Simulation, données, information, connaissance et prise de décision : configurant la 4ème révolution industrielle

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I’m an engineer

luck or disgrace?
Scientists discover the world that exists, engineers create the world that never was

Theodore von Karman
Arguments against new ideas generally pass through distinct stages from:

“It’s not true” to
“Well it’s true but not important” to
“It’s true and it’s important, but it’s not new – we knew it all along”

From *The Artful Universe*
by John D. Barron
Predicting should precede creating!

But, how predicting the behavior of something that never was?

Many options ...
The best way to predict the future is invent it

Alan Curtis Kay

It rarely works …
a particular state of mind is required!
The scientific approach
Example:

Astronomy

First was the data - Babylonian astronomy - then were the models

\[ F = G \frac{M \cdot m}{d^2} \]
All models are wrong but some are useful

George Box
Numerical simulation based on models

✓ Present

✓ Future
• Material parameters: $M_1, \ldots, M_m$
• Geometrical parameters: $G_1, \ldots, G_g$
• Applied loads: $L_1, \ldots, L_l$

$U(x,t; M_1, \ldots, M_m, G_1, \ldots, G_g, L_1, \ldots, L_l)$
ISSUE

Combinatorial explosion

Solution for each choice of parameters

10 parameters
10 values / parameter = $10^{10}$ possibilities !!
When all “possible” solutions have been pre-calculated!!
Towards modern vademecums ...
PGD constructor circumvents curse of dimensionality

\[ U(x,t; p_1, \ldots, p_m) \approx \sum_{i=1}^{N} X_i(x) \cdot T_i(t) \cdot P_i^1(p_1) \cdots P_i^m(p_m) \]
Automated Tape Placement

\[ T(x, y, z, t, V, Q, o_1, \cdots, o_n, h_1, h_2, h_3) \]
ISSUES

Sometimes “uncorrelated” parameters are not evident!

Parametric solutions are not always feasible!

Simulated data – Information – Knowledge – Decision making
First was the data,
then were the models,
today data-driven applications systems appears as the new paradigm in SBES
From data to information: removing correlations

\[ S(p_1, p_2) \]

\[ S(p_1) \text{ or } S(p_2) \]
Patient-specific surgical planning

Liver data
Only two uncorrelated parameters

New patient liver

Data interpolation

Real-time simulator
patient specific
Data-Driven alleviates modeling

Nowadays

Experiments → Model → Simulation

Simulation includes modeling errors

Future

Experiments → Manifold learning based model → Simulation

Simulation collaborative enrichment

KIAS?
From a methodological viewpoint:
If Hooke had never existed, linear elasticity finite element simulations (based on data) would have existed?

YES, and not only elasticity!
Cheap manifold constructor

Model-free simulation

Test, IC

Trial behavior manifold

Comparison

Manifold updating
Model-Free Upscaling

Phase A: behavior model A
Phase B: behavior model B

What behavior?
What model?
Methodological example

\[
\begin{pmatrix}
u \\ v
\end{pmatrix} = \alpha \begin{pmatrix} x \\ 0
\end{pmatrix} + \beta \begin{pmatrix} 0 \\ y
\end{pmatrix} + \gamma \begin{pmatrix} y \\ x
\end{pmatrix}
\]

DNS

\[
\left\{ \sigma(x), \varepsilon(x) \right\} \Rightarrow \begin{pmatrix} \Sigma \\ E \end{pmatrix} \in \mathbb{R}^{12}
\]

Model free macro simulation

Manifold learning $\rightarrow$ Dim = 2
Macrostructure manifold

Behavior manifold
Data-Driven, Data-Mining and Machine Learning, Deep-learning, ... open plenty of possibilities.

BUT be careful, surprises are not excluded
Big data en campagne

Comme les publicités commerciales, les messages politiques font l’objet d’un ciblage de plus en plus fin. Dans le numérique, les démocrates ont une longueur d’avance.
L’élection de Trump et les trois échecs du « big data » électoral

La campagne de Hillary Clinton, supposée être à la pointe des technologies de ciblage électoral, a échoué à la faire élire. Du côté des médias, les modèles prévisionnistes, eux aussi basés sur le « big data », n’ont pas su prédir l’issue du scrutin.

Faithless electors: wrong data
Sampling deficiency
Data-mining
In the 4th industrial revolution there is still room for the human being