CPSL
Cyber-Physical Systems Laboratory

CSE 531A

# AI for Health

Chenyang Lu
AI for Health Institute


Washington University in St. Louis

# AI for Health

- Data-driven tools for health care
  - Phenotype complex diseases
  - Predict individual outcomes and treatment effects
  - Discover risk factors
  - Support clinical decisions

- Extract knowledge from diverse data

**Electronic Health Record (EHR)**
- **Collected in hospitals**
- **Complex and high-dimension data**

**Internet of Things (IoT)**
- **Longitudinal monitoring in daily life**
- **Noisy and lossy data**

# AI for Health

- Data-driven tools for health care
  - Phenotype complex diseases
  - Predict individual outcomes and treatment effect
  - Discover risk factors
  - Support clinical decisions

- Extract knowledge from diverse data

**Electronic Health Record (EHR)**
- **Collected in hospitals**
- **Complex and high-dimension data**

**Internet of Things (IoT)**
- **Longitudinal monitoring outside hospitals**
- **Noisy and lossy data**

# Wearables

- Commonly available: step, heart rate, sleep stages
- More sensing modalities
  - Oxygen saturation (SpO2)
  - Skin temperature
  - Breathing rate
  - Heart rate variability
  - ECG
  - Stress
- **500+ million** wearables sold in 2021



