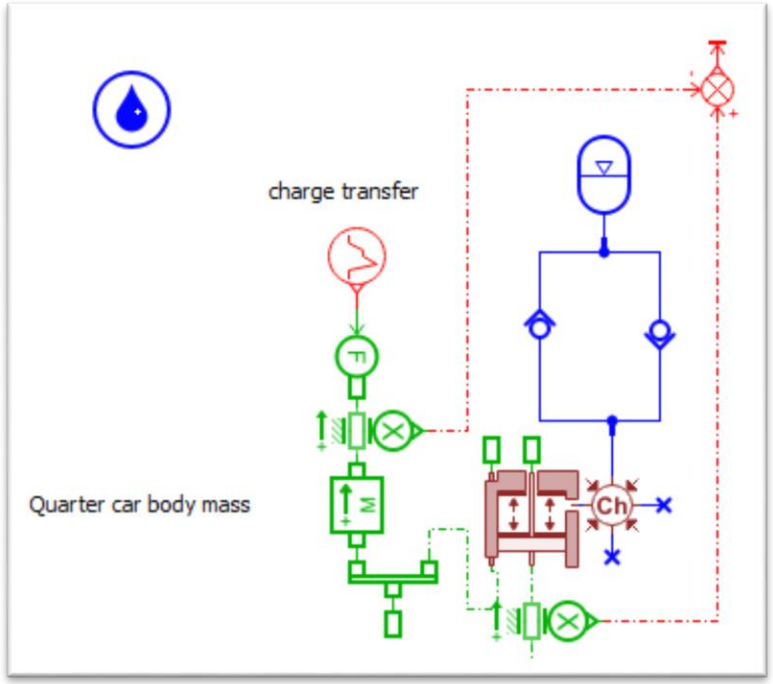
How to generalize these elements to make the framework applicable in a real context?

Suspension models

Model-based development

Our core business and knowledge.

- Use specialized software for physical modeling.
- As detailed as possible.
- Capture low and high frequency behavior.
- Use empirical data for system identification.
- Answer engineering questions!
  - *What if this tube breaks?*
  - *What if I add a valve there?*
  - *What if I use a bigger accumulator?*



Intelligent Suspension Portfolio

Selective

Dual Mode

Ford Focus RS - 2015
Other models coming

Select your preferred ride experience. With the touch of a button, simply switch between comfort and a more sporty ride.

Soft and firm mode independently tunable
Large damping spread
Internal valve
Shocks and struts

Adaptive

DRiV ™

In development

Easy to integrate Solution placing Valves, sensors and electronics inside the damper itself. Provides Increased comfort and Performance at a Competitive price

16 stage discrete damper settings
On-board sensor and control Shocks

Semi-active 1 valve

CVSAe

Market leading on 40+ models

Continuously senses the road and driving conditions to adjust The dampers in real time for a more comfortable and controlled ride

3rd generation continuous damping control
Shock and struts

Semi-active 2 valve

CVSA2

McLaren 540 - 2015
Premium SUV - 2018

An even more refined ride with enhanced control of comfort and vehicle handling

Independent rebound and compression damping
High level road isolation
Light weight design
Shocks

Semi-active 2 valve + roll control

CVSA2/Kinetic®

McLaren 650
Kinetic® on Infiniti QX80

Hydraulic roll control
Track performance
Increased road comfort
Off-road performance
Zero energy usage

Full-active wheel and body control

ACOCAR®

In development

Flying carpet like control
For wheel and body
Motion to deliver
the ultimate level
In ride and handling
experience

