AI in Health

Research Promises, Education Perils & Clinical Practice Impact

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Slides available online
Google "*SOCR News*"

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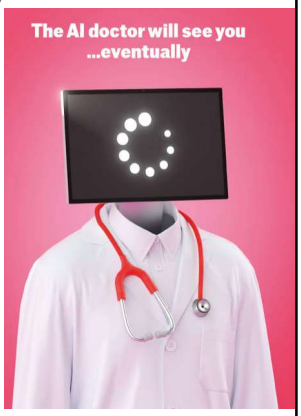
Outline

- ❑ Duality of Evidence-based Scientific Discovery
- ❑ What is AI and why is it relevant in health?
- ❑ AI Provenance
- ❑ Present AI status-quo
- ❑ Future R&D promises & Education perils
- ❑ Case-Studies
  - ❑ Pressure Injury Prediction
  - ❑ Aging – Normal Cognition & Dementia
- ❑ AI Spacekime Analytics



Economist, Mar 30, 2024

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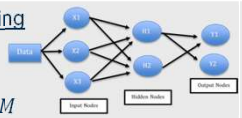
Duality of Evidence-based Scientific Discovery

experimental → theoretical → computational → data sciences

Mapping *Examples*	Analysis Observables/Data → Compact Models	Synthesis Compact Models → (simulated, actionable info)
1. *Lossless* Math Transforms	(A.1.1) Linear transform, $L: V \to W$, e.g., *2D rigid body* $L = \begin{pmatrix} \cos\theta & -\sin\theta \\ \sin\theta & \cos\theta \end{pmatrix} : \mathbb{R}^2 \xrightarrow{rotation} \mathbb{R}^2$ (A.1.2) Fourier transform: $\hat{f}(\omega) = \int_{-\infty}^{\infty} f(x) e^{-i2\pi\omega x} dx$	(S.1.1) Inverse linear transform, $L^{-1}: W \to V$, e.g., $L^{-1} = \begin{pmatrix} \cos\theta & \sin\theta \\ -\sin\theta & \cos\theta \end{pmatrix} : \mathbb{R}^2 \xrightarrow{rotation} \mathbb{R}^2, \quad LL^{-1} \equiv \mathbb{I}$ (S.1.2) Inverse Fourier (IFT): $f(x) = \int_{-\infty}^{\infty} \hat{f}(\omega) e^{i2\pi\omega x} d\omega$
2. DNA	(A.2.1) DNA Packing in Chromatin Fiber Chromosomes contain enormously long linear DNA molecules associated with proteins that fold and pack the fine DNA double helix into a *tight compact structure*	(S.2.1) DNA Unpacking The process of unfolding the DNA from the chromosome to support the processes of gene expression, DNA replication, and DNA repair
3. *Lossy* Data/Stats Science	(A.3.1) Info Compression, e.g., linear models $Y = 4582.70 + 212.29\,X$ $Data \xrightarrow{assum} Model$ 	(S.3.1) Information Inflation, Simulation & Generation, e.g., forecasting, regression, interpolation, extrapolation (*predict* & *classify new data*): $Input \xrightarrow{mod} Output$
4. Artificial & Augmented Intelligence	(A.4.1) Building, Fitting & Training large foundational, generative & deep network AI models $Data \xrightarrow{human+infrastructure} GAIM$ 	(S.4.1) Generative Artificial Intelligence Modeling (GAIM) $Human\ Prompt \xrightarrow{GAIM} Result$ 

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What is AI? Why is it relevant in Health?