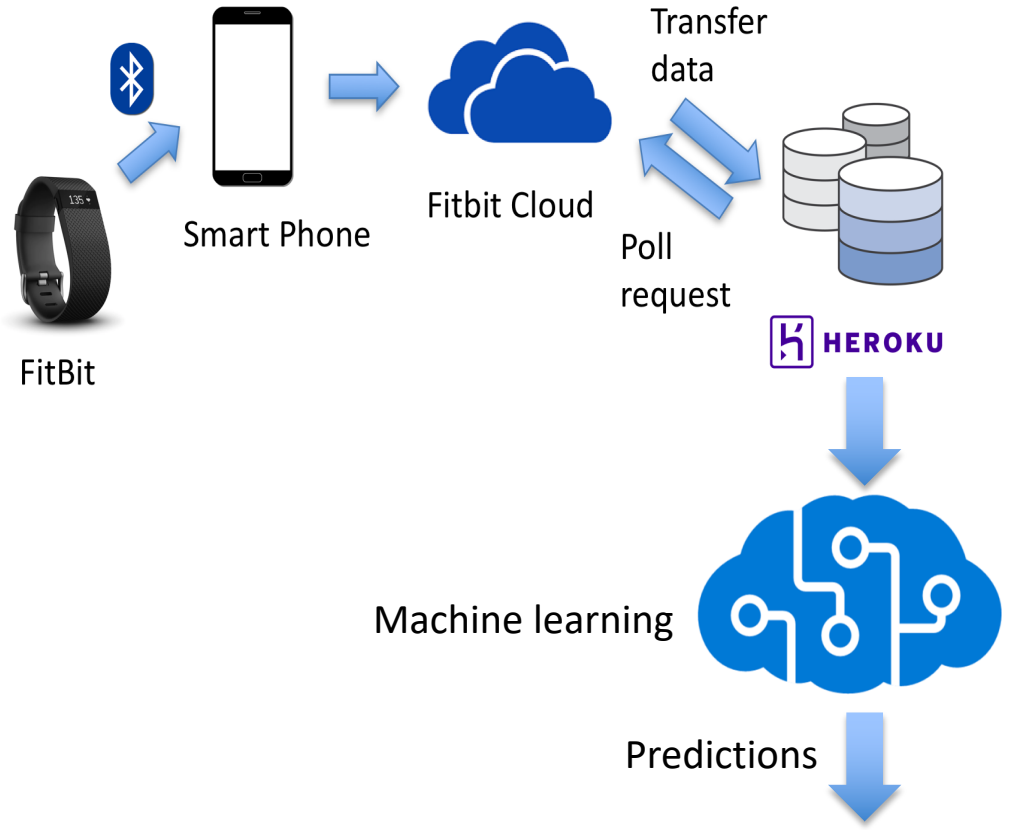




***Unprecedented monitoring capability outside hospitals!***

# IoMT: Internet of Medical Things

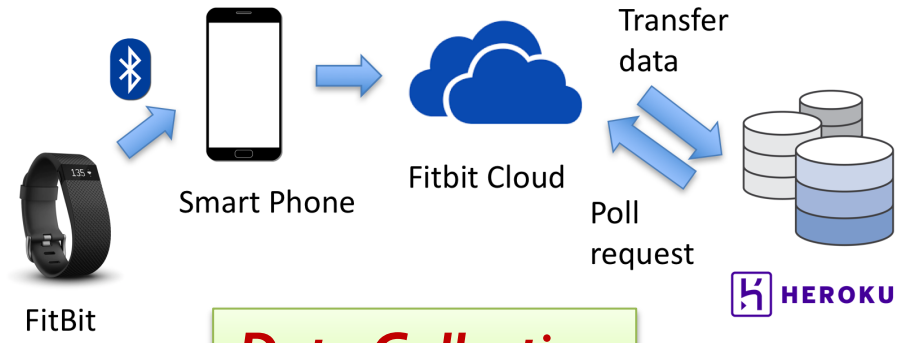
- **Wearables**: wristband, watch, ring…
  - Long-term, non-obtrusive monitoring
- **Connectivity**: Bluetooth, WiFi, cellular
  - Remote monitoring and intervention
- **Cloud**: computing and storage
  - Scalable to large population
- **Analytics**: machine learning
  - Predict outcomes and support intervention



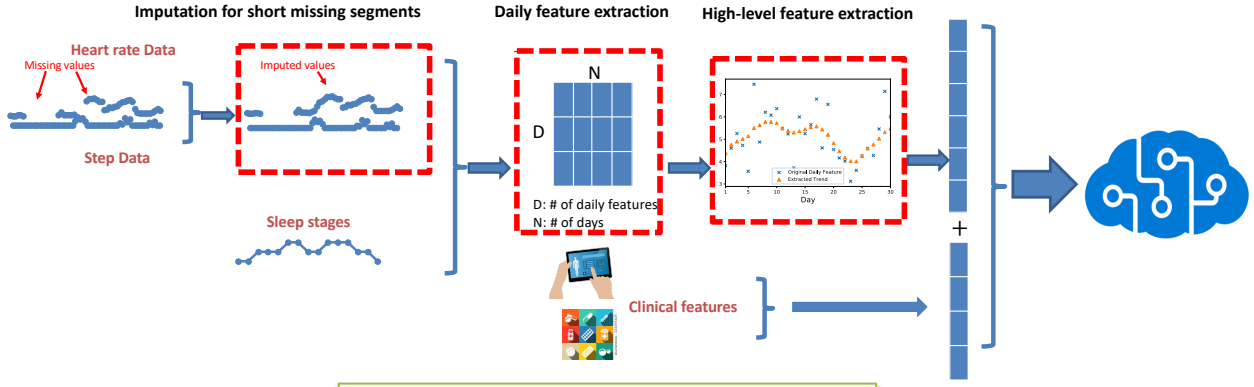

"I believe, if you zoom out into the future, and you look back, and you ask the question, 'What was Apple's greatest contribution to mankind?', it will be about health." --Tim Cook

# IoMT for Precision Medicine

- **Perioperative care**
  - Surgical complications after pancreatic surgery [Standard of Care in Surgical Prehabilitation]
  - Recovery outcomes after spine surgery
  - Surgical outcomes of periacetabular osteotomy for hip dysplasia [NIH R01]
- **Mental health care**
  - Depression and weight loss of older adults undergoing behavioral therapy [NIH R01]
  - Mental disorders in the community [NIH All of Us]
  - Dynamic cognitive function in youth with diabetes




**Data Collection**




**Machine Learning**

# Need: Predict Outcomes of Pancreatic Surgery

- Pancreatic cancer has a 5-year survival rate less than 5%.
- Surgery is the only cure but commonly followed by complications.
- Predict postoperative complications before surgery
  - **Decision support**: suitability for surgery
  - **Intervention**: pre-habilitation

