The concept behind modeFRONTIER

Some conceptual fundamentals for introducing the modeFRONTIER design environment
Defining modeFRONTIER

modeFRONTIER is a multi-objective optimization and design environment, written to allow easy coupling to almost any computer aided engineering (CAE) tool, whether commercial or in-house.
The concept behind modeFRONTIER

Input Variables:
Entities that define the design space.

Output Variables:
Measures from the system

The Black Box:
Generates the outputs accordingly to the inputs
The input variables

Variables:
Variables are the free parameters, i.e. the quantities that the designer can vary or the choices the designer can make.

Continuous variables:
• point coordinates
• process variables

Discrete variables:
• components from a catalogue
• number of components
The Black Box

The black box can be:

- A set of solvers that models and solves in a numerical manner the design problem (e.g. CAD/CAE tools)
- A set of experiments that produces some data

Multi-disciplinary Scenario

- CFD (StarCD, Fluent, CFX)
- CAD (CATIA, UGS, PROE)
- FEM (Nastran, Ansys, Madymo, etc)
- Others (In-House codes, MATLAB, Excel)
The output variables

The **output variables** are a measure of the system response and/or performance, i.e.:

- acceleration, speed, consumption, confort,…
- deformation, stress, mass, volume,…
- lift, drag,…
- defects, number of failures, cost,…
- ….
Input Variables: Entities defining the design space.

The Black Box: (ANSYS, FLUENT, Workbench, MatLab, etc...)

Output Variables: Measures from the system

Optimization means to find a set of system configurations (input variables) that meets the objectives and satisfy the constraints.
The optimization can be multiobjectives.

Many softwares can be used to describe the behavior of the system under exam.
Multidisciplinary Optimization - MDO

Discipline 1
Discipline 2
Discipline 3
Discipline 4
Discipline ...

Objective 1
Objective 2
...
Objective k

Multiobjective optimization, Approximation methods, Sensitivity Analysis, Space exploration, Multivariate Analysis
EMO and its fields*

Leisure & Sport

*On a database of 148 real world applications
Leisure & Sport Applications

- Study of innovative solutions of a cycle wear crotch pad for Campagnolo
- The optimization considered the ergonomic level of the crotch pad function of both geometry and materials.
Innovation – HOW?

Objective: Product *innovation* for high performances

Technologic issue *(cost)* - appearance/ *Marketing* - performances

- Simplified product analysis ⇒ Decrease in cost
- Alternative materials ⇒ Stiffness and energetic absorption
- Ergonomic/Marketing ⇒ Independence by anthropomorphic features
- Ergonomic improvement ⇒ Shape and thickness modification
Parametric models carrying out
Objective: **Ergonomic improvement** ⇒ **Shape change, thickness, material**

Assessment of the critical zone
Parametric models carrying out

Objective: Ergonomic improvement $\Rightarrow$ Shape, thickness, weight change
Geometric parameters

Simulation CAD parameters. These parameters have been implemented in modeFRONTIER.

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Optimization process

Workflow

Excel node

Objectives

Ansys node - WorkBench
Optimization process

The optimization process:

- **Input variables**: Geometry, materials mechanical properties
- **Objectives**: Minimization of back and front cushions volume, minimization of pressure distribution and its maximum value.
- **DOE**: Sobol (50 designs initial population)
- **Optimisation algorithm**: MOGA II
Optimization process
Optimization – Assos F13

Comparison between initial configuration and optimal points

http://www.campagnolosportswear.com/
Example of Applications: Biomechanics

Graph of relative drag difference between a cyclist using a rear wheel with and without a disk in a range of crosswinds.
Example of Applications: Biomechanics
Constructions - Brenner Railway Base Tunnel

- Two single track railway tunnels connecting Fortezza (Italy) and Innsbruck (Austria).
- Tunnel section: 72,4 m²
- Length: 56 km
- Up to 1650 m under the Alps
- Tunnels about 70 apart, connecting galleries every 330 meters

The problem:

- Uncertainties of data on the mechanical behaviour of the rock mass
- Passing from south to north, the tunnel will be drilled through granite, paragneiss, schist, gneiss, marble, phylite.
- It also crosses the Periadriatic Seam, caused by the collision of the African plate and the European Continent
Time and Cost Reduction

modeFRONTIER tasks

- Reliability analysis (general) - and documentation
- Reliability analysis with respect to rock models (behaviour of the mass during borging)
- Scenario and decision on the best excavation method.

