

The Elegant Theory, the Observed Societal Reality and the Potentialities of Coupled Models

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ASSESSMENT OF THE CONCEPTS: OBSERVATIONAL AND MODELING

***The limits of their self-sufficiency**

***Model-observation relate**

AMENDED MODELS

***Observation is directly related to reality and
model comes from theory in a given field**

***Model approaches closer to observed reality
accounting for coupling and/or more theoretical domains**

APPLICATION ELECTROMAGNETIC SYSTEMES

**I. The world (the observable)
and
the theory (the model)**

**Self-sufficiency of both
concepts**

The observable

**A real objet, observable,
behaves according to real
environmental events
that are observable**

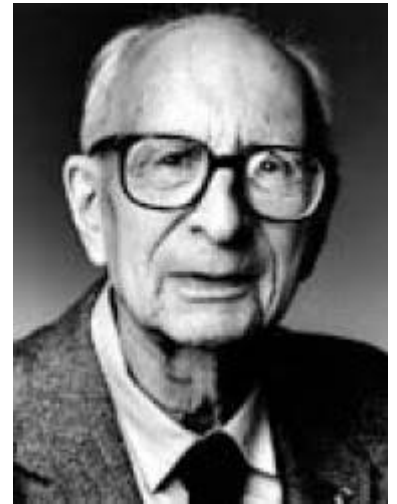
Observation auto-sufficiency?

Observation alone?

e.g. Anthropology (e.g. myths)

Observation alone, despite its richness of memory, limits the field of research!

**Claude Lévi-Strauss (1908-2009) ,
Structural Anthropology, Paris 1958**



**Putting it in a theoretical context
opens the research opportunity!**

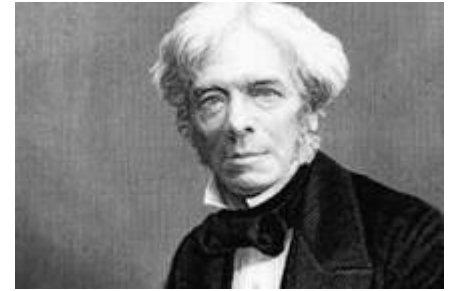
p. 336:

**Structural researches
in the social sciences are
indirect consequences of
modern mathematics:
logic, sets, groups and topology**

e.g. In physical science

Michael Faraday (1791-1867)

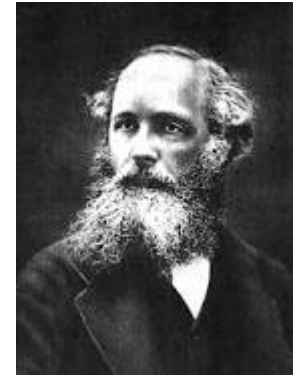
electromagnetic induction



An excellent observer, Experimental work in a very simple style, Mathematical skills are limited to the simplest algebra

James Clerk Maxwell (1831-1879)

Put it, with others, in a mathematical context “Maxwell equations”, basis of Modern researches on electromagnetic phenomena



Observation needs modeling for deeper research!

The model

The observed behavior of a real object can be dominated by a science (physical, chemical, ...) or a phenomenon involved in this science (EM, Mechanics, ...)

Modeling auto-sufficiency?

Model alone?

**The world (the observable) and
the theory (the model)**

Almost **The eye and the spirit, 1960**

Maurice Merleau-Ponty

(1908-1961)

***Science manipulates
things and gives up living
inside**



***Science takes the world as
an object of knowledge
'dissociated' from
the existing subject**

***Model = f (its author)**

*The model and the mind are matched
and scientists see the world with a
spirit related **only** to the model*

Observables and observers

(50 years after Maurice Merleau-Ponty)

Functional MRI



Brain mapping

Mirror neurons

(existing observable and observer)

(2 observers)

(model author and user)

(2 users)

e.g. In physical science

Parity violation in weak interactions

Symmetries in physics

Parity was naturally assumed to be conserved in the 4 fundamental interactions:



electromagnetism, gravity & strong and weak interactions,
(long-range forces) (subatomic)