**Preoperative Clinic**




**Surgery**



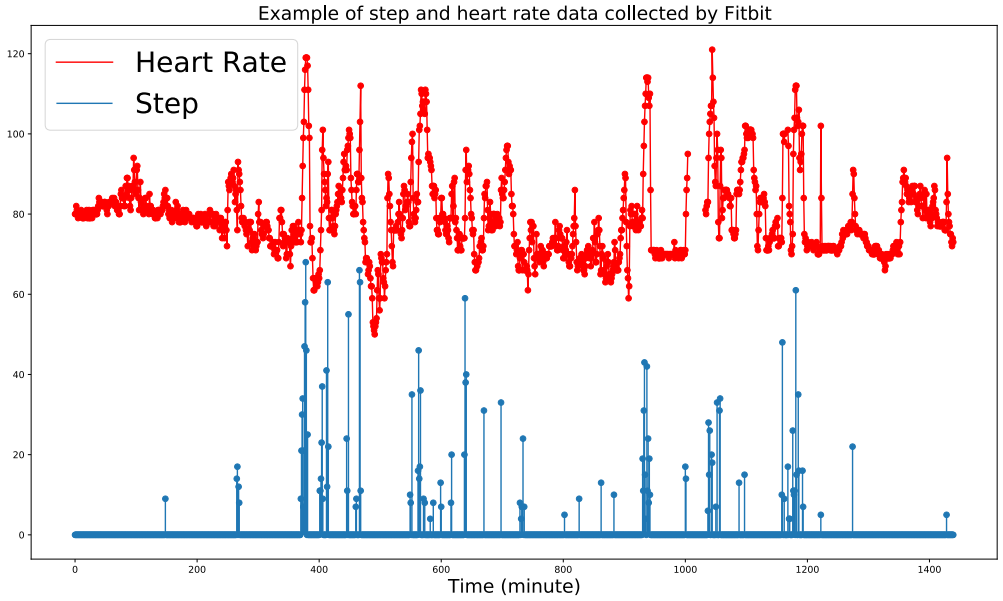
**Outpatient Recovery**

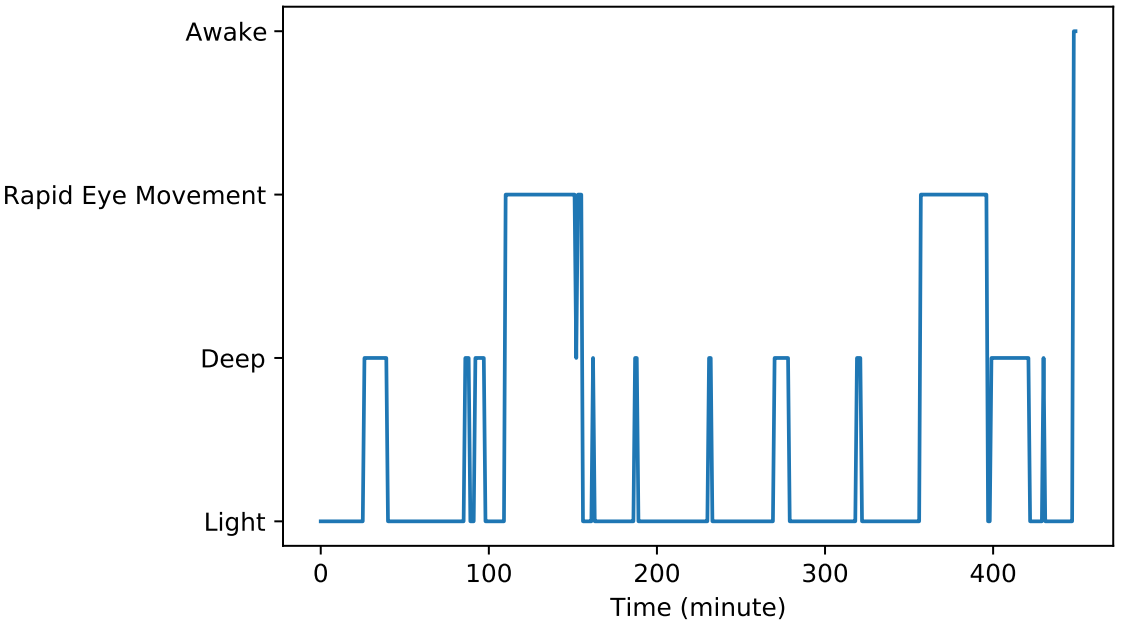


Joint work with Chet Hammill (Surgery), Jingwen Zhang, Dingwen Li, Ruixuan Dai (CSE)

# Prediction Problem

- Wearable time series: step count, heart rate, sleep stage




- Complications: composite outcome of readmission or severe complications within 30 days of hospital discharge

# Robust Prediction of Surgical Complications

CPSL Cyber-Physical Systems Laboratory

- **Machine learning models outperform standard surgical risk scores.**
  - x2 AUPRC
  - x3 sensitivity at the same specificity

| Data Source | AUROC | AUPRC | Sensitivity | Specificity |
|---|---|---|---|---|
| Random weighted classifier | 0.5097 (0.0585) | 0.4322 (0.0469) | 0.1520 (0.0854) | 0.8583 (0.0504) |
| NSQIP with Clinical Characteristics | 0.6114 (0.0000) | 0.4075 (0.0000) | 0.2800 (0.0000) | 0.8571 (0.0000) |
| ML with Clinical Characteristics | 0.7632 (0.0085) | 0.7374 (0.0206) | 0.5800 (0.0699) | 0.8583 (0.0083) |
| Wearable Data | 0.7326 (0.0074) | 0.7192 (0.0154) | 0.5480 (0.0440) | 0.8583 (0.0083) |
| Clinical Characteristics + Wearable Data | **0.8802 (0.0050)** | **0.8871 (0.0087)** | **0.8320 (0.0160)** | 0.8583 (0.0083) |

- NSQIP: American College of Surgeons National Surgical Quality Improvement Program
- AUROC: Area Under the Receiver Operating Characteristic Curve
- AUPRC: Area Under the Precision-Recall Curve

