AI Bio-Innovations in Health & Neurooncology

Research Promises, Learning Opportunities & Clinical Practice Impact

Ivo D. Dinov, University of Michigan
Director, UM Research Cores – Bioinformatics, Statistics, SOCR Analytics
https://www.socr.umich.edu

Slides available online
Google search for "SOCR News"

1

Outline

- ❑ What is AI and why is it relevant in biomedicine & health?
- ❑ AI Provenance & Status-quo
- ❑ Future R&D promises & Education perils
- ❑ Spacekime Analytics – *new math foundation for complex time (kime) representation of repeated* $\mathbb{R}^3 \times \mathbb{R}^+$ *measurements (data)*
- ❑ Case-Studies – *integrated experimental, theoretical, computational & data sciences*
  - ❑ Individual Pediatric Glioma: early AI detection, geno-pheno-typing, holistic modeling, prognosis, dynamic clinical decision support
  - ❑ Aging Cohort Study: Normal & Pathological Aging

2

What is AI? Why is it relevant in Health?

- AI represents a synthetic mockup of common human intelligence tasks & processes.
- AI models create virtualized states, processes, actors, actions, and responses. AI manifests as applications, algorithms, or interfaces built as services, tools, apps, or integrated computing environments. AI services attempt to disrupt current protocols, upscale process efficiencies, optimize resources (time, manpower, energy, moneys), and augment human decision-making
- 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 to enhance healthcare than can be humanly processed
  - Significant opportunities exist to optimize existing processes (e.g., process time-reductions, cost-efficiencies, lower environmental-impacts, improved clinical outcomes, strengthen education & training, enhanced health-equity, expedite global health advances)

3

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)
- The Persian scholar 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)
- Many historic accounts attest to early attempts to *imagine* artificial intelligence
  - Myths, fairytales, stories and rumors of inanimate objects endowed with intelligence or consciousness by master craftsmen, e.g., Frankenstein (1818 AD), Pinocchio (1883 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 Networks, GPU computing (2012+ AD)

4

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

- AI relevance
  - Students are already using AI Chat Bots for completing homework assignments
  - Researchers are using crowdsourcing and AI to derive theoretical results
  - Practitioners are utilizing AI in clinical applications (e.g., tissue-cell classification, reading MRIs)
  - Stakeholders are demanding rapid Dx, optimal Tx plans, low costs, process efficiencies, improved population outcomes, and better policies

- Most people use/encounter AI technology in many aspects of their daily experiences, but few have formal training in AI ethical-use & reliable-development

- *Difficult tasks*: AI design, training, tuning & validation (time, resource & infrastructure intensive)
- *Expeditious tasks*: AI applications, testing, forecasting, classification & clustering

5

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

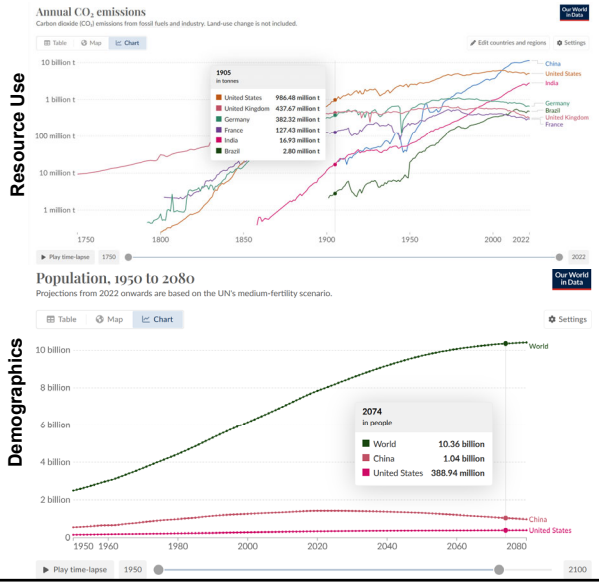
---

- Potential Perils
  - Potentially rapid AI-divide (accessibility imbalance between haves & have-nots)
  - Potentials for 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
  - Continuity in "…*the ultimate AI is just about to arrive* …" (always 10 years in the future)

6

What drives AI into the Stratosphere?