- AI ≈ synthetic mockup of common human intelligence tasks & processes
- AI *manifests* as applications, algorithms, or interfaces built as services, tools, apps, integrated computing environments, or decision-support systems
- AI is predicated on
  - Massive amounts of complex, heterogeneous, time-varying & multi-source data (Big Data)
  - Integrated computational systems (elastic Clouds) with effective human & machine interfaces
  - Efficient data management, aggregation, harmonization, augmentation, processing & Viz
  - Sophisticated techniques (methods) and advanced algorithms (software)
- Relevance in Healthcare (PMC8437645, PMID36626192, PMC4795481, PMC8550565, PMC7031195, ISBN 978-3-031-17482-7, ...)
  - More biomed data are created daily than can be humanly processed
  - Many opportunities exist to optimize existing processes (e.g., process time-reductions, cost-efficiencies, lower environmental-impact, improve clinical outcomes, strengthen education & training, enhance health-equity, expedite global health advances)

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AI Provenance

- ❑ Ancient Greek artisans designed the bronze Greek mythology giant Talos to guard the island of Crete by imaginatively throwing boulders at hypothetically invading ships (300 BC)
- ❑ Al-Jazari's programmable automata, mechanical devices (1206 AD)
- ❑ Leibniz & Descartes suggested that all rational thought could be made as systematic as algebra or geometry & reduced to mechanical calculation (late 1680's AD)

- ❑ Invention of a programmable digital computer (1940 AD), algorithmic machine abstraction of mathematical reasoning
- ❑ Turing Test (Alan Turing) – creating machines that think (1950 AD)
- ❑ "*Dartmouth Summer Research Project on Artificial Intelligence*" McCarthy (1955 AD)
- ❑ _____ AI Winter_____
- ❑ Deep Blue beat a reigning world chess champion Garry Kasparov (1997 AD)
- ❑ Deep Learning Nets, GPU computing (2012+) ➔ OpenAI (2022) ➔ SOCR AI Bot (2023), …

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Present AI status-quo

- Latest AI can
  (1) Synthetically simulate intelligent text responses prompted by human text/voice. Write papers, bios, grants, clinical notes, prognoses, speeches, reviews, summaries, etc.
  (2) Simulate realistic 2D brain images of specific clinical phenotypes and image-modalities
  (3) Write software code driven by simple commands, verbal descriptions, or human language
  (4) Solve theoretical problems (e.g., prove math theorems) & applied challenges (e.g., support Augmented Practitioners)
  (5) AI systems have polymathic ability to *reason* about high-dimensional problems (humans are monomathic)
- AI relevance
  (1) Students are already using AI Chat Bots for completing homework assignments & conducting R&D
  (2) Researchers are using crowdsourcing and AI to research, discover & derive theoretical results
  (3) Practitioners are utilizing AI in clinical applications (e.g., tissue-cell classification, reading MRIs)
  (4) Stakeholders are demanding rapid Dx, optimal Tx plans, lower costs, process efficiencies, improved population outcomes
- Most people use/encounter AI technology in many aspects of their daily experiences, but few have formal training in unbiased AI design/development, ethical-use & reliable-utilization
- *Difficult tasks*: AI design, training, tuning & validation (time, resource & infrastructure intensive)
- *Expeditious tasks*: AI applications, testing, forecasting, classification & clustering

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Future AI promises & potential perils

❑ Promises
- Radically transform formal education, informal learning & vocational training
- Catapult scientific discoveries (theoretical, experimental, computational & data sciences)
- Democratize access to knowledge & level certain playing fields
- Augment many decision-making processes & automate various tedious tasks

❑ Potential Perils
- May induce rapid AI-divide (accessibility imbalance between haves & have-nots)
- Prevent potential training biases & balance AI precision & variability (tradeoffs)
- Instead of aiming to ban, stifle & control AI immersion, we need to embrace it, manage it, and use it for "*social & environmental good*" –
  - Recall how airplanes became the safest mode of transport, safer than cars, bikes & running shoes
- Yet, "…*the ultimate AI is just about to arrive* …" (always 10 years in the future)

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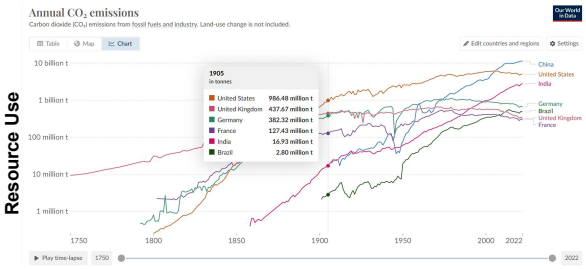
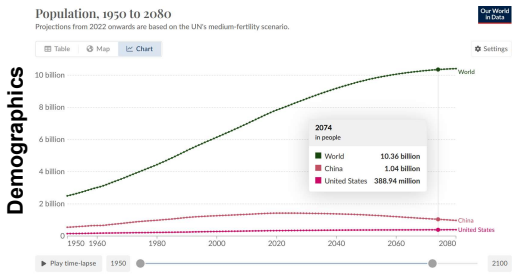
What drives AI into the Stratosphere?

