Rethinking Engineering Education

Engineering Education Seminar
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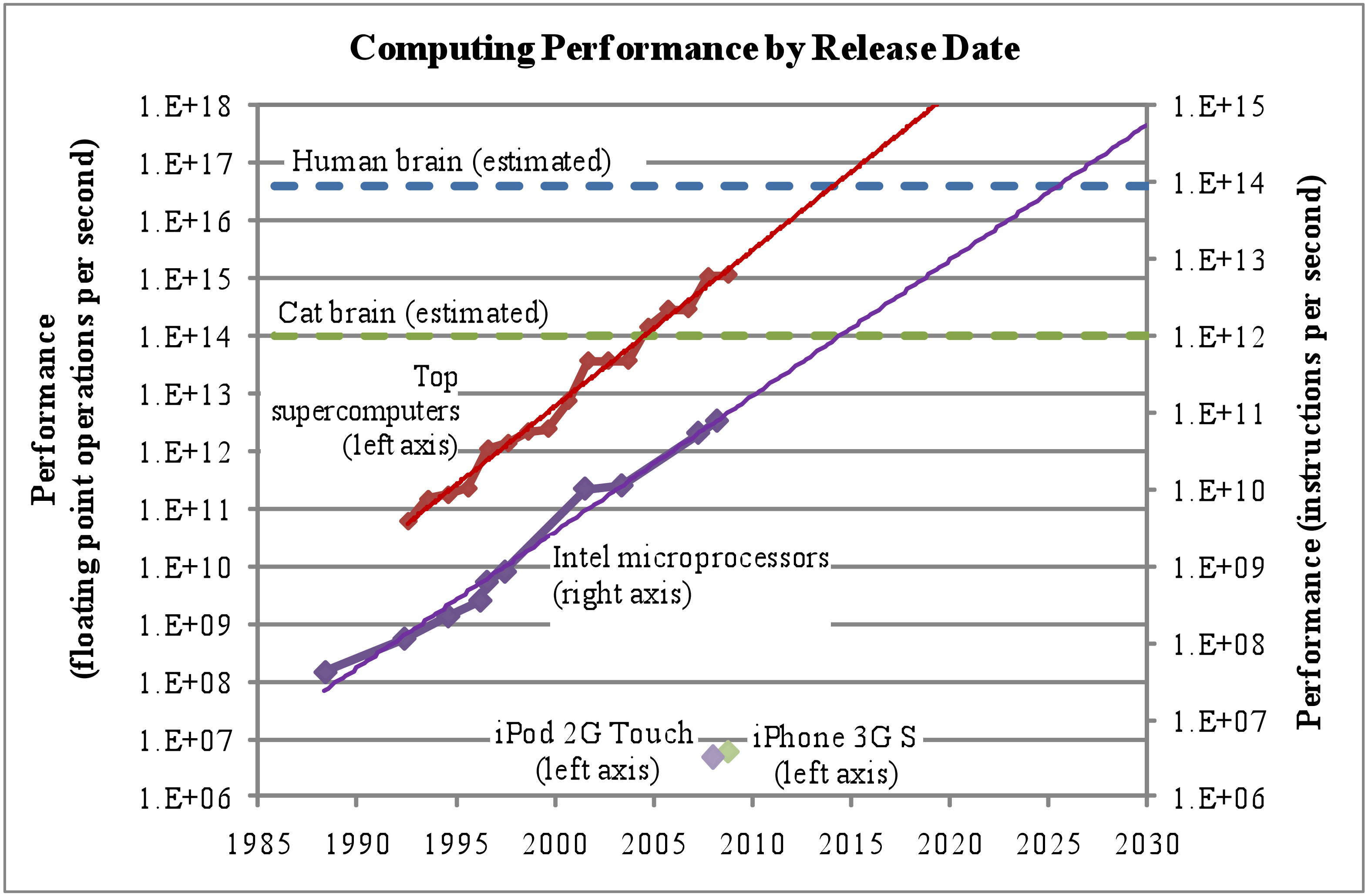
Why We Are Failing: Heidegger

"So long as we do not, through thinking, experience what is, we can never belong to what will be."

"The flight into tradition, out of a combination of humility and presumption, can bring about nothing in itself other than self deception and blindness in relation to the historical moment."

Source: M. Heidegger, *The Question Concerning Technology and Other Essays*, translation by W. Lovitt (New York, Harper Torchbooks, 1977), "The Turning," p. 49; "The Age of the World Picture," p. 136.