# Mental Health Crisis

- Mental disorders are prevalent.
  - **~3.8%** of the population (i.e., **280 million**) experience depression (WHO).
- Over **50%** of patients are not recognized or treated.
- Clinical visit is time-consuming and expensive.
  - Hindering timely diagnosis and intervention

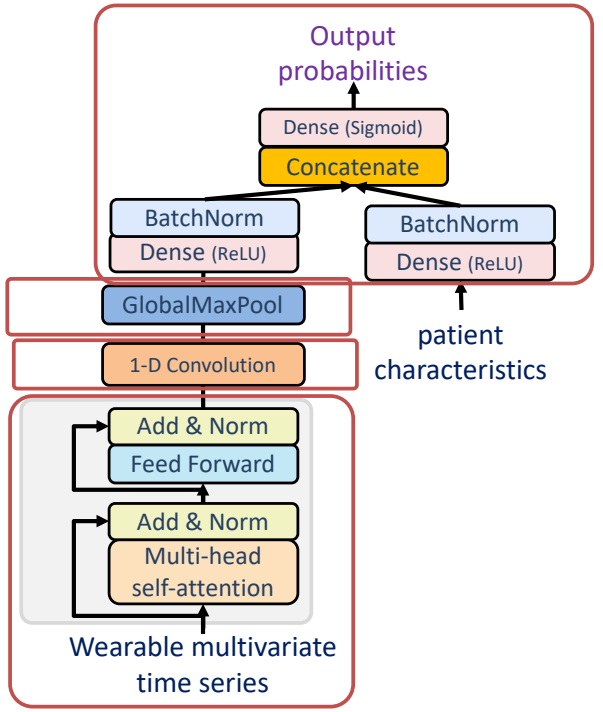


- Detect mental disorders with wearables devices?
  - Unobtrusive, multi-modal sensing
  - Activities, heart rate, and sleep are associated with mental health



# Detect Mental Disorders in the Community

- Detect mental disorder (depression & anxiety) using
  - **wearable data**: multi-variate time series of daily features
  - **patient characteristics**: age, race, ethnicity, gender, education, smoke, alcohol
- All of Us program: **8,996** participants with wearables (**1,247** with mental disorders)
- **WearNet**: deep model for detecting mental disorders




Joint work with Thomas Kannampallil (Informatics), Laura Jean Bierut (Psychiatry), Ruixuan Dai (CSE)

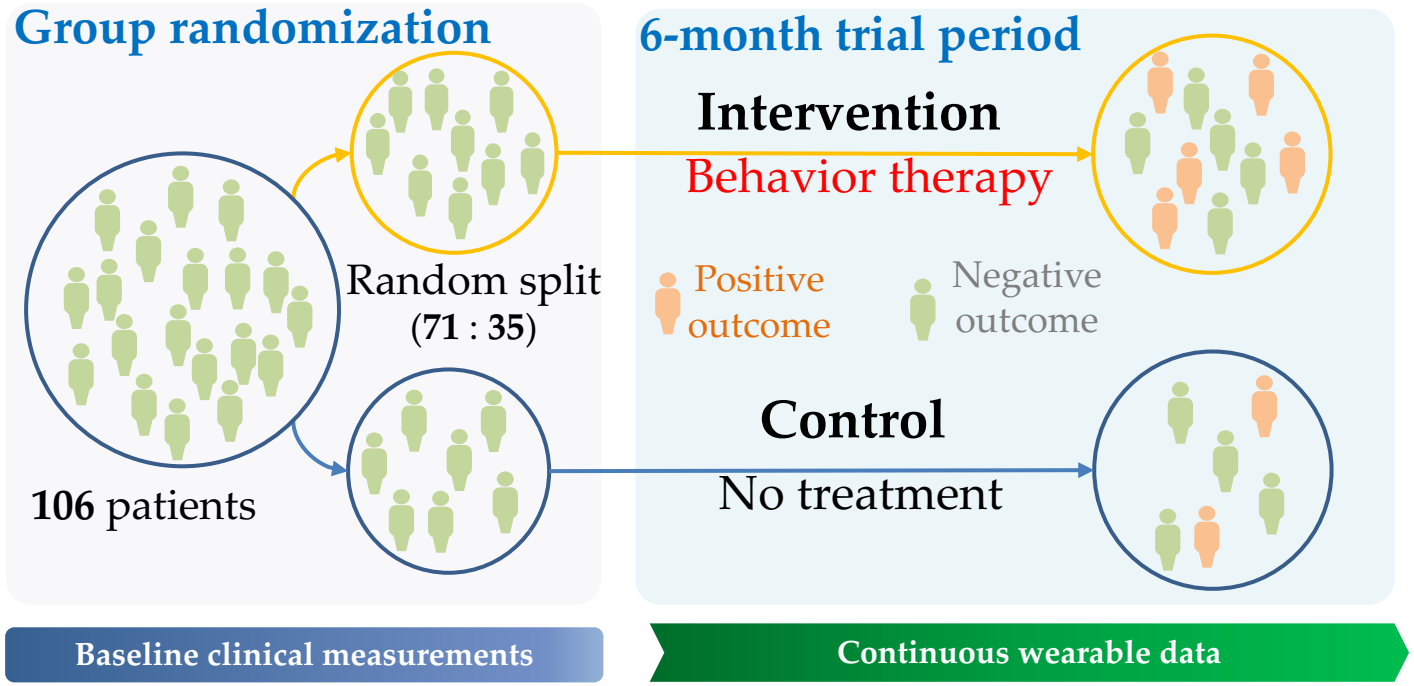
# Personalized Prediction of Treatment Response

