

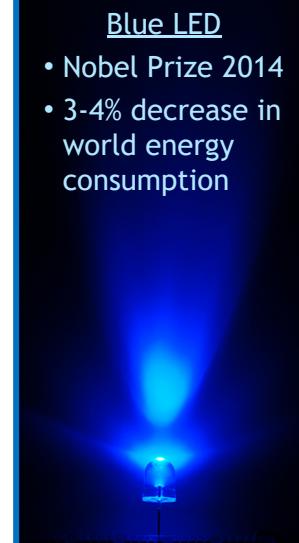


CREATIVITY IN SCIENCE & ENGINEERING: FROM THE HUMAN TO THE ARTIFICIAL

The common wisdom of a society of agents is provisional and sometimes false

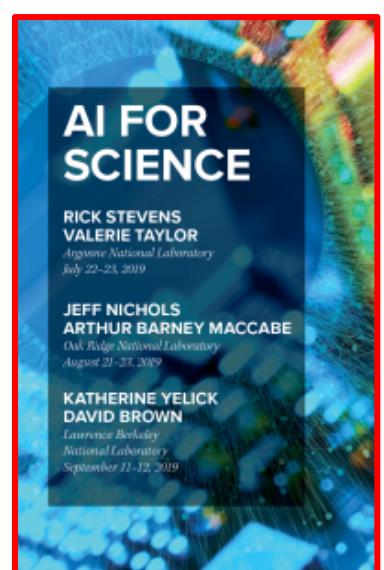
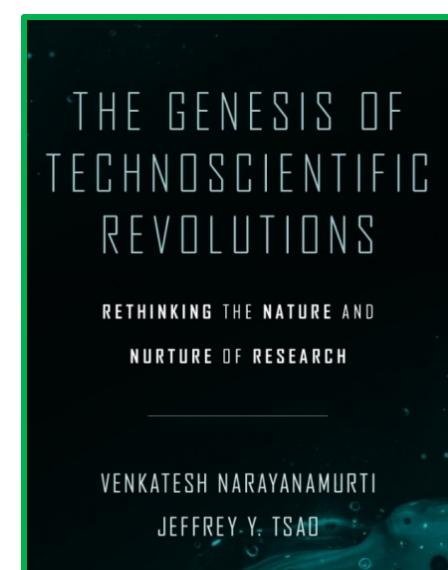
Creativity in science and engineering = overturning that provisional knowledge by individual agents who see and think differently