○ Forward-Looking Human Nature (Demands)
- 𝔼 ↑ (expected) resource utilization demands per capita (energy, consumables, natural resources)
- Pursuits of productivity growth & better experiences for everyone, everywhere, all at once

○ Demographic Changes
- *Rich-World*: Working-age population is expected to peak in this decade (by 2030) throughout the Organization for Economic Co-operation & Development (OECD) Countries
- *China*: Working population peaked in 2015

○ Relentless Digitalization & Virtualization of most Human Experiences





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Personal Academic Perspective on Future AI

Rather than describing one immutable technology or a specific computational platform, contemporary *generative-AI refers to a very broad, amorphous, rapidly evolving, and highly potent technology*.

Instead of trying to restrict, control, delay, or subdue generative-AI proliferation, there are at least three important directions the academic community can focus on:

- **Train-the-trainer** – the first impressions and the most knowledge Gen-Z learners gain about generative-AI appear to be from random sources (e.g., TikTok videos). Training faculty/instructors about the technical pillars of generative-AI, its enormous promises and potential pitfalls, will go a long way towards establishing a pedagogically-sound, trustworthy, consistent, and responsible faculty-led student-training in ethical AI development and use.
- **Level-the-playing-field** – presently, there is a huge AI-divide between the haves and have-nots. Some students have the means to acquire access to extremely powerful generative-AI, or may have access to such services via specialized lab-resources, whereas others will not.
- **Endorse the free and open sharing of generative-AI resources** (data, algorithms, models, services). Think about the enormous societal benefits and productivity gains realized over the past few decades from the design, implementation, sharing and community support for the open infrastructure underpinning the world wide web. With strong academic support of free and open generative-AI, this impact may increase exponentially. Increase *engagement in core AI design & dev*.

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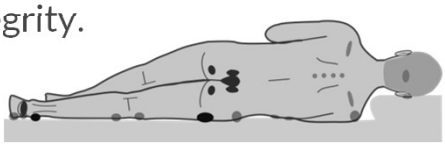
Case-Study: *Pressure Injury*

- ❑ Pressure injuries (PIs), or pressure ulcers, are caused by stress on the skin (the largest organ in the human body) that compromise its integrity.



- ❑ PIs may be acquired during patient hospitalization, which leads to substantial burden, patient suffering, increased medical costs, and co-morbidities.

- ❑ This work utilizes advanced AI and Data Science to interrogate large, incongruent, incomplete, heterogeneous, and time-varying data of hospital-acquired PIs.

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Investigative Team, Data & Pubs

- Clinical Team
  - Dana Tschannen, PhD
  - Chris Anderson, PhD
- Data Science & AI Team
  - Zerihun Bekele, PhD
  - Yongkai Qiu, MS
  - Ivo Dinov, PhD
- Data: EHR, n=20K patients, p=200+ features
- Pub: DOI: 10.1186/s12911-021-01608-5 | PMC8406893




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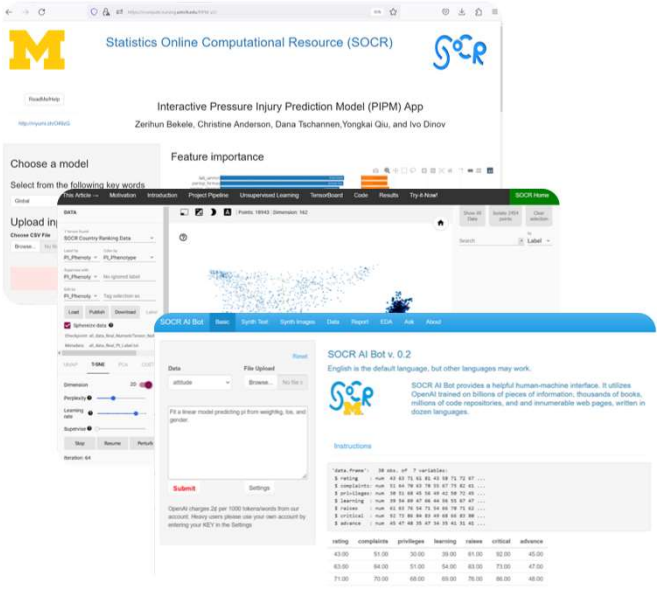
AI Model Demos