- Statistical analysis → **population-level** effectiveness of treatment

- **Personalized** prediction of treatment response → **precision** medicine

- **Machine learning from RCT data**
  - Clinical (baseline): age, anxiety…
  - Fitbit (2 months): heart rate, sleep
  - Depression outcome (at 6 month)

## Randomized Controlled Trial of Depression Therapy




R. Dai, T. Kannampallil, J. Zhang, N. Lv, J. Ma, and C. Lu, Multi-Task Learning for Randomized Controlled Trials: A Case Study on Predicting Depression with Wearable Data, Proceedings of the ACM on Interactive, Mobile, Wearable and Ubiquitous Technologies (UbiComp'22), 6(2), Article 50, July 2022.

# AI for Health

- Data-driven tools for health care
  - Phenotype complex diseases
  - Predict individual outcomes and treatment effect
  - Discover risk factors
  - Support clinical decisions

- Extract knowledge from diverse data

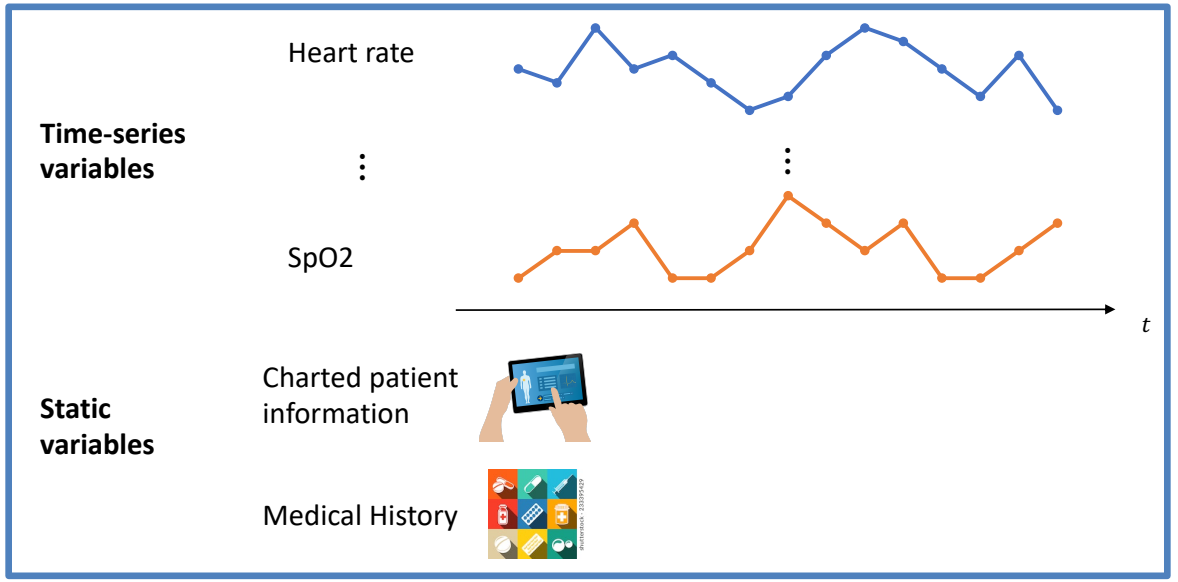
**Electronic Health Record (EHR)**
- **Collected in hospitals**
- **Complex and high-dimension data**

**Internet of Things (IoT)**
- **Longitudinal monitoring outside hospitals**
- **Noisy and lossy data**

# Oncology Early Warning System

- Predict clinical deterioration of hospitalized cancer patients

- Inpatient data from EHR
  - 128 static variables
  - 41 time-series variables




- Static and time series variables
  - make complementary contributions to prediction of clinical deterioration
  - have cross-modal correlation

Joint work with Patrick Lyons, Marin Kollef, Brian Gage (Medicine), Dingewen Li (CSE)