Examples – Constructions - Transportation
Automotive Application

The aim of this activity is to **OPTIMIZE CONFLICTING ASPECTS** in terms of **Handling performances** as well as **Ride&Comfort performances**.

**Handling**

- Stability and response of the vehicle
  - Understeer
  - Side-slip angle
  - Rolling
  - Yaw speed

**Comfort**

- Comfort for driver and passengers
  - Peak accelerations
  - Time of dissipation after impact
  - RMS of low frequency accelerations on uneven road, highway, obstacles

The study results in a set of vehicle set-up, concerning suspension vertical and longitudinal stiffness, elasto-cinematic behavior, optimizing both aspects without forgetting the robustness of the solution.
Full-vehicle MSC.ADAMS/Car Models

Assembly Handling
- Front Suspension (incl. flexible subframe)
- Rear Suspension
- Steering
- Antirollbar
- Conceptual Driveline
- Front & Rear Tires
- Rigid Body

Assembly Comfort
- Front Suspension (incl. flexible subframe)
- Rear Suspension
- Steering
- Antirollbar
- Engine
- Front & Rear Tires
- Rigid Body

For more information visit: www.esteco.com or send an e-mail to: modeFRONTIER@esteco.com
Definition of Input variables

Vehicle parameters able to influence both the Ride-Comfort and Handling performance

**Input variables:**
- Spring Stiffness and preload
- Bumpstop clearance and characteristics
- Anti-roll-bar diameter
- Damper characteristics
- Bushing characteristics

**Vehicle parameters**

- **VERTICAL STIFFNESS AND ROLLING STIFFNESS**
- **VERTICAL DAMPING**
- **LONGITUDINAL STIFFNESS AND DAMPING**
- **ELASTO-CINEMATIC CHARACTERISTICS**
Objectives and Constraints

Objectives:

- **Key synthesis Handling parameters** (understeer, sideslip curve, yaw, rolling - gains, time delays)

- **Key synthesis Comfort parameters** (peak accelerations, time dissipations, RMS/RMF)

Constraints:

- **Ride height** in various load conditions

- **Feasibility of the components** for ex. rate between axial and radial bushing stiffness, damper characteristics, bumpstop length and characteristics etc.

- **Top mount stiffness for damper efficiency**

- **Performance constraints**
Coupling modeFRONTIER & ADAMS/Car

Example Process includes modifying and launching 3 models (K&C, Assembly Handling e Comfort), 7 analysis (4 K&C, 2 Handling e 1 Comfort).

Every run requires approx. 5min => weekend 2.5ggr = about 800 run
DOE Study and Optimization Method

**Influence Study:** 8 Input variables, 4 Targets for example

DOE Study Sobol/Full-factorial => Excluding input variables (and constraints/objectives) + Adapting range of study

**Optimization** with limited numbers of variables, objectives, constraints - real or virtual response surfaces

Pareto FRONTIER => Selection of “optimum” solutions related to the particular project vehicle target setting

Verification of optimum solutions belonging to Pareto FRONTIER
Aerospace Application

The geometric model built-up in Catia V5 has been imported into ANSYS WorkBench 11.0.

Superfici Alari (Skins)

Centine (Ribs)

Longheroni a C (Spars)

Courtesy of Alenia Aeronautica
Geometric model set-up

Subdivision of the wing into 6 parts

In this way it is possible to reduce the number of skins while getting closer to the tip of the wing (more efficient optimization process)

Different values of skin and caps structural parameters between the wing underside and the top surface

With the aim to get the best material performances

The input variables values (thickness, skins number, ...) are constant within every 6 parts
Optimization strategy

The optimization process has been sub-divided into the 2 following phases:

1. Firstly, the whole design space has been explored with the scope to get the **global optimal solution**. This initial search exploited the **MOGA-II**

2. In a second step, the more important input parameters have been further investigated, while the remaining ones have been fixed to constant values. This approach enabled to get more accurate solutions. In this phase **both MOGA-II and B-BFGS** (hybrid approach) have been used.
Workflow modeFRONTIER

DATA FLOW
17 input variables + 67 constants  
29 output variables  
1 objectives  
30 constraints

LOGIC FLOW
DOE: 4 best designs fase 1  
Optimizer: B-BFGS
DOE: 16 best designs B-BFGS  
Optimizer: MOGA-II

CPU TIME
Around 680 analyses  
10' per run  
≈ around 4.5 days
Results

The flexural and the total deformation (torsion and flexural) are depicted. In both cases (positive and negative nz) the maximum deformation values belong to the feasibility domain.