- Forward-Looking Human Nature (Demands)
  - Resource utilization demands per capita (energy, consumables, natural resources) $\mathbb{E} \uparrow$ (expected)
  - Productivity growth pursuits & 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



https://ourworldindata.org/population-growth

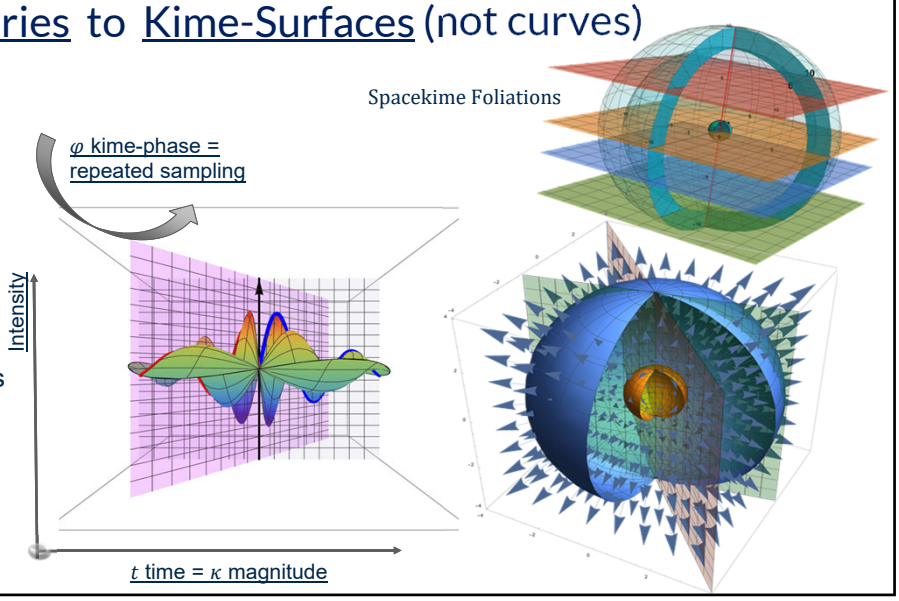
7

Complex-time (Kime) Representation

- From Time-Series to Kime-Surfaces (not curves)

In the 5D spacekime manifold, time-series curves extend to kime-series, i.e., surfaces parameterized by kime-magnitude (t) and the kime-phase (φ).

Kime-phase aggregating operators that can be used to transform standard time-series curves to spacekime kime-surfaces, which can be modeled, interpreted, and predicted using advanced spacekime analytics.

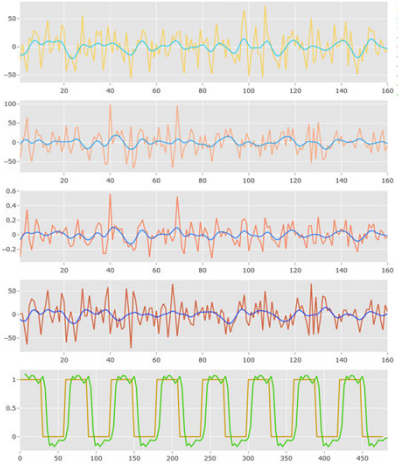


8

Complex-time (Kime) & Spacekime Analytics

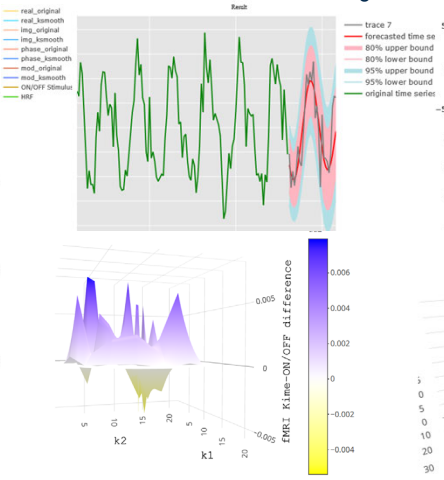
- Complex-valued finger tapping fMRI ($64x * 64y * 40z * 160t$)