Blue LED
• Nobel Prize 2014
• 3-4% decrease in world energy consumption

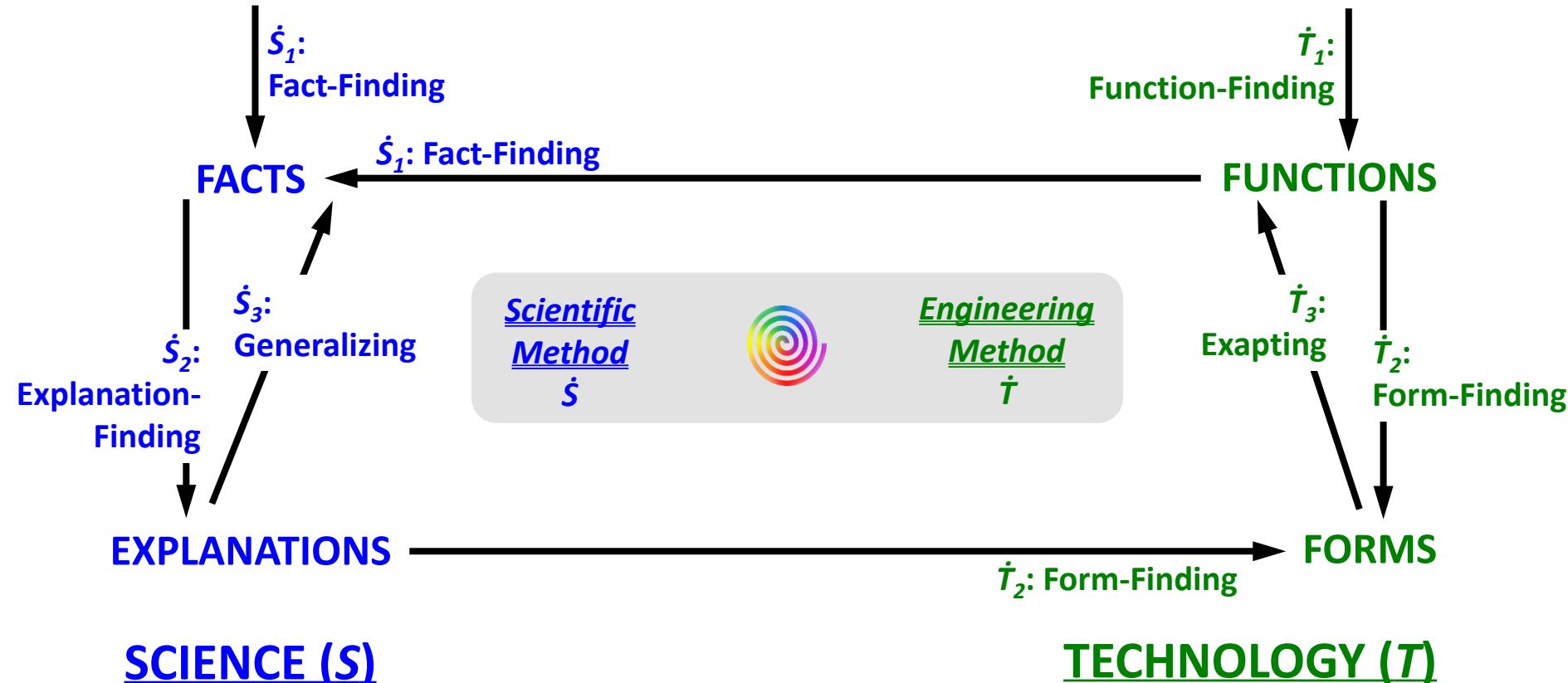


Outline

1. The Technoscientific Method
2. Creative Outcome
3. Surprise and Multi-Agent Coopetition
4. Coopetition and Neurosymbolic Knowledge Representations



1 The Technoscientific Method



The technoscientific method, as practiced by human intelligences, is *complete*: every mechanism is necessary, and there are no additional mechanisms



2 Creative Outcome = Useful Learning \approx Implausible Utility

The Simonton ansatz

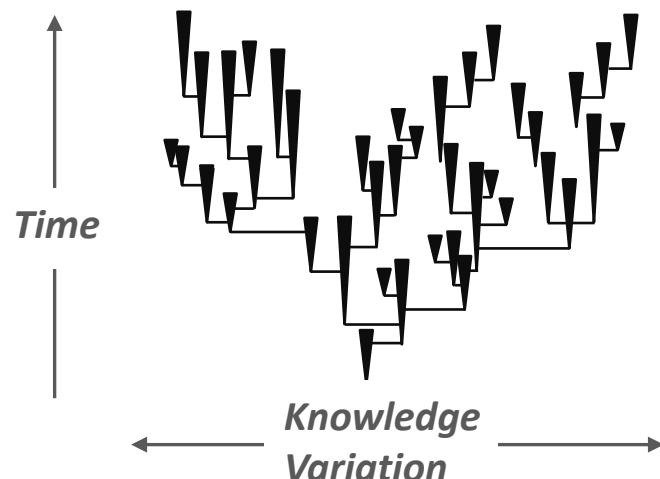
$$u \cdot l = u \cdot D_{KL}(p_{post}, p_{prior}) = u \cdot f(\Delta b, s) \approx u \cdot s^2$$