- Interactive Pressure Injury Prediction Model (PIPM) App (RShiny)
- Visual Exploratory Data Analytics (SOCR TB Webapp)
- Quantitative AI-driven Analytics (SOCR AI Bot)



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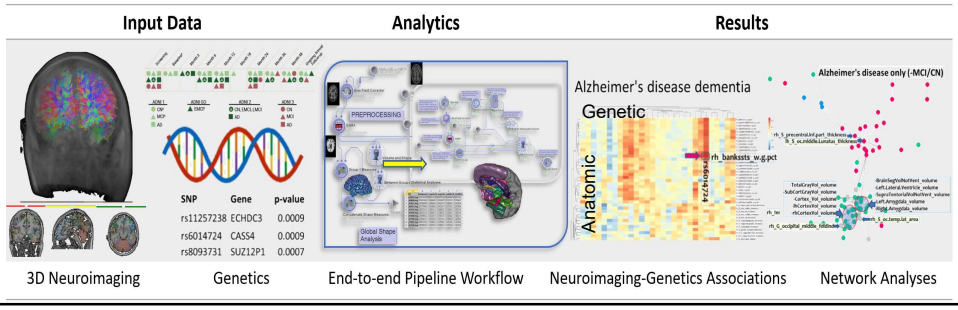
Case-Study: *Normal & Pathological Aging*

- ❑ **Problem** – Model age-related cognition in 3 participant cohorts – (1) *Asymptomatic Controls*, *(2) Mild Cognitive Impairment*, (3) *Dementia Patients*
- ❑ **Evidence** (data types) – *clinical* evaluation (tables), *genetic* information (sequences), and 3D/4D *neuroimaging* (spatiotemporal)
- ❑ **Status-quo** of clinical care – independent analysis of the 3 different data types followed by inference pooling
- ❑ **Challenge** – introduce new holistic Health-Analytics Protocol for AI modeling, Dx, classification, and Tx plan using the joint distribution of the entire observed data.

Refs: https://www.socr.umich.edu/people/dinov/publications.html | **Apps**: https://socr.umich.edu/HTML5/ | **Pubs**: DOI: 10.1111/cns.14073



