Zhen Hua

765-337-6746
huazhensdu@gmail.com
https://www.linkedin.com/in/zhenhua23

Computational physicist and AI-driven biomedical researcher with a Ph.D. in Physics and 8+ years of experience integrating simulation, deep learning, and signal modeling to investigate structural dynamics in high-resolution biological imaging. Specialized in modeling tissue deformation, intracellular transport, and biomechanical response using physics-based simulation frameworks and interpretable machine learning techniques. Experienced in both hypothesis-driven mechanobiology and data-driven phenotype discovery.

SKILLS

- **Programming**: Python, MATLAB, SQL
- **Modeling Tools:** Scikit-Learn, PyTorch, Grad-CAM, SHAP, FFT, PCA, XGBoost
- **Core Competencies:** Computational Modeling (Monte Carlo simulation), Deep Learning (CNNs), Tree-Based models, Linear Models, Unsupervised Learning (Clustering, Anomaly Detection), Frequency-Domain Simulation, Feature Engineering, Model Interpretability, Biomedical Image Analysis

PROFESSIONAL EXPERIENCE

National Eye Institute, National Institutes of Health (Bethesda, MD, USA)
Research Scientist — June 2023- current

- **Deep Learning-Based Classification and Localization of Retinal Microvascular Disease**
  - Trained a suite of pretrained CNNs (InceptionV3, ResNet50, VGG16, Xception) on AO-ICG retinal images to classify healthy vs. diseased choriocapillaris structure, achieving robust ROC-AUC and confusion matrix performance across models.
  - Fine-tuned classification heads on augmented CC datasets with limited sample size, leveraging transfer learning to stabilize training and improve generalization.
  - Achieved mean ROC-AUC of 0.86 across folds and consistent disease prediction sensitivity above 85%, supporting robust performance under small-sample constraints.
  - Applied Grad-CAM to visualize attention maps, revealing spatial regions associated with disease prediction and aligning with known vascular degradation zones.
  - Demonstrated the effectiveness of supervised CNN-based models in identifying and localizing microvascular changes, offering a high-performance, spatially interpretable framework for CC disease analysis.
- **Interpretable Frequency-Domain Biomarker Modeling for Retinal Disease Detection**
  - Built an image analysis pipeline to quantify microvascular structure in AO-ICG retinal images using FFT-based spatial frequency analysis.
  - Extracted three interpretable features—peak location, peak prominence, and FWHM—from radially averaged power spectra to assess vascular spacing, regularity, and integrity.
  - Applied PCA to reveal variance-driven separation between healthy and diseased subjects and identify dominant features explaining group differences.
  - Performed supervised modeling (Random Forest, logistic regression) and SHAP analysis to evaluate feature importance and diagnostic utility.
  - Conducted unsupervised clustering using cosine similarity and hierarchical linkage, achieving 83% accuracy and full sensitivity in recovering true disease labels without using any ground truth during training.

Purdue University (West Lafayette, IN, USA)
Graduate Research Assistant — May 2017-December 2022

- **Phenotype-Driven Outcome Prediction in Tumor Biosignals Using Neural Networks**
  - Built a dynamic imaging and analysis pipeline using low-coherence digital holography to monitor patient-derived cancer biopsies under chemotherapeutic exposure.
  - Extracted time–frequency biomarkers from intracellular fluctuation spectrograms, revealing latent spectral phenotypes linked to metabolic response and tissue viability.
  - Applied hierarchical clustering to sub-sample spectrograms, revealing four phenotype classes (Pheno-1 to Pheno-4) across species and cancer types.
  - Improved AUC for predicting treatment response from **0.64 to 0.75** by excluding metabolically inactive (red-shifted) subgroups during neural network training.
  - Identified stable biomarkers that consistently differentiated responders from non-responders across both species.