Replaces ARC adds pitch and heave control
Road isolation
Vehicle stability

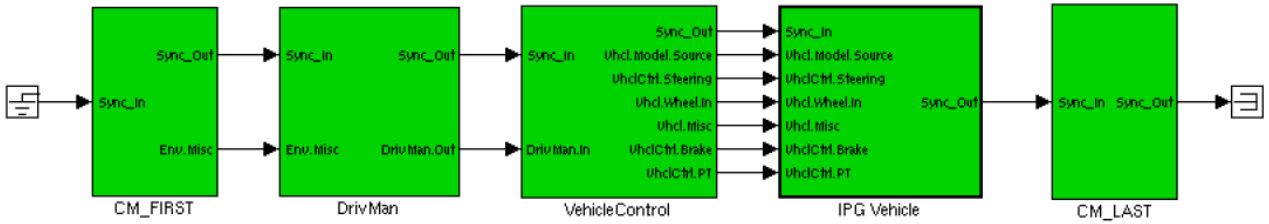
Vehicle models

The importance of the research question

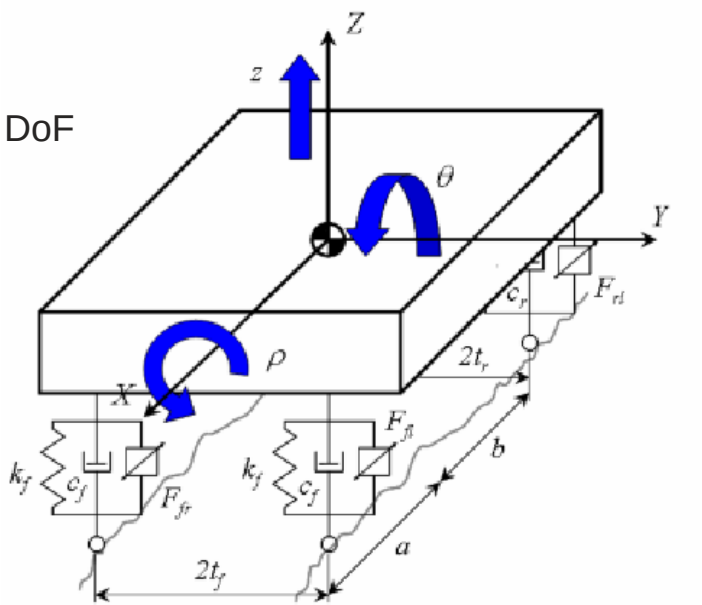
Needed to study system functionality

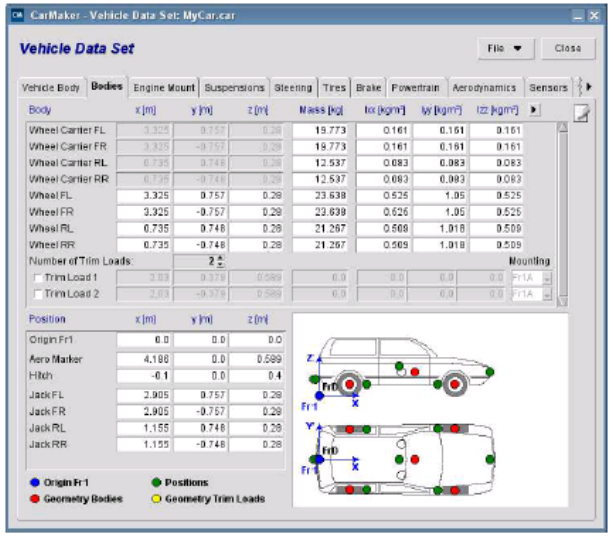
- May use specialized software.
- As simple as needed.
- Think of the research question!

Hundreds of DoF



3 DoF





Roads, maneuvers, etc.

The role of standards

INTERNATIONAL STANDARD **ISO 8608**

Second edition
2016-11-01

Mechanical vibration — Road surface profiles — Reporting of measured data

Vibrations mécaniques — Profils de routes — Méthode de présentation des résultats de mesures

Table C.2 — Road classification

Road class	Degree of roughness			
	Lower limit	Geometric mean	Upper limit	Geometric mean
	Spatial frequency units, n			
	$G_d(n_0)$[a] 10^{-6} m^3			$G_v(n)$ 10^{-6} m
A	—	16	32	6,3
B	32	64	128	25,3
C	128	256	512	101,1
D	512	1 024	2 048	404,3
E	2 048	4 094	8 192	1 617
F	8 192	16 384	32 768	6 468
G	32 768	65 536	131 072	25 873
H	131 072	262 144	—	103 490

Annex A is an example of a report which meets the minimum requirements of this document.