Raw task-specific fMRI time-series



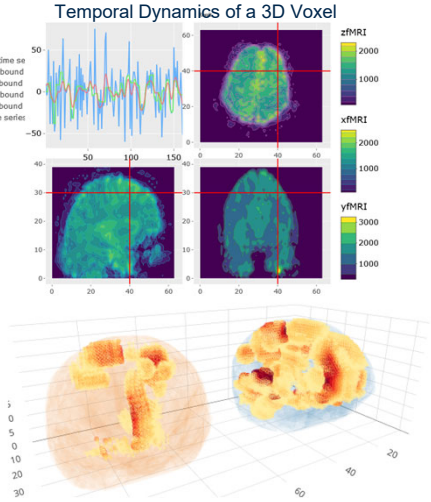
Dinov & Velev (2021)

fMRI time-series forecasting



On-Off fMRI time-series to Kimesurface

Temporal Dynamics of a 3D Voxel



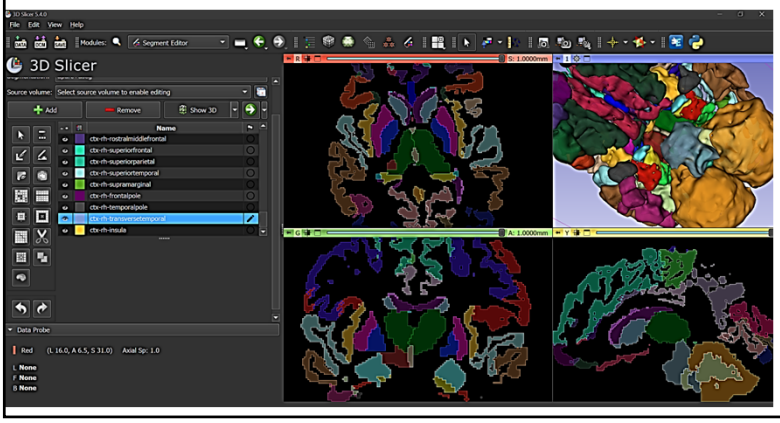
Level-1 and Level-2 3D Stat Significance Maps

9

Individual Study: *Pediatric Brain Cancer*

- In kids, thalamic pediatric high-grade gliomas (HGGs) accounts for 13% of child HGGs and 5% of all pediatric brain tumors, low gliomas (LGGs) tend to be more common

https://doi.org/10.1093%2Fneuonc%2Fnor045 | https://doi.org/10.3390%2Fgenes13040624



3D ROI Differences (Follow-up vs. Baseline)

Structure	Region ID		Raw Differences		Normal Brain Atlas Statistics			
ROI Name	Ind	Seg ID	# Vox	Vol mm^3	norm Mean	Norm StdDev	norm Min	norm Max
Left-Lateral-Ventricle	1	4	0	-0.1	15.94	16.37	0	87
Left-Inf-Lat-Vent	2	5	0	0.6	41.61	15.28	12	80
Left-Cerebellum-White-Matter	3	7	0	-0.2	81.48	10.84	29	130
Left-Cerebellum-Cortex	4	8	-29	-29	59.33	14.39	14	180
Left-Thalamus	5	10	0	1.5	74.92	11.55	25	168
Left-Caudate	6	11	0	-1.1	69.50	10.94	18	118
...	...	...	...	...	...	...	...	...