Computing Performance



Note that human and cat brain estimates apply to both the left and right y-axes.

Prepared by Carolyn Mattick. Adapted from Ananthanarayanan, Esser, Simon, & Modha (2009), Bennett (2008), EconomicExpert.com (n.d.), Moravec (1998), Polsson (2009), and TOP500.Org (n.d.).

World has Changed

- **Complexity**
  - Static complexity: more nodes, more links everywhere
  - Dynamic complexity: more interactions and shifts over time everywhere
  - Wicked complexity: human reflexivity, and technological and social evolution, create contingency and unpredictability
  - Anthropogenic complexity: humans operating at scale of interconnected global systems
- **Contingency: there are no stable assumptions anymore**
  - Human as design space
  - Everything from atmosphere to food is increasingly product of human design

World has Changed

- **Unpredictability**
  - Can’t foresee implications of emerging technologies and related policy decisions
  - Can’t foresee implications of interplay between technologies, society, and natural systems (e.g., geoengineering)
- **Technological evolution: the Five Horsemen**
  - Nanotechnology
  - Biotechnology
  - Information and communication technology
  - Robotics
  - Applied cognitive science

Situation Analysis

- Current educational methods are obsolete and increasingly dysfunctional
- Students have changed
  - Digital natives versus digital immigrants; gap keeps growing wider
  - Multitasking in complex, information dense environments, versus linear logic of older cohorts
  - Rapidity of technological change obsoletes specifics of education ever more rapidly

Situation Analysis

- **Cognitive networks are profoundly but subtly different (e.g., Google means long term memory is now dispersed function across Net)**
- **Development of augcog and augmented reality implies distribution of cognitive functionality across technology systems (e.g. cars, military technologies)**
- **Their world is profoundly multidisciplinary; we need “T” rather than “I” but some current faculty strongly oppose**
- **Global market: engineer “made in America” less important than technically competent and inexpensive**
- **Changes in existing academic standards**
  - **Plagiarism?**
  - **Why are we educating individuals rather than networks?**

What Has Changed?

- **Student cognition:**
  - Characteristics of short attention span, flitting above information landscape rather than diving in, are adaptive, not artifacts of superficial technologies.
  - Logic of complex information environment is networked association, not linear.
  - Offloading cognitive function – e.g., memory to Google, prioritization of environmental stimuli to augcog (DARPA; autonomous vehicle development) – is unappreciated but fundamental shift in human cognitive patterns.

What Has Changed?

- Digital native students function in networks which display network cognition, where cognition is emergent behavior of integrated human/technology networks.

- In periods of slow change, different cognitive structures can be ignored in mass production education processes; in periods of rapid change, the gap between leading edge digital natives and digital naïves grows much more rapidly, and mass production education processes fail.

- Routine cognitive enhancement:
  - First generation, e.g., Ritalin and Adderall (focus, enhancement of cognitive tasks), Provigil (modafinil – memory enhancer; wakefulness and alertness enhancer).
  - Stronger, more effective pharma likely because of military pressure to develop.

What Has Changed?

- **Engineering education, however:**
  - Powerfully conservative
  - Distrusts course content that is not quantitative and traditional
  - Little idea of how world has changed, nor how students have changed
  - Social networked intelligence leading to emergent cognition is comfortable for digital natives, but everything we teach is aimed at individuals.
  - Should teach “network intelligence” but every cultural and institutional incentive (tenure, disciplinary structure of engineering and intellectual endeavor, reductionist model of Enlightenment) is to remain wedded to Cartesian model of individual education and cognition.

What Has Changed: Personal Computational Power

- Combine:
  - Social network
  - Augcog
  - Cat brain iPod
  - Google for memory/info processing on Net

- What do you think the value added of an engineer will be ten years from now?

What Has Changed: Engineering Education

- **Because accelerating technological change widens the differences between social groups:**
  - Current generation versus previous generation
  - Within current generation, between digital natives and digital immigrants

***Implication*: batch processing methodologies characteristic of early Enlightenment education fail**

***Implication*:** professors rapidly decouple from the population they are supposed to be teaching

- this is not a result of incompetence, but of technological change;

- the problem is not intelligence, but a failure to perceive, much less respect, the cognitive differences between this generation and their teachers;

- it cannot be cured by changing professorial attitudes; it is not that they need better teaching methods, it is that they don't know what to teach

High Stakes

- Current educational methods are obsolete and increasingly dysfunctional.
- Incremental change is inadequate both in scale and in substance.
- Current educational institutions are too resistant to change to be able to respond adequately.
- Problem is not simply that professors need to improve pedagogy. They have never been taught, and do not know or understand, what they need to teach.
- The culture that evolves the best way to perform cognitive tasks in a networked, technology dense world will outperform competitors.