Kullback-Leibler divergence

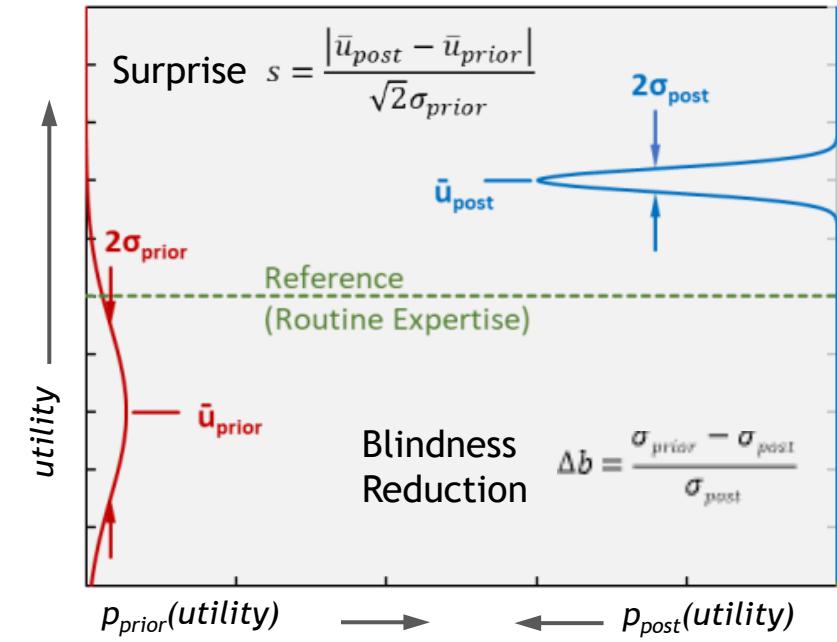
Not *novel* utility:
surprise, not novelty, is prime



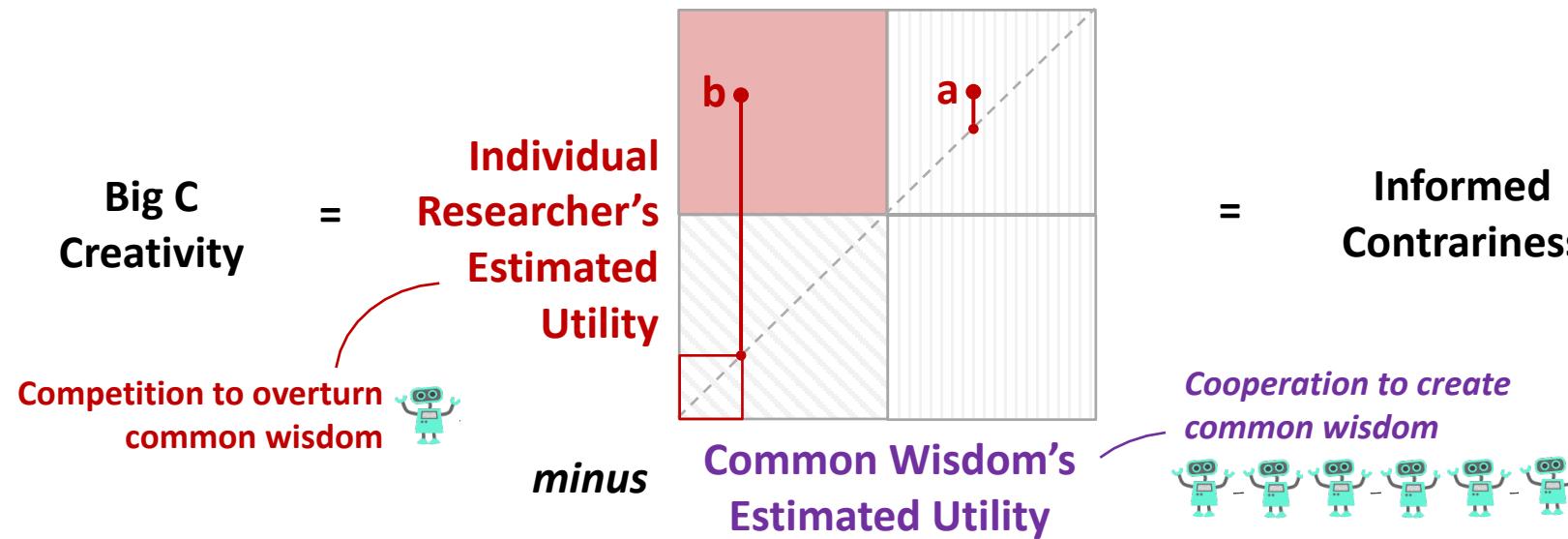
Not *more-certain* utility:
 Δb and s play different roles in evolution by punctuated equilibria