Annex B gives means of approximately characterizing specific road profiles in order to facilitate the division of road profiles into general classifications. A general classification is also given. A curve fitting method is presented for characterizing spectral data.

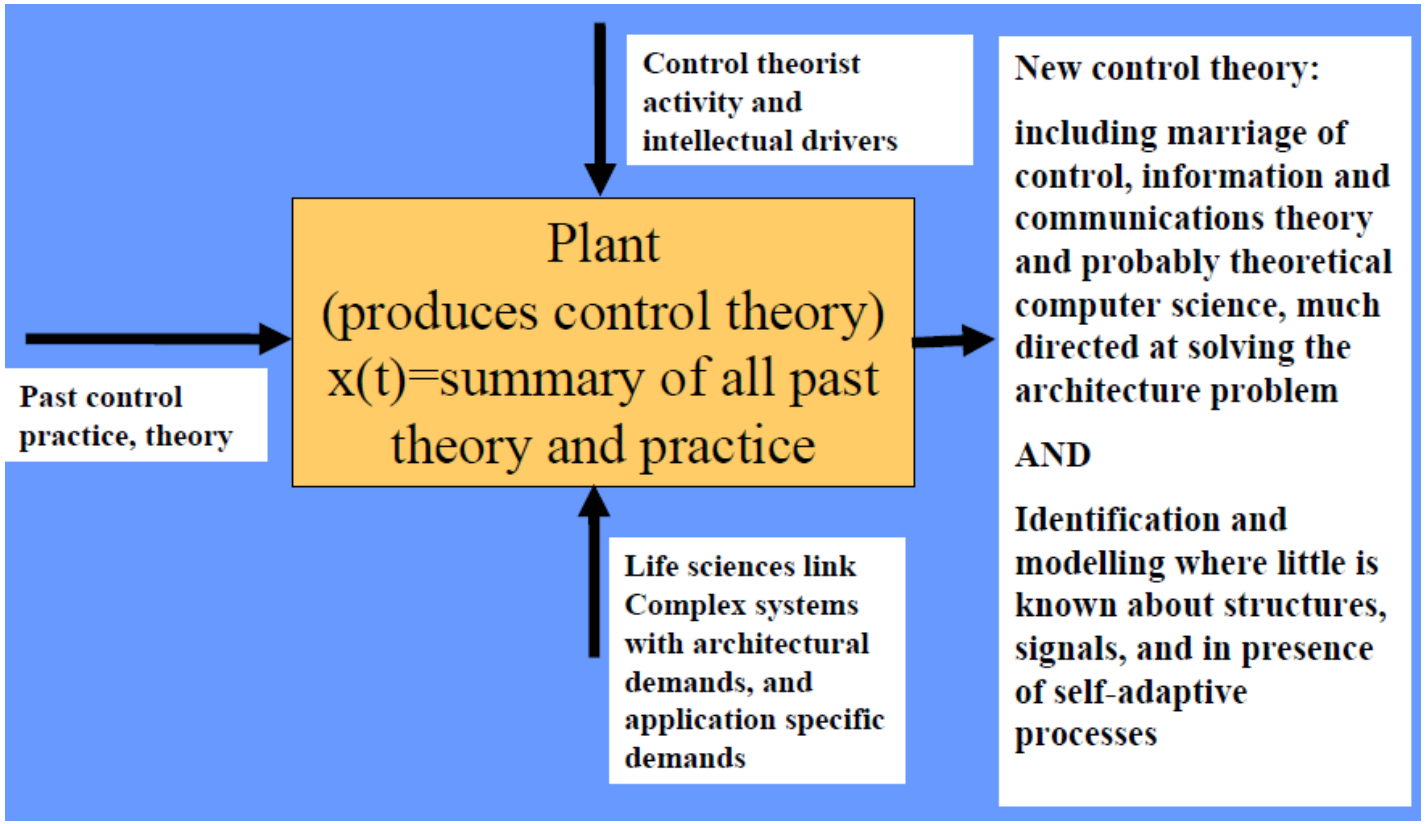
Annex C provides general guidance for the use of road profile statistical data for simulation studies and for related studies such as evaluation of comfort, suspensions and road profiles.