The Challenge

- Develop new teaching models while continuing with and incrementally augmenting existing models (should meet existing requirements such as ABET while responding to new environment.

- Maintain competency of graduates under existing domain-related standards while preparing them for contingency, unpredictability, and responsibility of new environment.

- But – prepare students for the unpredictable, rapidly changing future they will face, not the stable and defined past their elders faced

Response Portfolio

- **Stage 1**: Incremental Improvement
  - E.g., add modules, and perhaps an additional class, on sustainability
  - Old guard firmly in control; traditional departments rule
- **Stage 2:** Engineering as Liberal Art
  - E.g., Smith, Dartmouth, UVM, Olin
  - General engineering undergrad; specialization at grad level
- **Stage 3**: Reinvent Engineering Education
  - You want the truth? You can’t handle the truth.

Response Portfolio

- Complexity of challenge, and difficulty of change, mean we need to work on all three simultaneously

- At this point, Stage 1 is active; Stage 2 is discussed; and Stage 3 is ignored.

Stage 3: Personalized Education Skunkworks

- Begin with Engineering
  - bounded discourse
  - technology rich, so critical to anthropogenic Earth and its management
  - and in recognized need of curricular change.
- Set up skunk works: a test system outside existing institutions so that radical change can be played with.
- Avoids immune reaction by status quo, direct challenge to existing educational structure
- May be led by military or industry, rather than academia, if institutional resistance is too strong

One Route: Personalized Education Skunkworks

- Technology has undermined the current system; it must be the basis of the future system:
  - Move from batch processing to individual trajectories through learning space
  - Maintain existing technical proficiency metrics
  - Space designed as AI expert system so it provides as much guidance as possible, minimizing demand on professors that would otherwise make personalized education unscalable
  - All important skills obtained, and testable, as part of institutional and ICT environment design when student reaches end of program
  - Students proceed at own pace
  - Begin with selected students at freshman level, minor disciplinary distinctions at BS level, disciplinary focus primarily at MS level. All students to stay in program through MS.
  - Ph.D. level not offered (initially), because of heavy socialization and networking implied by work at that level.

Stage 1

- Incrementally improve current situation
  - Courses on sustainable engineering (e.g., FSE 194)
  - Courses on earth systems and environmental/ governance context of modern engineering

Stage 2

- Engineering as liberal art: spread existing model
- Try to shift production from “I” to “T” or “H” type
- Needed step: change production process to produce 3 types of graduate:
  - Technologists
  - I-type (subject to intense global competition)
  - True T-type (engineer as integrator/leader)

Stage 3: Personalized Education

- Create ICT hypervolume realities through which individual students progress
  - AI capability enables real time testing/reprogramming to emphasize weaknesses
  - Student is able to rapidly pass through spaces they have already mastered, spend more time in spaces where they are weak (e.g., for many engineering students, written communication)
  - Hypervolume is created so can be constantly updated, and can follow individual throughout professional career
  - Hypervolume is interactive learning program, and as part of it learns, it updates across hypervolume universe
- Content of program to integrate social science, liberal arts, and earth systems perspectives in many different design environments (virtual, augmented, real).

Stage 3: Personalized Education

- Goal is to create not just competent engineers, but competent designers and managers of complex adaptive systems – the engineer as leader.
- Reconceptualize students as active nodes in complex cognitive systems, in addition to Cartesian individual entities
- Students and professors are both learners; each brings different information to learning process
  - Thus, students help design learning spaces
  - Choose professors willing to partner with students
  - Professor changes from delivering information to coaching professional competence

Personalized Education: First Steps

- Create new institution structured around personalized education
  - Physical location may be desirable, at least at beginning of program, to provide coherence and ensure close communication
  - Could be co-located with existing university, or greenfield (each plan has advantages and disadvantages)
- Multiple participating universities, businesses and other institutions
- The one way flow of authority and information from professor to student replaced by mutual learning (students know far more about their world than the professors ever will)
- Students and professors both “turn over” – no tenure
- Commitment to freshest technology – graduating students should be valuable in part because they understand shape of technological frontier
- Ethics component to all education – identifying questions, not proposing prepackaged answers

“He, only, merits freedom
and existence
Who wins them each day
anew.”

Goethe, *Faust*