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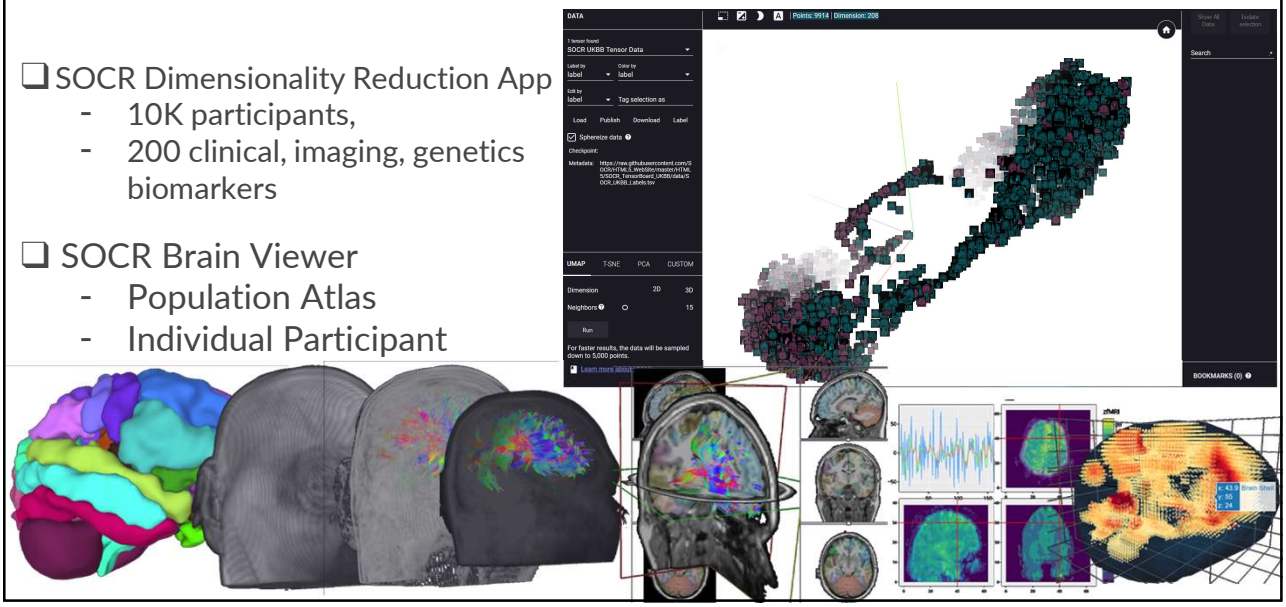
(Brain) Aging Demos

- ❑ SOCR Dimensionality Reduction App
  - 10K participants,
  - 200 clinical, imaging, genetics biomarkers
- ❑ SOCR Brain Viewer
  - Population Atlas
  - Individual Participant



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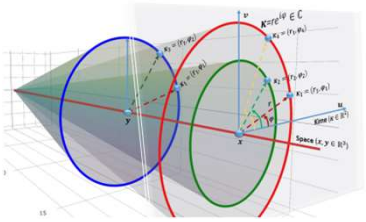
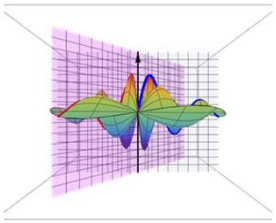
Cutting-edge Science – *AI & Spacekime Analytics*

Rationale for Time → Kime Extension

Wesson (2004, 2010), Dinov & Velev (2021), Wang et al. (2022), Zhang et al. (2023), Dinov & Shen (2024)





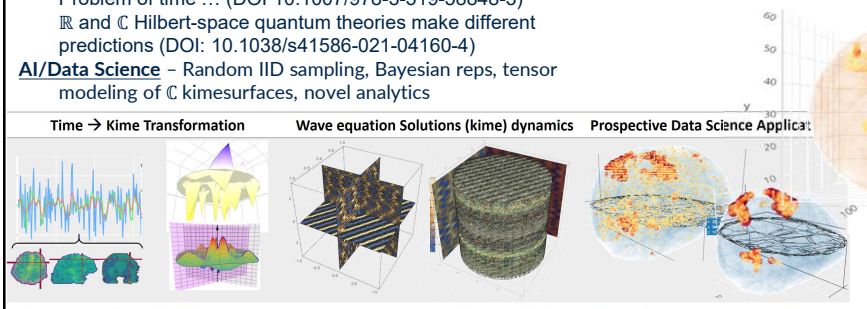
Math – $Time$ is a special case of *kime*, $\kappa = |\kappa|e^{i\varphi}$ where $\varphi = 0$

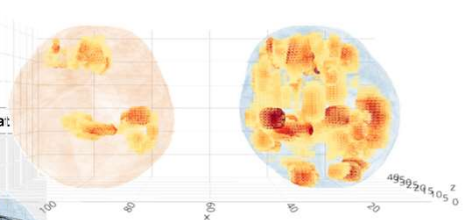
- **Time ($\mathbb{R}^+$) is a subgroup of the multiplicative Reals group**
- **Whereas kime ($\mathbb{C}$) is an algebraically *closed prime field* that naturally extends time**
- *Time* is ordered but *kime* is not!
- Kime ($\mathbb{C}$) represents the smallest natural extension of time, as a complete filed that agrees with time