Lee and Yang (Nobel 1957)

suggested parity violation in weak interactions after experimental confirmation (by Wu)



Tsung-Dao Lee (李政道)

1926



Chen-Ning Yang (杨振宁)

1922

Chien-Shiung Wu (吴健雄)

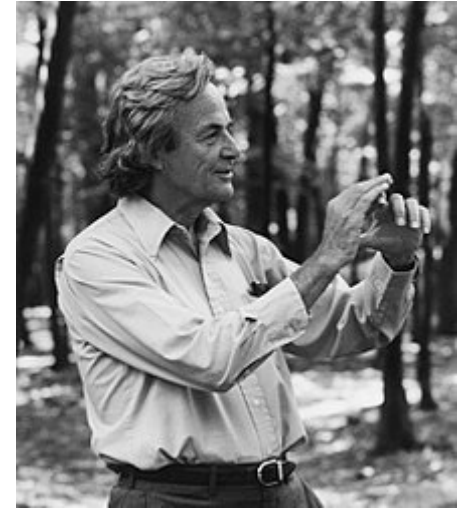
(1912-1997)



Contribution originated explorations in elementary particles (subatomic) concerns

Sound tongue of Feynman

Richard Phillips Feynman (1918-1988)
Quantum electrodynamics, Nobel 1965
Quantum computing...



**“No matter how beautiful your theory is,
No matter how smart you are,
No matter if you're famous ...
If your theory is not in tune with experience,
It's wrong. That's all.”**

**Modeling needs observation,
simply to be credible!**

Theory-Observation managing

***Standard: Theory validated (or not) later by experience:**

e.g.

Superposition states

S Haroche & D Wineland 1996

(Nobel 2012) validated

E Schrödinger 1930 (Nobel 1933)

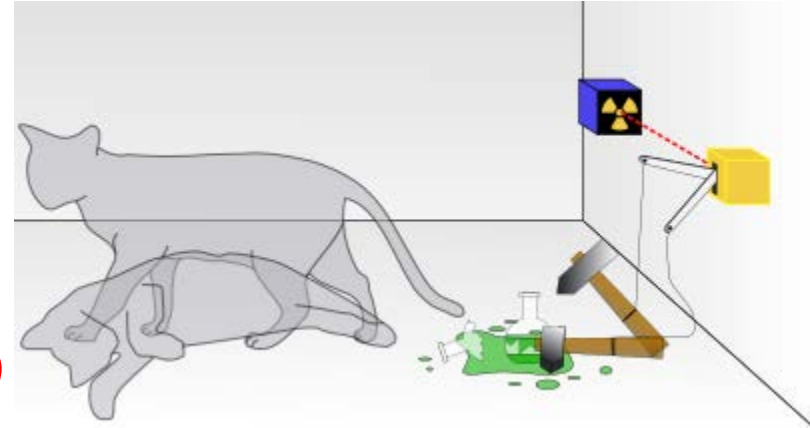
&

Hall effect

E Hall 1879 invalidated (JC Maxwell 1873)

***Experience first: e.g. superconductivity:**

Kamerlingh Onnes (1853-1926) Nobel 1913



...

***Simultaneously: e.g. Duality Particle-wave:**

Louis Victor de Broglie (1892-1987) Nobel 1929 &

Clinton Joseph Davisson (1881-1958) Nobel 1937

(Bell teleph. Labs: Nickel in electronic components + electrons,

Explosion, Nickel crystalline, Max Born conference)

***Same work: e.g. Graphene...Dirac cone:**

Andre Geim & Konstantin Novoselov Nobel 2010

(Adhesive tape! A.G. Ig Nobel 2000: magnet Frog levitation)

***+ Observation-theory Evolution and Serendipity**

Rulings on Theory-Observation

In general,

**One can consider
a theory only established after
validation by observation**

Moreover,

**Such a theory remains valid until
disagreement with observation**

Therefore,

**The theory-observation couple is
necessarily always associated**

II. Amended models

One of theory-observation relate interests: Amended models accounting for more theory to fit reality

***The societal observable is just and the model is necessary**

***The model does not match the societal observable and has to be adapted to fit better the reality**

**Mathematical models come from
coherent and pleasant theories
under idealizing assumptions**

When such theories apply to:

***situations corresponding to these**

**hypotheses, the model may represent
reality**

...

