RESEARCH ON TAP Artificial Intelligence for Biomedicine and Healthcare

Wednesday, November 9, 2022

bu.edu/research/events



Agenda

- Welcome Remarks
- Presentations
 - Yannis Paschalidis
 - Margrit Betke
 - Mark Kramer
 - Kayhan Batmanghelich
 - Vijaya B. Kolachalama
 - Adriana Tomic
 - Daniel Segrè
 - Ji-Xin Cheng
 - Emma Lejeune
 - Lei Tian
- Closing Remarks



Al for (Good) Health

Yannis Paschalidis

Distinguished Professor of Engineering (Electrical & Computer, Systems, and Biomedical) Founding Professor of Computing & Data Sciences Director, Hariri Institute



Rafik B. Hariri Institute for Computing and Computational Science & Engineering





COVID and **Preventing** the next Pandemic

Home People Research Publications Courses Ne

Paschalidis NOC Lab

COVID Calculators



We examined records of 2,566 consecutive COVID-19 patients aftive Masschusetts hospitals and sought to predict level-of-care requirements based on cinical and laboratory data. Several classification methods were applied and compared against standard pneumonia severity scores. The need for hospitalization. (UC ucare, and mechanical ventilation were predicted with a validation accuracy of 895, 875, 861 685, respectively.) contrast, standard pneumonia severity scores activers respective accuracios et 73% and 74% for ICU care and ventilation. When predictions neurosco # the OL unetworthing predictions

are limited to patients with more complex disease, the accuracy of the ICU and ventilation prediction models achieved accuracy of 38% and 52%, respectively. Vial signs, age, BMI, dyspenea, and comotribilities were the most important predictors of hospitalization. Opacities on chest imaging, age, admission vial signs and symptoms, male gender, admission laboratory results, and diabetes were the most important risk factors for ICU admission and mechanical ventilation. The factors identified collectively form a signature of the novel COVID-19 disease.

Reference: The work is published in Boran Hao, Shahabeddin Sotudian, Taiyao Wang, Tingting Xu, Yang Hu, Apostolos Gaitandils, Kerry Breen, George C. Velmahos, and Ioannis Ch. Paschalidis, "Early prediction of level of care requirements in patients with COVID-19," eLife, 2020;9:e60519, doi: 10.7554/eLife.05519.



Predictive Models for Level-of-Care Requirements

- Worked with datasets from Wuhan, Mexico, Brazil, MGH-Brigham, BMC (n=900-113,000)
- Predicting Hospitalizations, ICU Admissions, Need for Ventilation, Mortality
- BMC cohort revealed role of Social Determinants of Health and Racial Biases

A multidisciplinary team from Hariri, CISE, CEID, NEIDL, and BTEC, working on an NSF-funded project to develop models that predict disease emergence and spread, and to devise pandemic mitigation strategies

BOSTON UNIVERSITY Hao et al., eLlfe, 2020; Hao et al., JAMIA, 2022; Yuan et al., Engineering, 2022; Wollenstein-Betech et al., Int. J. Med. Inform., 2020; Wollenstein-Betech et al., PLOS One, 2020; Wang et al., JMIR Med. Inform, 2020

Alzheimer's Disease & Dementia



- Most common form of dementia, > 5M in the US with AD (\$300B) → 14M by 2050 (\$1.1T)
 - Most clinical trials fail

Digital Biomarkers



Automated Cognitive Assessment Pipeline



- Leveraging Automated Speech Recognition (ASR) and Natural Language Processing (NLP)
- Does (almost) as well as clinicians (93% AUC)
- Visit <u>health-ai.bu.edu</u>



Amini et al., J. of AD, 2021; Amini et al., Alzheimer's & Dementia, 2022; Xue et al., Alzheimer's Res. & Therapy, 2021

Predictive and Prescriptive Modeling

Foundations and Trends® in Optimization 4:1–2

> Distributionally Robust Learning Ruidi Chen and Ioannis Ch. Paschalidis





Key Challenges in Health Applications

- Interpretability & Robustness
- Statistical ML & Optimization

Predictive Models of Pregnancy

- SPH PRESTO (Pregnancy Study Online) dataset
- elVF dataset

ESHRE 24hr Tweetutorial 1.045M Impressions 902 Tweets

Prescriptive Models for Hypertension

- Launching a BMC Pilot Study
- Al model to make personalized recommendations for Hypertension drugs



Yland et al., Human Reproduction, 2022; Xu et al., Scient. Reports, 2022 Boston University Office of Research