Physics –

- Problem of time … (DOI 10.1007/978-3-319-58848-3)
- $\mathbb{R}$ and $\mathbb{C}$ Hilbert-space quantum theories make different predictions (DOI: 10.1038/s41586-021-04160-4)

AI/Data Science – Random IID sampling, Bayesian reps, tensor modeling of $\mathbb{C}$ kimesurfaces, novel analytics





Voxel-based TLM/Analysis
Corrected (left) vs. Raw (right)
https://tciu.predictive.space/

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Mapping Time-series→ Kime-surfaces

Apply the ILT ($\mathcal{L}^{-1}$) to reconstruct a time-series, $\hat{f}(t) = \mathcal{L}^{-1}(F)(t)$:

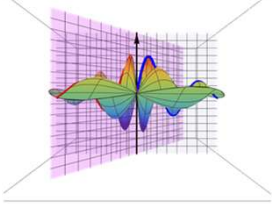
$$F(z) = \mathcal{L}(f) = \underbrace{\frac{1}{z+1}}_{F_1(z)=\mathcal{L}(f_1(t)=e^{-t})} + \underbrace{\frac{1}{z^2+1}}_{F_2(z)=\mathcal{L}(f_2(t)=\sin(t))} \times \underbrace{\frac{z}{z^2+1}}_{F_3(z)=\mathcal{L}(f_3(t)=\cos(t))} + \underbrace{\frac{1}{z^2}}_{F_4(z)=\mathcal{L}(f_4(t)=t)},$$

$$f(t) = \mathcal{L}^{-1}(F) = \mathcal{L}^{-1}(F_1 + F_2 \times F_3 + F_4)) = \mathcal{L}^{-1}(F_1) + \left(\underbrace{\mathcal{L}^{-1}(F_2) * \mathcal{L}^{-1}(F_3)}_{\text{convolution}}\right)(t) + \mathcal{L}^{-1}(F_4) =$$

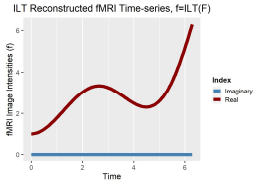
$$\mathcal{L}^{-1}(\mathcal{L}(f_1))(t) + \left(\mathcal{L}^{-1}(\mathcal{L}(f_2)) * \mathcal{L}^{-1}(\mathcal{L}(f_3))\right)(t) + \mathcal{L}^{-1}(\mathcal{L}(f_4))(t),$$

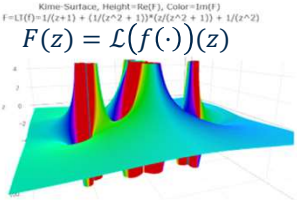
$$f(t) = \mathcal{L}^{-1}(F)(t) = f_1(t) + (f_2 * f_3)(t) + f_4(t) = e^{-t} + \int_0^t \sin(\tau) \times \cos(t-\tau)d\tau + t = t + e^{-t} + \frac{t\sin(t)}{2}.$$

Repeated Longitudinal Data Sampling

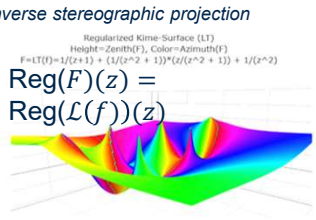


$f(t) = \mathcal{L}^{-1}(\mathcal{L}(f))(t)$





Inverse stereographic projection



Shen et al., 2024 | Zhang et al., 2022 | Dinov & Velev (2021)