When such theories apply to:

***Situations corresponding to all other non-idealized conditions (societal applications), we need revised models**

This is possible by accounting for more theory in the model

...

**The observed (societal) behavior
is dominated by different
sciences and/or involved
phenomena**

***The simple model will be
substituted by a compound model***

***Models ... all together to do better !!!**

***If the mathematical models concerned are particularly interdependent, only a coupled solution of these models can give an acceptable answer**

***Models interdependence is strongly guided by their time evolutions proximity and their self and mutual stuff behavior laws density**

Coupling of interdependent models

Degree of interdependence corresponds directly to the degree of coupling required

Weak: consider the models individually in an iterative process linking their stuff behavior laws

Strong: consider a simultaneous solution of models enclosing their behavior laws

For a given degree of coupling, we need to opt for:

- *an appropriate mathematical formulation,
- *suitable space and time scales
- *a proper resolution method

Validation

***Through analytical solutions with simplified geometries and constitutive laws of substances (for verification)**

***With experience by means of real laboratory device, on which precise measurements can be accomplished**

III. CASE OF ELECTROMAGNETIC SYSTEMES

***Present in most of societal applications:
mobility, health, security, communication ...**

***Behave under 4 occurrences:
electrical, magnetic, mechanical, and
thermal**

***Thermal: has a slower time evolution
(higher time-constant)**

Coupling of the fields of the different occurrences in EMS

Couplings classification:

**Causatives (system behavior),
integrated (electrical and magnetic),
material intrinsic (functional)**

Smart materials:

**Magnetostrictive, electrostrictive,
shape-memory, thermoelectric**

Solution of the equations of the involved governing occurrences

***Complex geometry and materials with non-linear behavior laws:**

local distribution of variables: fields, potentials,...

***2D or 3D discretized geometrical cells or elements :**

local solution,... on Node, Edge, Facet,...and B.C.

***Nature of the concerned system behavior :**

frequency domain or time domain analyses

***Degrees of discretization refinement of space and time :**

geometry, temporal evolutions, and individual and

interdependent laws of behavior of variables

Occurrences couplings strategies

With very different time constants

*Independent occurrences and linear behavior

Simple coupling solution (direct separate solutions)

*Non-linear behavior and/or variables are interdependent

Weak separately iterative coupling

e.g.

*A Sekkak, L Pichon, A Razek: 3-D FEM **magneto-thermal analysis in microwave ovens**, IEEE Transactions on Magnetics 30 (5), 3347-3350, 1994

With the same order of time constants

In general simultaneous strong solution

The non-linearity and the variables interdependence are included in the solution through iterative convergence procedure

e.g.

*F Piriou, A Razek: Finite element analysis in **electromagnetic systems-accounting for electric circuits**, IEEE Transactions on Magnetics 29 (2), 1669-1675, 1993

*Z Ren, A Razek: A strong coupled model for analyzing **dynamic behaviors of non-linear electromechanical systems**, IEEE Transactions on magnetics 30 (5), 3252-3255, 1994

Material intrinsic interactions

Smart materials:

Magnetostrictive, electrostrictive, shape-memory, thermoelectric
(mag.-mec.) (elec.-mec.) (therm.-mec.) (therm.-elec.)

***Linear behavior and/or very different time constants**

Weakly coupled solution

e.g.

*H Hariri, Y Bernard, A Razek: A traveling wave **piezoelectric beam robot**, Smart Materials and Structures 23 (2), 025013, 2013

***Otherwise: f (complexity of the nonlinear relationships)**

Strong coupling and multiscale methodologies

e.g.

