# Knowledge-Aided Engineering - A Formalism

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# Outline

- Philosophical musings
- Data, information, and engineering knowledge
- Correlation, causality, and sensitivity
- Knowledge modeling and embedding
- Concluding remarks

# Philosophical Musings

- Evolution sequence:
  Data -> Information -> ***Knowledge*** -> Wisdom?
- Several “soft” definitions, especially from knowledge management consultants.
- But engineering needs harder definitions.
  - Roger E. Bohn, “Measuring and Managing Technological Knowledge”, Sloan Management Review, Fall 1994.

# Data

- **Data**: Raw "stuff", both qualitative and quantitative
- **Kelvin's Dictum**: "*When you can measure what you are speaking about, and express it in numbers, you know something about it; but when you cannot measure it, when you cannot express it in numbers, your* ***knowledge*** *is of a meager and unsatisfactory kind: it may be the beginning of* ***knowledge,*** *but you have scarcely, in your thoughts, advanced to the stage of science."*

Measurements and numbers still give you only data.

# Information

- **Information**: Structured, organized data
  - placed in context, thus endowed with some semantics (meaning)
- **Example:** XML-tagged data becomes information. It has structure, and this gives it some meaning.

**Knowledge** is something a lot more than information.

# Bohn's Classification of Production Process Knowledge Stages

| Stage | Name | Comment | Typical Forms of Knowledge |
|---|---|---|---|
| 1 | Complete ignorance | | Nowhere |
| 2 | Awareness | Pure art | Tacit |
| 3 | Measure | Pre-technological | Written |
| 4 | Control of the mean | Scientific methods feasible | Written & encoded in hardware |
| 5 | Process capability | Local recipe | Hardware & operating manual |
| 6 | Process characterization | Tradeoffs to reduce cost | Empirical equations (numerical) |
| 7 | Know why | Science | Scientific formulas & algorithms |
| 8 | Complete knowledge | Nirvana! | |

# Generalization

- Engineering knowledge is not static; it evolves dynamically.
- It involves:
  - **Discovering correlation**
  - **Causal association**
  - **Assigning proportion (sensitivity)**

  **so as to make predictions and prescribe actions.**

# Correlation

- Correlation is easier to establish than causality.
  - **Conservation laws in physics provide only correlation.**
  - **Some designs can be done using just correlation.**
- Structured data can be “mined” to discover correlation - especially that were not suspected.

# Causality

- Causality is much harder to establish.
- In the engineering context, causal association can be made only through carefully designed and controlled experiments.
- Causal association is essential for manufacturing and quality control.

# Sensitivity

- Rank ordering of causes - separating the “vital few” from “trivial many”.
- All causal (and correlation) associations have to deal with sensitivity.
- Causality and sensitivity knowledge form the proprietary asset of an engineering firm.

# Knowledge Modeling

- Representing, manipulating, and reasoning about knowledge.
- In general, we don't know how to computerize them. For example:

State of automated commonsense reasoning (E. Davis, 1998):

"*As far as I know, no one currently knows how to automate these inferences nor how to represent the knowledge used in them. I do not believe that this will be known any time in the near future*"

# Knowledge Modeling

- A more modest approach:
  - Capture the elements of engineering knowledge in traditional prose, equations, and graphics.
  - Make them available to engineers using current and emerging web technologies.
  - Look for niches where some degree of automation is possible.

# Embedding Knowledge

**A design tool example:**

- Let's suppose that in some domain
  Knowledge Rules Constraints
  - In VLSI design:
    circuit & process knowledge ground rules
    geometric constraints
  - Being mimicked in mechanical CAD.
  - Beware of its limitation!

# Concluding Remarks

- In the context of engineering, a formalism for knowledge is attainable.
- This knowledge can be placed at the disposal of the engineer.
  - **Some of these may even be embedded in his tool set.**
- Lot of excitement in industry - too early to tell its impact.