Guessed utilities of potential nugget of knowledge before and after test



3 Surprise and Multi-Agent Coopetition



	Informed contrarian	Informed contrarian's implausible utility	Societal common wisdom overturned
Fact	Galileo	Jupiter has moons	Earth exceptionalism
Explanation	Einstein	Special relativity	Time and space are independent
Function	Jobs	iPhone	No one will pay \$500 for a phone
Form	Wright Bros	Airplane	Heavier-than-air flight is impossible

Tell me something that's true that almost nobody agrees with
-- Peter Thiel

4 Neurosymbolic Knowledge Representations

Both necessary but for different purposes



Symbolic (S&T):

key to accumulation of common wisdom

Chalkboard content includes:

- Coordinate geometry: $y = a(x-b)^2 + c$, $V = \frac{4}{3}\pi r^3$, $SA = 4\pi r^2$, $AB = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2}$, $4^{\frac{3}{2}} = \sqrt[2]{4^3}$, $\log_c(\frac{a}{b}) = \log_c a - \log_c b$, $\pi \approx 3.14$, $\sin 30^\circ = \frac{1}{2}$, $\sin 45^\circ = \frac{1}{\sqrt{2}}$, $\sin 60^\circ = \frac{\sqrt{3}}{2}$, $SA = 2lw + 2(lh + wh)$.
- Trigonometry: $\cos(\frac{\pi}{6}) = \frac{\sqrt{3}}{2}$, $(\frac{a}{b})^c = \frac{a^c}{b^c}$, $a+b+c+d = 360^\circ$, $a+b+c = 180^\circ$, $8^2 + 6^2 = c^2$, $64 + 36 = c^2$, $100 = c^2$, $\sqrt{100} = \sqrt{c^2}$, $\pm 10 = c$.
- Calculus: $2x^2 + 3x + 4 = y$, $y = kx^2$, $k > 0$, $\log_a 1 = 0$, $\sum_{k=1}^n k = \frac{1}{2}n(n+1)$, $(x+y)^n = \sum_{k=0}^n {}^n C_k x^{n-k} y^k \sqrt{2}$.
- Geometry: A sphere, a cone, a cylinder, and a trapezoid.
- Algebra: $f(-x) = a(-x) + b = -(ax - b)$, $a^b a^c = a^{b+c}$, $\sin^2 y + \cos^2 y = 1$, $(a-b-c)^2 = a^2 + b^2 + c^2 - 2ab + 2bc - 2ca$, $\frac{x}{x+2} - \frac{8}{x+6} = \frac{16}{x^2 + 8x + 6}$, $c^2 = a^2 + b^2$, $\tan 60^\circ = \sqrt{3}$.

Neuro (S&T):

key to surprise to common wisdom

Explain the Aha ← → *Instinctivize the Symbolic*



- Formal (Polanyi), Logical, Reductionist: Explanatory
- Teachable and Cumulative
- Think Slow (System 2), Compute Intensive
- Newton: “If I have seen further it is by standing on the shoulders of Giants.”

- Tacit (Polanyi), Recognitional, Holistic
- Underlies Analogical Reasoning
- Think Fast (System 1), Compute Efficient
- Einstein: “Imagination is everything. It is the preview of life’s coming attractions.”

Take-Aways



1. The technoscientific method is not mysterious, so how human agents execute it should be translatable to how artificial agents might execute it
2. Creativity in science and engineering is also not mysterious, its essence is surprise and implausible utility.
3. Implausible utility is also not mysterious, it's just a multi-agent coopetition game: agents cooperating to create common wisdom, while competing to surprise that common wisdom
4. Different knowledge representations may be necessary: symbolic for accumulating common wisdom; and connectionist for going beyond common wisdom.