# CrossNet

- **Unified** deep recurrent model for integrating static and time-series inputs
- **Multi-modal fusion**: integrating heterogeneous input data
- **Cross-modal imputation**: exploiting cross-modal correlation

*CrossNet detects **10x** deterioration events than MEWS at the same false alarm rate*

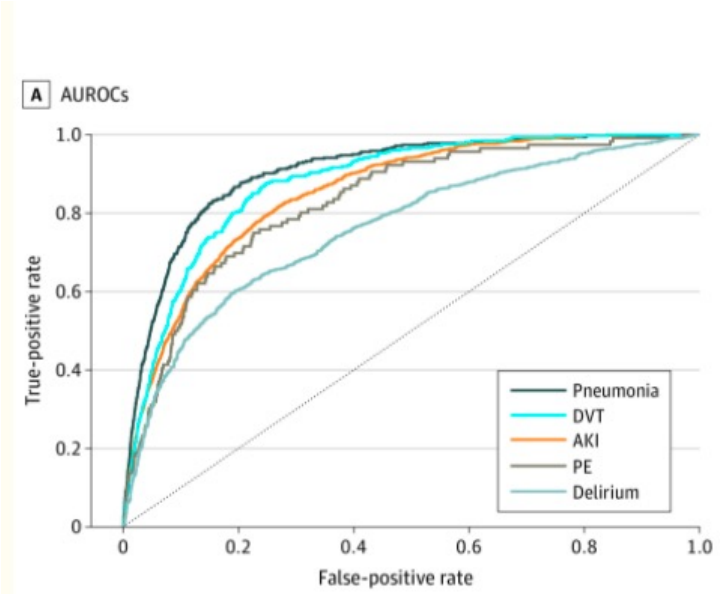
| Model | Alarm rate control | | False alarm control |
|---|---|---|---|
| | Sensitivity | Specificity | Sensitivity |
| MEWS | 0.3358(0.0115) | 0.8257(0.0142) | 0.0392(0.0062) |
| C. BRITS | 0.3899(0.0134) | 0.9394(0.0097) | 0.3581(0.0092) |
| S. BRITS | 0.3891(0.0122) | 0.9396(0.0105) | 0.3586(0.0131) |
| CrossNet | **0.4218(0.0130)** | **0.9486(0.0093)** | **0.3952(0.0118)** |

MEWS: Modified Early Warning Scores

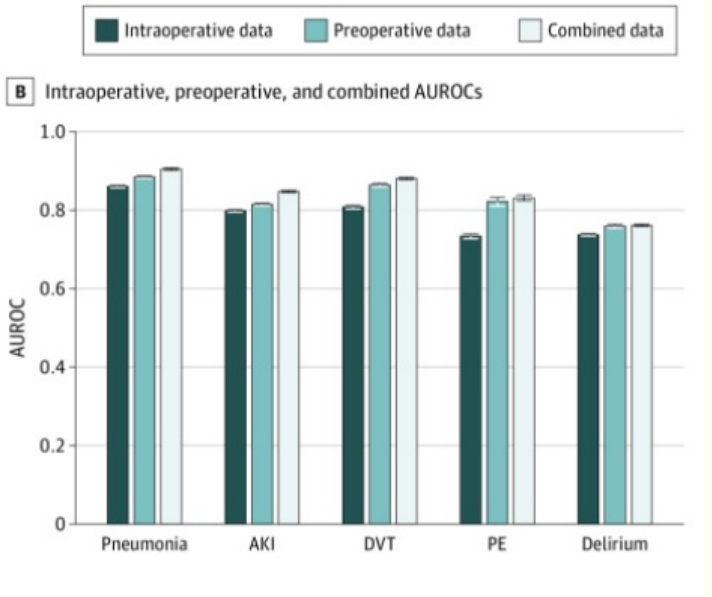
D. Li, P. Lyons, J. Klaus, B. Gage, M. Kollef, and C. Lu, Integrating Static and Time-Series Data in Deep Recurrent Models for Oncology Early Warning Systems, ACM International Conference on Information and Knowledge Management (CIKM'21), November 2021.