Goal: Early AI detection, geno-pheno-typing, holistic modeling, prognosis, dynamic clinical decision support

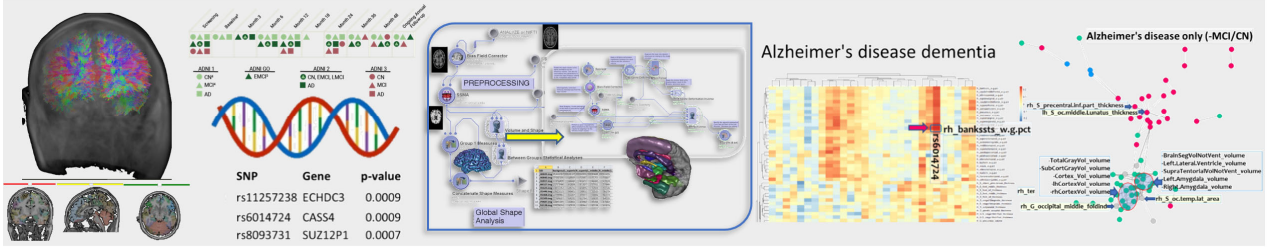
10

Cohort Study: *Normal & Pathological Aging*

- ❑ **Problem** – Model age-related cognition in 3 participant cohorts – (1) *Asymptomatic Controls*, *(2) Mild Cognitive Impairment*, (3) *Dementia*
- ❑ **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/

Input Data | **Analytics** | **Results**

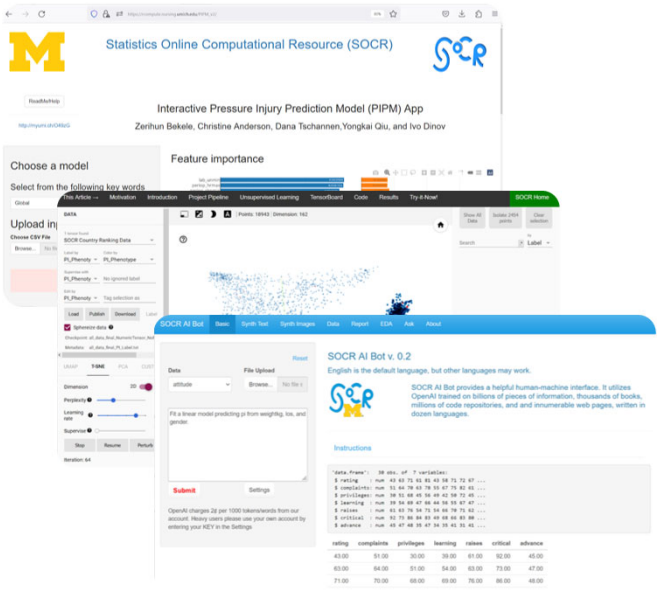


3D Neuroimaging | Genetics | End-to-end Pipeline Workflow | Neuroimaging-Genetics Associations | Network Analyses