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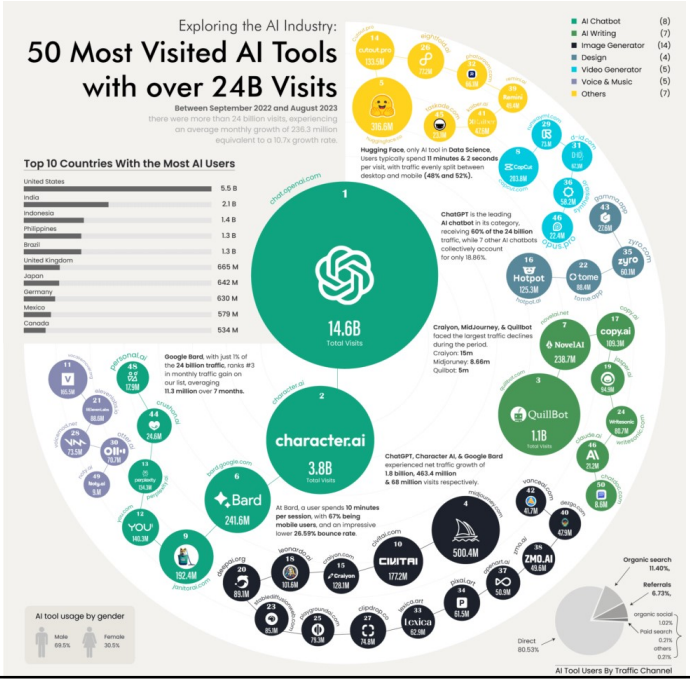

writerbuddy.ai

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So what? Highly subjective speculations …

- Unscientific Poll – **AI-driven cars are safer?** (1) Yes; (2) No; (3) Unsure
- What are the expected *personal*, *communal*, and *humanity* implications?
- What can we individually/collectively do to respond/incent AI advances?
- What is likely to immerge in the next decade?
- AI cost–benefit analysis? *Strengths*, *Weaknesses*, *Opportunities* & *Threats*?
- Short, mid-term & long-term impacts?
- What about AI self-reproduction & evolution through natural selection?

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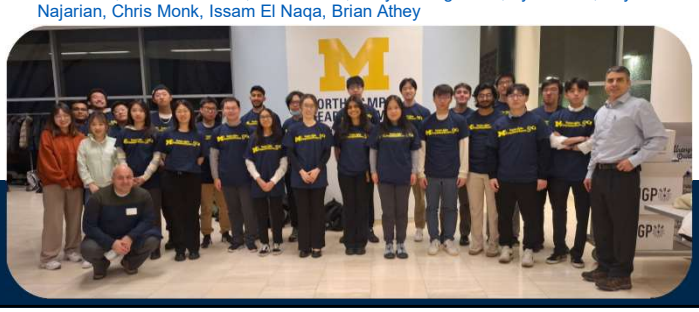
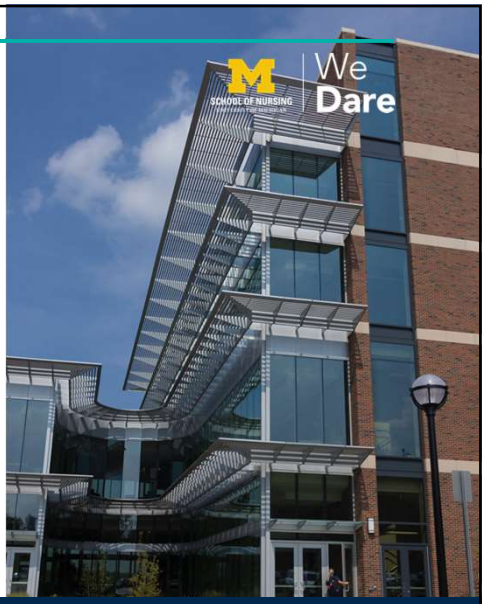
Open Science Community

SOCR AI Bot is powered by R/RStudio/Posit, ChatGPT, OpenAI, RTutor & CRAN

Collaborators

- SOCR: Zerihun Bekele, Milen Velev, Yueyang Shen, Kaiming Cheng, Shihang Li, Daxuan Deng, Zijing Li, Yongkai Qiu, Zhe Yin, Yufei Yang, Yuxin Wang, Rongqian Zhang, Yuyao Liu, Yupeng Zhang, Yunjie Guo, Simeone Marino
- UMSN/DCMB/MIDAS/MCAIM Centers: Dana Tschannen, Chris Anderson, Michelle Aebersold, Maureen Sartor, Josh Welch, Maryam Bagherian, Lydia Bieri, Kayvan Najarian, Chris Monk, Issam El Naqa, Brian Athey





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