Network Optimization & Control Lab





COVID: Boran Hao, Yang Hu, Shahab Sotudian, Dr. Taiyao Wang, Dr. Salo Wollenstein-Betech, Dr. Tingting Xu, Zahra Zad & BU, MGH, BMC, Brazil, China

AD: Samad Amini, Boran Hao, Aman Gupta, Mengting Song, Lifu Zhang, Jingmei Wang, & Dr. Rhoda Au, Dr. Vijaya Kolachalama, Dr. Cody Karjadi at BUMC and FHS

Fertility: Zahra Zad, Dr. Taiyao Wang, Dr. Tingting Xu & Dr. Lauren Wise (SPH), Dr. Elizabeth Hatch (SPH), Dr. Shruthi Mahalingaiah (Harvard)

Hypertension: Yang Hu & Dr. Rebecca Mishuris (BMC), Dr. Nick Cordella (BMC)

Theory: Dr. Ruidi Chen

BOSTON university Yland et al., Human Reproduction, 2022; Xu et al., Scient. Reports, 2022 Boston University Office of Research

Al for Pediatric US Diagnosis, Al for Physical Therapy, Al for Post-Stroke Prognosis

Margrit Betke

Professor Department of Computer Science, CAS



AI to Interpret Ultrasound Videos for the Diagnosis of Pediatric Pneumonia in Limited Resource Settings (here Lusaka, Zambia)

Pneumonia is leading cause of death in children < 5 years worldwide with mortality 68% at 6 month

<u>Goal:</u>

Develop AI cell phone app for first-line health care workers to use mobile US device to image infants & diagnose and treat pneumonia.

Results:

Collected 12 videos/infant of 2 cohorts of 200 infants. Developed AI models for single image analysis. Low F1 score.

<u>Ongoing Work:</u> Developing AI model for US video analysis.



NIH R21 TW 011343-01, PI Gill

ExerciseCheck -Home-based Physical Therapy with AI

Results:

App for managing logistics. Initial experiments.

Ongoing Work:

Developing attention-based deep-learning model for 3D human pose tracking.





AI to Predict Response to Post-Stroke Rehabilitation

Stroke is a leading cause of severe and complex long-term disability. Aphasia affects approximately 1/3 of stroke survivors. A personalized prognosis on the evolution of aphasia provides guidance for clinicians to select appropriate treatment.

<u>Results:</u>

Developed support vector machine and random forest models to predict responsiveness to treatment using pretreatment behavioral, demographic, and structural and functional neuroimaging data.

Best model's prediction score F1=0.94.

<u>Ultimate Goal:</u> Recommend treatment

Ongoing Work: Developing traditionally-learned & deep-learned models for patient outcome prediction.



with Swathi Kiran, Prakash Ishwar, Archana Venkataraman, Janusz Konrad & students

AI to Predict Response to Post-Stroke Rehabilitation



Examples of Machine Learning in Biomedicine: Applications to Epilepsy

Mark Kramer

Professor, Mathematics and Statistics, CAS Associate Director, Center for Systems Neuroscience



Epilepsy impacts brain dynamics





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Detect these subtle dynamics





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BU: Wodeyar, Eden **UMN**: Schatza, Widge

So now what?





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BU: Wodeyar, Eden **MGH**: Chinappen, Chu

Close the loop

Practical problems (in human health)

- motivate mathematics & statistics
- to impact these problems.

BU: Nadalin, Shaw, Han, EdenMGH: Shi, Chinappen, Walsh, Richardson, ChuUMN: Schatza, Widge



AI in Healthcare: From Theory to Practice

Kayhan Batmanghelich

Assistant Professor Electrical and Computer Engineering College of Engineering



Technical/Theoretical Development





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S. Singla, B. Polack, S. Wallace, M. Eslami, **K. Batmanghelich**, "Explaining the Black-box Smoothly: A Counterfactual Approach," to appear in MedIA.

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Technical/Theoretical Development



Bedside Practice

Medical Concepts

Impression:

Mild left costophrenic blunting, basilar pleural effusion, increased left suprahilar opacity, differential diagnosis includes increased volume loss and apical pleural fluid. Right costophrenic, right lung free of focal consolidation.

MTI Tags: Degenerative changes



Medical Research

BOSTON UNIVERSITY Practical Deployment Boston University Office of Research



Question: Is there any way we can use "unpaired" data?