# Predict Postoperative Complications

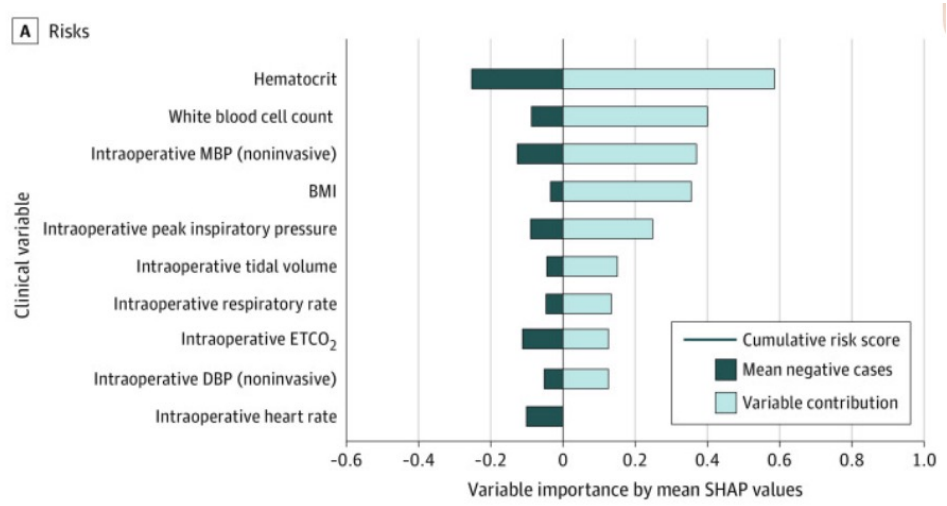
- Anticipatory management for perioperative contingency planning
- Preemptive and early identification of risk factors
- Example: OR-ICU handoff [ARHQ R01]