*M Besbes, Z Ren, A Razek: A generalized finite element model of **magnetostriction phenomena**, IEEE Transactions on Magnetics 37 (5), 3324-3328, 2001

Validations

***By analytical solutions**

For simple geometries and linear materials (verification)

***By observation**

**e.g. TEAM (Testing Electromagnetic Analysis Methods)
workshop**

**Started in 1986 in two-year rounds, as a satellite event of
the COMPUMAG Conference**

**The TEAM problems: list of test-problems, with precisely
defined dimensions, constitutive laws of materials,
excitations, ...**

**Each backed by a real laboratory device, on which
measurements can be accomplished**

e.g. TEAM Problem 12: Cantilevered beam in crossed field

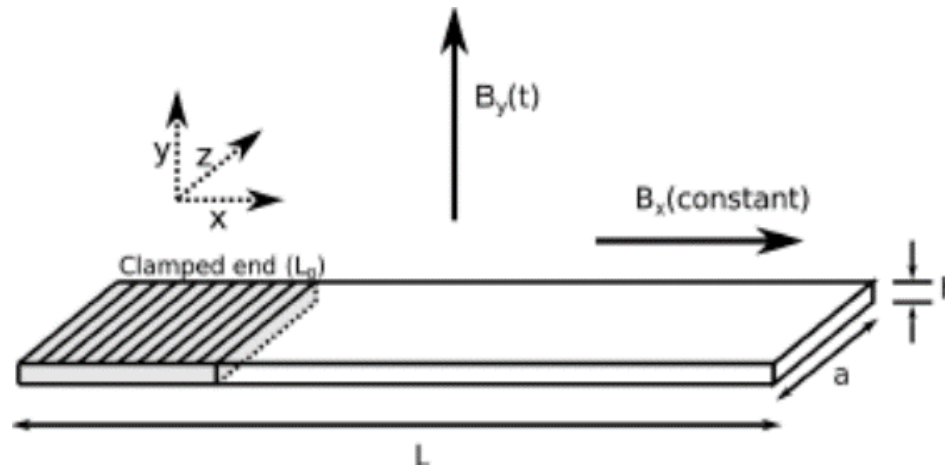
Coupled problem with moving conductor

(A clamped beam is placed in a uniform magnetic field B_x)

$B_y(t)$ exponentially decaying with time,

induced current in the beam,

interact with B_x , create a force that will cause the beam's movement



Schematic diagram for the cantilever beam

e.g. for validation by analytical solution and by observation (TEAM)

*Z Ren, A Razek, **A coupled electromagnetic-mechanical model for thin conductive plate deflection analysis**, IEEE Transactions on Magnetics 26 (5), 1650-1652, 1990

Go on theory-observation relate interests

*Bayesian relate (**Digital Twin** concept) using integrated multi-phenomena, multiscale, probabilistic approach: real object, digital/virtual item, and their connections (sensors, history,...)

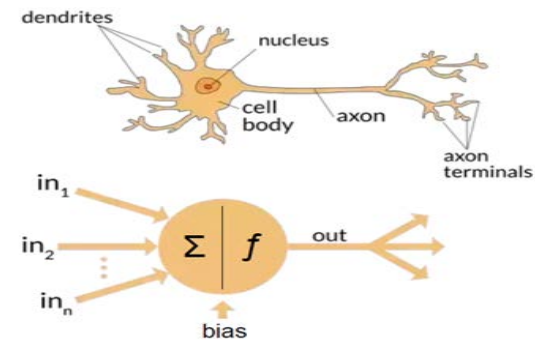
***Bayesian Brain**: The predictive model creates sensory expectations; only the error (prediction versus observation and history) is represented in the spread neuronal discharges.

Human brain (10^{11} neurons, each tied to 10^4 others)

***Quantum and Neuromorphic** technologies (computing) derive from observed reality (quantum physics and neurosciences):

Quantum: 2 states (0 & 1) switched to 2^N , with N energy levels; capacity, speed,...

Neuromorphic: ANN or BNN; optimization, diagnostics, images, machine learning,...



MERCI de m'avoir supporté!!!

THANK YOU for supporting me !!!