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Batmanghelich et al., "Unpaired Data Empowers Association Tests," Bioinformatics Oxford Academics, 2020

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Medical Research











Practical Deployment Boston University Office of Research





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Batmanghelich, et al. Prediction of Voxel-level Liver Stiffness in Patients with Non-alcoholic Fatty Liver Disease using Deep Learning, Al Radiology, 2021

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Medical Research













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Carotid Endarterectomy





Stroke *during* surgery is diagnosed *after* surgery.

Surgeons*



Stroke rate: 7%

No brain monitoring. AI Model





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Technical/Theoretical Development



Bedside Practice

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MTI Tags: Degenerative changes



Medical Research













Practical Deployment Boston University Office of Research

Digital Pathology and Spatial Biology: Opportunities for Multimodal Machine Learning

Vijaya B. Kolachalama, PhD, FAHA

Associate Professor

Department of Medicine, Boston University School of Medicine

Department of Computer Science and Faculty of Computing & Data Sciences, Boston University



Introduction

- Build tools to bring efficiency within the clinical workflow
 - <u>Current Team</u>: Yi Zheng, Olivia Zhou, Anika Walia, Meagan Lauber, Meysam Ahangaran, Chonghua Xue, Michael Romano, Lingyi Xi, Cody Karjadi, Akshara Balachandra, Diala Lteif, Sandeep Sreerama, Caitlin Newman, Lindsey Claus, Yichi Zhang, Aakash Bhatnagar, Tejus Surendran
- PhD students and postdocs with computational background
- MD students, residents and clinical fellows
- Background in more than a single discipline



Ongoing revolution in pathology









Pathologist report: Detailed grading

- Grade 0/1/2/3
- Ouantitative Identification of characterization of histologic features pathology





Current workflow for cancer therapies





Representation learning for cancer pathology



<u>A Graph-Transformer for Whole Slide Image Classification.</u> Zheng Y, Gindra RH, Green EJ, Burks EJ, Betke M, Beane JE, Kolachalama VB. IEEE Trans Med Imaging. 2022 Nov;41(11):3003-3015.

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Summary

- Our laboratory is focused on the development of representation learning approaches to process highresolution microscopic and patient-specific genomic data.
- Huge opportunity for multidisciplinary collaboration between computer scientists and clinicians to build multimodal data analysis frameworks in cancer medicine.







Microbiology | Boston University School of Medicine Biomedical Engineering | College of Engineering





SIMON says: The Power of AI to Transform Human Immunology





@TomicAdriana





atomic-lab.org

Boston University Office of Research Research on Tap

Biological processes are **COMPLEX**

We need a DIFFERENT PERSPECTIVE

It is time for INTELLIGENT IMMUNOLOGY



Diana Lange, OpenProcessing; https://www.diana-lange.de/





AI to the rescue

If we can teach computers to ...



Can we teach them **PROVIDENTIAL Constant**



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<u>Sequential</u> Iterative <u>Modelling</u> Over <u>Night</u>



Join open-source community supporting **SIMON**!

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						Support Vector Machines with Linear Kernel			svmLinear2 >	,
0 18 0				_					► Validate de	ata



Tomic et al, SIMON: open-source knowledge discovery platform. Patterns, 2021







From AI to MI (Microbial Intelligence) Daniel Segrè



Professor of Biology and Bioinformatics Director, BU Microbiome Initiative Department of Biology, CAS Bioinformatics Program



Can we understand, predict and design microbial communities?





ML can help map interactions and design environments that lead to a given community composition (in silico)



Demetrius DiMucci, Mark Kon mSystems, 2018

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Dynamic metabolic modeling + Reinforcement learning \rightarrow Microbiome Design



Opportunities



Hybrid Mechanistic + Al predictive approaches





From genomics to phenomics

with Yannis Paschalidis BioRxiv 2022



NIVERSIT



Can microbiome engineering mitigate climate change?

DeLisi et al. BioDesign Research, 2020 Michael Silverstein, Jennifer Bhatnagar et al.

...ask me how!

