Engineering in the Era of Convergence

The 4th Industrial Revolution: Convergence of physical, chemical, biological, behavioral and social phenomena

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TECHNOLOGY: EXPLOITING A PHENOMENON* FOR USEFUL PURPOSES

- PHYSICAL (e.g. Photoelectric Effect)
- CHEMICAL (e.g. Catalysis)
- GEOLOGICAL (e.g. petroleum)
- BIOLOGICAL (e.g. Brain Imaging)
- SOCIAL-BEHAVIORAL

*And combinations of phenomena or technologies
**Including the discovering of new phenomena

Convergence is an intrinsic part of technology

Increasing complexity
Shaded areas represent 2009 research activity of Viterbi faculty.
ENGINEERING + X

*Where X is anything!*

E.g. Media, Medicine, Entertainment, Biology, Education,…

Three pathways:

E₂X (Engineering Empowers X)

X₂E (X empowers Engineering)

E∪X (Engineering and X comingle)
E2X

ENGINEERING EMPOWERS X

E makes X “smarter”; more “efficient”; opens new dimensions, many disruptive. It is also the ubiquitous digitization of everything (Digital Technologies)

E and X can be vectors
We will call it X-mimetic
Biomimetic: Nature’s optimization through evolution
Perhaps other
E makes X “smarter”, more “efficient”. X discovers new phenomena which create new E. A “double helix” of E and X.

Nanotechnology, Biotechnology, Cognitive (Exponential Technologies)
What if X is human or society-centric?

e.g. In Complex Systems

- **E₂X**: Enables social or behavioral phenomena
  
  *Social Media; AI for Social Good*

- **X₂E**: Ethical decision making in autonomy
  
  *Drones, driverless cars*

- **EUX**: Augmented Intelligence
  
  *HMI (human-machine interaction)*
  
  *HBI (human-building interaction)*

(Also, any businesses, organizations, systems, innovation)
TWO EXAMPLES

INNOVATION IS INTRINSICALLY CONVERGENCE

Technology (Feasibility)

Business (Viability)

Design (Desirability)

Useful Purposes

TECHNOLOGY: EXPLOITING A PHENOMENON FOR USEFUL PURPOSES*

- ETHICAL-MORAL
- UNINTENDED CONSEQUENCES
- COMPLEXITY
- POLICY

DECIDE: Center on Decision Making
Convergence at USC (many Xs =18)
SEEDING CONVERGENCE CENTERS:

1. BIOSCIENCES
2. IOT
3. CENTER FOR ADVANCED MANUFACTURING
4. MACHINE LEARNING
5. AI FOR SOCIAL GOOD
6. DECIDE

Viewed as VC investment- expected to result in large grants, gifts and sustainable growth
Currently

**Econophysics**: Use of statistical physics to explain economics.

**Agent-Based models**: Discrete entities interact through rule-based interactions.

1. *Each entity assigned a state property, updated through rules based on neighboring states.*

2. *Sometimes expressed through conservation laws and flux-flow relationships.*

At the fundamental unit (single-human) level, all social phenomena fundamentally involve (bio) chemical reactions. Behavioral responses often mimic the same.

Interested in the aggregate (interaction of multiple entities) => Natural to seek chemical kinetics analogues.

The (Chemical) Kinetics of Social Phenomena

Postulate:

All social interactions where there is a “chemical transformation” across many elements (“humans” as molecules): can be modeled as a chemical reaction

\[ A + B \rightarrow C \]

- Culture
  \[ A^* + B \rightarrow A^* + B^* \]
- The process of sales (or reaching objectives)
  \[ A^* + B \rightarrow A + B^* \]
- Transformative “experiences”
Requires

- Definition of “species”, “reactants” and “products” - e.g. demographic, ethnic, geographic, or basis of “contentment”, or of knowledge
- Random walks (e.g. web surfing?) and collisions
- Activation “energy” barrier and change of “energy” state
- Definition of an intermediate “complex” and the probability of its formation (political, legislative processes?)

May help model, understand and possibly control the phenomenon
LINEAR KINETICS: $A \rightarrow A$

$$\frac{\Delta A}{\Delta t} \approx \lambda A \quad \Rightarrow \quad A \approx A_0 \exp(\lambda t)$$

EXPONENTIAL INCREASE: MOORE’S LAW!

QUADRATIC KINETICS: $A + A \rightarrow 2A$

$$\frac{\Delta A}{\Delta t} \approx \lambda A^2 \quad \Rightarrow \quad A \propto \frac{1}{(t^* - t)}$$

SINGULARITY AT $t^*$!

KURZWEIL’S CONJECTURE?
**Education**: the process of facilitating learning; also augments an individual’s state of knowledge or skillset: A “chemical reaction”

\[ A \rightarrow A^* \quad (1) \]

**Individual course**: education in a specified time interval (typically quarter) and a prescribed sequence: A “chemical reactor” where (1) occurs

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**Figure 1a. Course as a Chemical Reactor**
Curriculum: A “flow and reaction” process, where a new cohort enters each year, with an overall residence time of 4 years, for a typical curriculum.
Engineering Education “flow diagram”: Each part consists of individual “control volumes” (within each of which is a sequence of “chemical reactors”).

Figure 2. Engineering Education as a Flow Process
- Process efficiency in each control volume necessarily means parity.

- Namely, demographics of output flow rates (e.g. undergraduate retention or graduation rates) must be statistically the same as those of the input.

- Entities owning control volumes and flow rates (admission valves), must own and be accountable for reaction efficiencies through them (i.e. parity).

- Best practices ("control strategies") needed to meet such objectives.
• Enhance D+I by establishing parity on input and output.
• Parity is process efficiency, to which an institution ought to aspire.
• Best practices should be developed to meet the parity objective.
• Wide adoption of the parity objective will have a non-trivial impact on increasing engineering D+I.
• If every engineering institution commits to this in each of the control volumes it owns, will automatically strengthen output flows, thus increase downstream flows.
Convergence of physical, chemical, biological, behavioral and social phenomena: Address the fundamental needs in Maslow’s hierarchy

In order to be able to further enrich life