11

Live SOCR AI Webapps

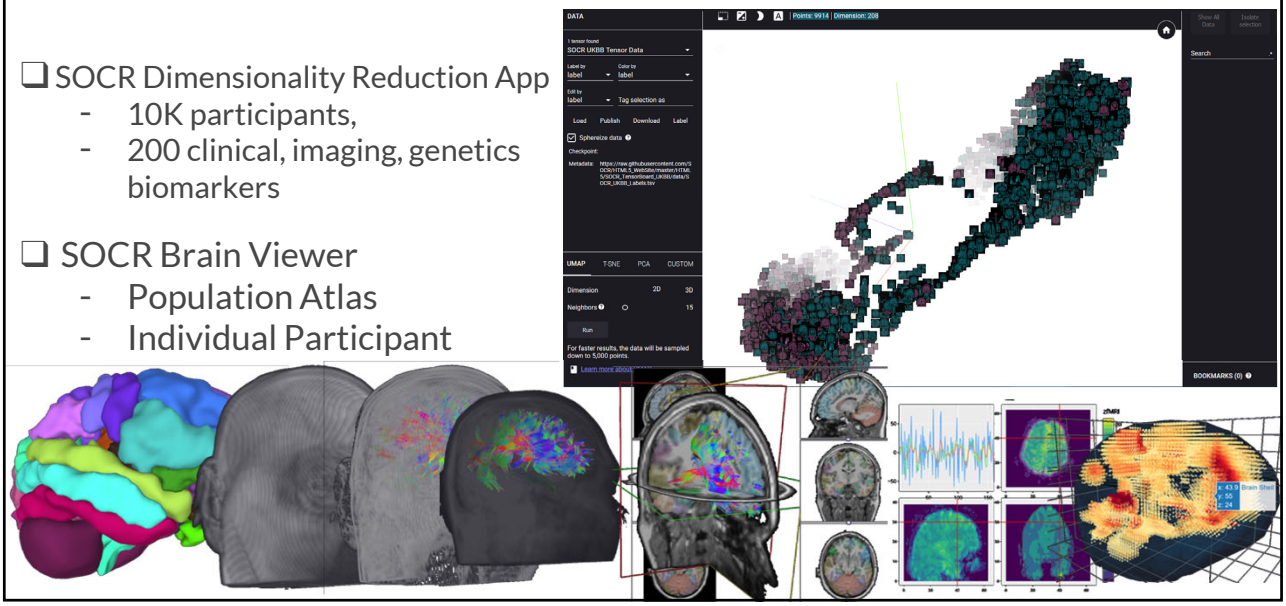
- ❑ Interactive Pressure Injury Prediction Model (PIPM) App (RShiny)
- ❑ Visual Exploratory Data Analytics (SOCR Tensorboard Webapp)
- ❑ Quantitative AI-driven Analytics (SOCR AI Bot)



12

Neuroscience Demos

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



13

So what? Highly subjective speculations …

- (Unscientific) Audience Poll – **Are AI-driven cars safer?** (1) Yes; (2) No; (3) Unsure
- Personal implications for each of us individually? Societally? Anthropologically?
- What can we individually/collectively do to respond to, incent, or halt AI advances?
- Strike against AI immersion, protecting *good-paying*, *manufacturing*, *white-collar* jobs?
- What is likely to immerge in the next decade?
- AI cost–benefit analysis?
- Short, mid-term & long-term impacts?
- What about AI self-reproduction? AI evolution through "natural selection"?

14

Acknowledgments

Funding

NIH: UL1 TR002240, R01 CA233487, R01 MH121079, R01 MH126137, T32 GM141746
NSF: 1916425, 1734853, 1636840, 1416953, 0716055, 1023115

Open Science Community

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

Collaborators

- SOCR: Yueyang Shen, Kaiming Cheng, Zerihun Bekele, Milen Velev, Shihang Li, Daxuan Deng, Zijing Li, Yongkai Qiu, Zhe Yin, Yufei Yang, Yuxin Wang, Rongqian Zhang, Yuyao Liu, Yupeng Zhang, Yunjie Guo, Jun Chen, 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, Gil Omenn, …

15

Available AI Resources

- SOCR Motto – *"It's Online & Freely Accessible, Therefore it Exists!"*
- Pubs: https://socr.umich.edu/people/dinov/publications.html
- GitHub: https://github.com/SOCR/PressureInjuryPrediction
- PIPM App: https://rcompute.nursing.umich.edu/PIPM_v2/
- AI Apps: https://socr.umich.edu/HTML5/
- SOCR AI Bot: https://rcompute.nursing.umich.edu/SOCR_AI_Bot/
- Demos: https://DSPA2.predictive.space (Appendix 9 – OpenAI Synth Text Img & Code)
- Tutorials: https://TCIU.predictive.space & https://SpaceKime.org
- Websites: https://nursing.umich.edu & https://socr.umich.edu

16