AI in Chemical and Biomedical Imaging

Ji-Xin Cheng

Moustakas Professor ECE & BME, College of Engineering



Augmented **Reality for Ultrasound**guided Kidney Stone Removal

Clinical Observation in 2013



Re: K202119

Dear Dr. Rao



Preclinical and clinical validation FDA U.S. FOOD & DRUG



FDA clearance 2020



We have reviewed your Section \$10(k) premarket notification of intent to market the device referenced above and have determined the device is substantially equivalent (for the indications for use stated in the above and have determined the device is substantially equivalent (for the indications for use stated in the enclosure) to legally marked prefericate devices marked in intrastice commerce prior to May 28, 1976. Or with the provisions of the Federal Fuel Cong and Cosmica Act Act (but that on tertuging approal al cost of the provisions of the Federal Fuel Cong and Cosmica Act Act (but that on tertuging approal cost of the provisions of the Act. Although this lefter refers to your product as a device, please be aware that some cleared products may interact be combination products. The SU(A) Potentark Netforation Database located at <u>https://www.accesdatef.fd.gev/erpite/cinf/cblesc/fpmmyprm.fm]</u> identifies combination product submissions. The general controls provisions of the Act. Include requirements (but your and a spitz) instign of devices, good manufacturing practice, labeling, and prohibitions against mishranding and alterations. Prese act. CDBH / does on calause information terided to construct labulary warrantees. We emind you, however, that device labeling must be truthful and not misleading

If your device is classified (see above) into either class II (Special Controls) or class III (PMA), it may be subject to additional controls. Existing major regulations affecting your device can be found in the Code of Federal Regulations, Title 21, Parts 800 to 898. In addition, FDA may publish further announcements ing your device in the Federal Register.

Please be advised that FDA's issuance of a substantial equivalence determination does not mean that FDA has made a determination that your device complies with other requirements of the Act or any Federal statutes and regulations administered by other Federal agencies. You must comply with all the Act's requirements, including, but not limited to: registration and listing (21 CFR Part 807; labeling (21 CFI

Acusee R&D (~ 2 years)





Computational Chemical Microscopy

Advanced Instrumentation + Data Science to break the tradeoff between Speed, bandwidth, and SNR



Collaborator: Lei Tian

Fingerprint Stimulated Raman Scattering (SRS) is Informative but Noisy





Denoising Fingerprint SRS by a Spatial-Spectral Residual Net

Mapping biofuel pinene and limonene inside *E.coli* SS-ResNet GT (100 averages) Raw image





Boston University Office of Research

Nature Communications, 2021, 12:3052

DH1 strain 1p

Visualization of a Limonene Synthesis Metabolon inside Living Bacteria by fingerprint SRS imaging





Boston University Office of Research

Jing Zhang,...Dunlop, Cheng, Advanced Science, 2022: 2203887

Curating Imaging Data for Computational Models in Biomechanics and Mechanobiology

Emma Lejeune

Assistant Professor Department of Mechanical Engineering, College of Engineering





Focus: methods for creating interpretable structurefunction computational models for biomechanics and mechanobiology.



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automated image analysis:



validation with synthetic data:







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Chad Hovey (Sandia)

Deep Learning Augmented Computational Imaging for Biomedical Microscopy & Neural Imaging

Lei Tian

Assistant Professor Department of Electrical and Computer Engineering Department of Biomedical Engineering School of Engineering



BU Computational Imaging Systems Lab



/ersi

Computational Miniature Mesoscope (CM²) for large-scale neural imaging



advanced computational algorithms



Collaboration with David Boas, Ian Davison

CM²

Self-supervised denoising for in vivo spatiotemporal neural imaging data





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Collaboration with Jerry Chen

Deep learning for information extraction from *multi-modal, multiscale* imaging data



 $\min_{G,E,R} \max_{D} L_{GAN}(G,D) + \lambda L_{\mathrm{Info}NCE}(G,E) + \alpha L_{\mathrm{reg}}(G,R) + \beta \|\phi\|_{TV}$

Relating label-free OCT measurements to Gallyas stain measurements for quantifying myelin content and neuron density in human brains



Boston University Office of Research

Collaboration with Irving Bigio, David Boas, Ann McKee, Douglas Rosene

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THANK YOU!



Upcoming Event





- Funding Info Session: BUMC & Hariri Institute Host Special Funding Call on Digital Health
 - Information Session and Cross-Campus workshop on Digital Health
 - **Date:** Wed, November 30, 2022 (in-person),12:00pm 2:00pm
 - Location: BUMC, 72 East Concord St, Instructional Building, Hiebert Lounge L 1407, Boston, MA 02215



UPCOMING EVENTS

Learn more & RSVP: bu.edu/research/events Topic ideas & feedback: bu.edu/research/topic-ideas

RESEARCH ON TAP

Developing Technologies for a Sustainable Future Wednesday, December 7, 2022 | 4-6 pm

RESEARCH HOW-TO

Meet the U.S.-Israel Binational Science Foundation Thursday, November 10, 2022 | 9:30-10:30 am

Working with the Media to Share Your Research Wednesday, November 16, 2022 | 3-4:30 pm