Annex D discusses the processing of the power spectral density (PSD) with the fast Fourier transform (FFT) technique. A discussion on the statistical precision is also given.

Controller development
Science VS Technology

- “Control theory is a subfield of **mathematics** that deals with the control of continuously operating dynamical systems in engineered processes and machines. The objective is to develop a control model for controlling such systems using a control action in an optimum manner without delay or overshoot and ensuring control stability.” (Wikipedia)
- Current mismatch between science and technology:
  - Ad hoc developments by highly experienced engineers.
  - Very complex controllers based on discretized events from sensors.
  - Tuning based on subjective evaluations.

Control theory
Contemporary trends



Brian DO Anderson, Present Developments in Control Theory, *IFAC 50th Anniversary Celebration*, 2006

SIAM, *Mathematics in Industry* (report), 2012

Mathematicians in the industry

The individual perspective

Area of Degree	All %	Survey %
statistics	54	39
applied mathematics	10	18
probability	9	5
discrete mathematics	6	4
algebra	5	4
numerical analysis	5	5
differential equations	4	2
optimization	3	5
geometry	3	4
analysis	2	5
other	0	4

Table 1: Degrees of all hires 2004-2008 and those in the survey

Job Title	%
statistician	17
analyst/ modeler	20
researcher	21
management	15
consultant	9
engineer	7
software developer/programming	11

Table 6a: Job titles from survey

Essential/important to annual review	%
mathematical models	67
software development	43
presentations to management	64
preparation of internal reports	59
presentations to customers	53
presentations at conferences	39
publication in the open literature	29

Table 8: Percent of respondents rating task outcomes as essential or important for their review

Rationale for Taking a Job in Industry	%
higher compensation	66
opportunities for career advancement	52
experience with industrial internships or programs	48
intellectual challenge	32
had a job in industry	32

Table 3: Rationale for joining industry

Very Satisfied/Satisfied with	%
compensation and benefits	88
lifestyle	80
intellectual challenge	74
opportunities for career advancement	72
opportunities for scientific growth	56

Table 4: Satisfaction with aspects of the job

Mathematics in the industry

The social perspective

THE IMPORTANCE OF MATHEMATICAL RESEARCH AND THE TRANSFER OF MATHEMATICAL TECHNOLOGY IN THE SPANISH ECONOMY

- Maths-intensive activities generated a million jobs in Spain in 2016, representing **6% of total employment**.
- In terms of **Gross Value Added** the impact of maths-intensive activities stood at **10.1%** of the total in 2016
- These impacts are **smaller than those calculated for other European countries** where similar studies have been carried out; there, the direct impact in terms of employment ranges between 10% and 11% of the total, whereas in gva the interval is 13-16% of the total.
- The productivity of the economic sectors in which this type of professional worked was 47.2 euros per hour worked in 2016 in Spain, similar to that of comparable countries. Thus, what accounts for the difference in the impact is Spain's economic structure, oriented more toward activities with a lower presence of professions requiring a certain mathematical intensity.

Math-intensive jobs are the key to a productive economy

https://institucionales.us.es/remimus/socio-economic-impact-of-mathematical-research-and-mathematical-technology-in-spain/

Conclusion

- There are really interesting opportunities as a mathematician in the industry.
  - Go on LinkedIn and explore: read job descriptions, find out what you like, what skills you have and you lack etc.
- You have a useful set of skills, leverage it.
  - Critical analysis and problem solving.
  - Prioritizing and organizing.
  - Explaining complex ideas.
  - Hard skills: programming, modeling, statistics...
- Do you like modeling / control / simulations? Contact me for a joint MSc thesis!