**Predict multiple complications**




**Exploit pre- and intra-operative data**

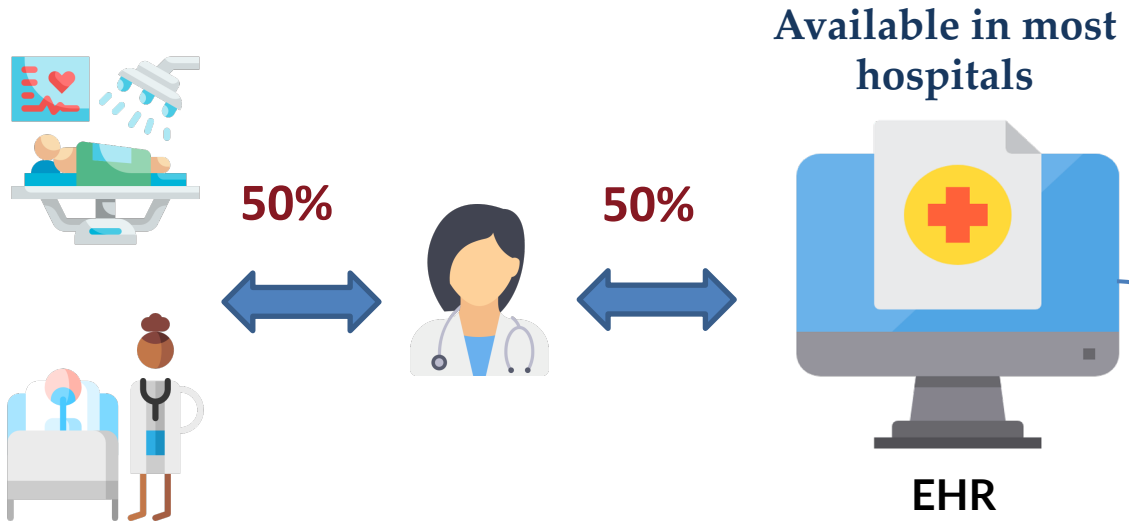


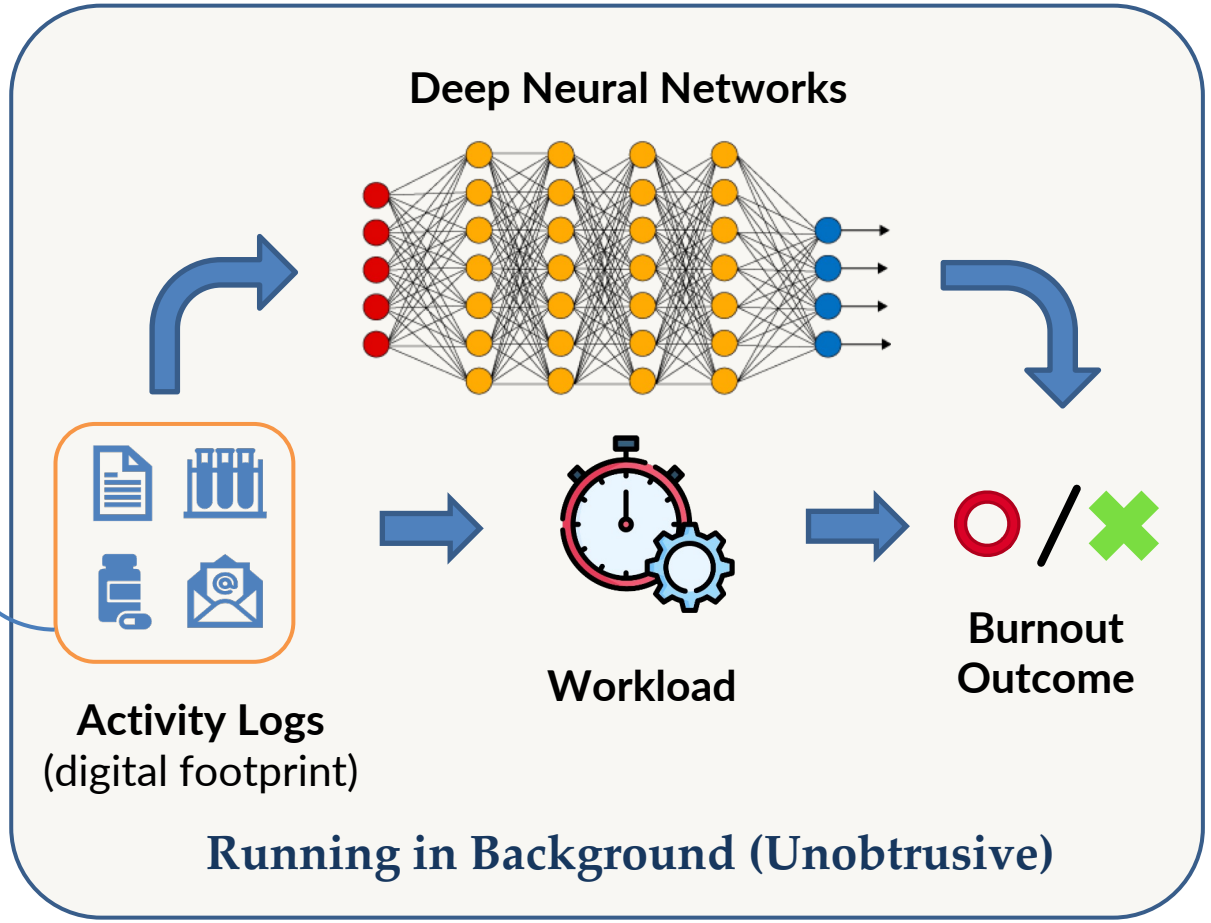

**Identify important risk factors**

B. Xue, D. Li, C. Lu, C.R. King, T. Wildes, M.S. Avidan, T. Kannampallil, J. Abraham, Use of Machine Learning to Develop and Evaluate Models Using Preoperative and Intraoperative Data to Identify Risks of Postoperative Complications, JAMA Network Open, 4(3):e212240, 2021.

# Predict Clinician Burnout based on EHR Logs

***Unobtrusively** monitor and assess the risk of burnout in **real time***




H. Liu, S.S. Lou, B. Warner, D.R. Harford, T. Kannampallil, C. Lu, HiPAL: A Deep Framework for Physician Burnout Prediction Using Activity Logs in Electronic Health Records, ACM SIGKDD Conference on Knowledge Discovery & Data Mining (KDD), 2022.

# AI + Health

- Significant **health information** can be learned from diverse data.
- **AI** is key to extract health information from complex clinical data.
- Rigorous **clinical studies** are needed to validate AI models.
- Close collaboration between AI and health researchers is essential

**AI for health research:** https://www.cse.wustl.edu/~lu/iomt.html

# Interdisciplinary Class on AIHealth

- **Projects 60%**
  - Proposal and presentation: 10%
  - Demo I: 5%
  - Demo II: 5%
  - Final report and demo: 40%
- Critiques 35%
- Participation 5%

- **Interdisciplinary**: co-taught by experts on AI and medicine
- **Research** experience on AIHealth

# Critiques

- Half-page **critiques** of research papers
- Due by 10am on class day
- Back-of-envelop - NOT whole essays
- Critique requirement

# Project

- **Two** students per team
  - Need TA permission for a three-member team.

- Develop AI models
- Train and validate models using clinical data
- Write a **paper**
- **Demos**

- Opportunity to contribute to **AIHealth** research

# Steps

1. Formulate your research problem
2. Form a team
3. Propose a research plan
4. Develop and train your models
5. Validate your models
6. Demo 1, 2 and Final Demo
7. Write a technical report

# Get Started Early

- Think about topics and ideas
- Talk to TA and professor
- Put together a team

- A **lot** of work (and fun) throughout the semester!

# Logistics

- Guidelines and slides are on the class **homepage**.
  - http://www.cse.wustl.edu/~lu/cse531a/
- Communication will be through **Piazza**.
  - e.g., search for teammate
- All work will be submitted through **Canvas**.
- Find critique and demo and due dates on the class **schedule**.

# Support

- Prof. Chenyang Lu <lu@wustl.edu>
- Ben Warner <b.c.warner@wustl.edu>
- Ziqi Xu <ziqixu@wustl.edu>

- Post on Piazza for Q&A.

- Make appointment for meetings.

# Next Class

- Project guidelines and topics