- **Doppler Spectroscopy and Simulation of Active Transport in Living Tissue**
  - Modeled intracellular transport dynamics in 3D tissue spheroids using Doppler fluctuation spectroscopy to characterize active subcellular processes across the ballistic-to-diffusive transition regime.
  - Derived statistical models of persistent walks based on the Ornstein–Uhlenbeck process and validated predictions through Monte Carlo simulations.
  - Designed a real-time optical biosensing system using biodynamic imaging with coherence-gated holography to acquire fluctuation spectra from living tissue.
  - Identified Doppler spectral signatures—such as the Doppler edge and spectral knee—as quantitative markers for metabolic activity and biomechanical state.
  - Applied the simulation-theory framework to distinguish bacterial invasion and intracellular slowdown via spectrally resolved biomarkers, enabling label-free phenotyping.
- **Recovering Drug Response Signals from Archived Biopsies Using Spectral Clustering**
  - Assessed the feasibility of using snap-frozen, thawed tumor biopsies for biodynamic drug response profiling using digital speckle holography.
  - Compensated for freeze–thaw damage using spectrogram normalization; extracted 40 spectral biomarkers per sample.
  - Applied similarity-based clustering to group patient samples by chemotherapeutic sensitivity, achieving correct classification in **12 of 14** archived cases.
  - Validated archived tissue as a viable input for unsupervised ML-based drug screening pipelines.

EDUCATION

Purdue University, Department of Physics and Astronomy (West Lafayette, IN, USA)
Ph.D., **Physics** December 2022
Shandong University, Department of Physics (Jinan, Shandong, China)
B.Sc., **Microelectronics** June 2015

SELECTED PUBLICATIONS & CONFERENCE PROCEEDINGS

Quantitative Modeling and AI-Driven Phenotyping

- **Zhen Hua** el. Comparative Cancer Chemosensitivity Phenotypes using Low-Coherence Digital Holography, Scientific Reports, Nature (2024). https://doi.org/10.1038/s41598-024-52404-w
- **Zhen Hua** el. Classifying Tumor Heterogeneity of Human Esophageal Cancer Biopsies by Dynamic Contrast OCT with Deep Learning, SPIE Photonics West Conference (2023) https://doi.org/10.1117/12.2647602
- **Zhen Hua** et al. "Quantitative Analysis of the Choriocapillaris Meshwork in Healthy and Diseased Eyes using Adaptive Optics Enhanced Indocyanine Green Angiography." ARVO (2024).
- Dawith Lim, **Zhen Hua** et al. "Observing cross-species cross-cancer chemosensitivity signatures with dynamic-contrast OCT." Optical Coherence Tomography and Coherence Domain Optical Methods in Biomedicine XXVIII, SPIE Proceedings Vol. 12830 (2024). https://doi.org/10.1117/12.3002602

Advanced imaging system application in cancer tissue study

- David Nolte, Dawith Lim, **Zhen Hua**. "Coherence-Gated Digital Holography for Personalized Cancer Care." Digital Holography and Three-Dimensional Imaging (2023). https://doi.org/10.1364/DH.2023.HM1C.2
- **Zhen Hua** et al. "Phenotyping Drug Response of Living Tissue based on Tissue-Dynamics Spectroscopy." SPIE Photonics West Conference (2022).
- **Zhen Hua** et al. "Chemosensitivity Testing of Revived Fresh-Frozen Biopsies using Digital Speckle Holography." arXiv (2023). https://doi.org/10.48550/arXiv.2303.12339
- **Zhen Hua** et al. "Doppler Spectroscopy of Intracellular Dynamics During Chemotherapy in Tumor Biopsies." American Physical Society (2020).

Advanced imaging system application in bacterial infection study

- Honggu Choi, Zhe Li, **Zhen Hua**, Doppler Imaging detects bacterial infection of living tissue, Communications Biology, Nature (2021) https://doi.org/10.1038/s42003-020-01550-8
- Dawith Lim, **Zhen Hua** et al. "Doppler Spectroscopy of Intracellular Dynamics Detects Pathogenic Infection and Antibiotic Resistance." CLEO (2024). https://opg.optica.org/abstract.cfm?uri=CLEO_AT-2024-ATh3B.4