Nicholas A. Gabriel

[website] [github]

Education:

The George Washington University **Washington, DC**
Ph.D. Physics *exp. 2025*
M.S. Physics *2021*
Thesis: "Neural Operators for Many-Body Complex Systems"

University of Mary Washington **Fredericksburg, VA**
B.S. Mathematics (with honors), B.S. Physics *2017*
Thesis: "Maxwell's Equations, Gauge Fields, and Yang-Mills Theory" [thesis]

Research and Work Experience:

The George Washington University **Washington, DC**
Research Assistant, Advisor: Dr. Neil Johnson *January 2019 - present*

Neural Operators for many-body complex systems: (AFOSR: FA-9550-20-1-0383)

Proposed a novel operator learning framework for modeling many-body complex systems, successfully combining advanced architectures for graph neural networks and neural operators. Scalability in both system size and model size was demonstrated on benchmarks with millions of nodes. Trained the largest physics-informed neural operator to date, ROMA-H (1.4B params), using the NVIDIA GH200 Superchip. [paper] [github]

– Developed a neural coarse graining procedure to learn multiscale dynamics based on state-of-the-art renormalization methods for complex systems.
– Demonstrated the utility for neural coarse graining in learning effective dynamics and forecasting the evolution of complex systems with millions of nodes.
– Implemented and tested several advanced graph neural network architectures including hyperbolic convolutional layers, edge convolution, and message passing.
– Designed a novel Transformer architecture to learn multiscale interactions, improving operator learning performance by up to an order of magnitude.
– Compared scaling laws of AI systems for complex systems with fluid dynamics benchmarks.

Graph learning for foreign influence detection: (AFOSR: FA-9550-20-1-0382)

Implemented a framework for detecting foreign influence on social media using graph learning and feature attribution to identify models and features that can generalize across influence operation campaigns.

– Investigated detection methods for inauthentic users on Twitter originating from Russia, China, and Iran.
– Implemented several graph learning models (node2vec, GCN, message passing) in PyTorch with PyG.
– Compared graph learning models (graph embeddings and graph neural networks) and augmented feature sets on several cross-campaign benchmarks.
– Determined the most effective content-based and graph-based indicators for identifying IO accounts using Integrated Gradients (IG) with an empirically derived neutral IG baseline.
– Analyzed coordinated link-sharing behavior across IO campaigns and baseline Twitter accounts.
– Reported hundreds of URL domains that were useful for detecting for detecting IO activity, as well as domains that were misleading.
– Detailed findings in a 31 page manuscript available on arXiv. [paper] [github]

Data Collection/Web Scraping:

Led data collection efforts for social media tracking of foreign influence and extremist communities.

– Wrote data collection tools for social media using Python Selenium, Beautiful Soup, and Gmail API. [github]
– Parsed and cleaned text data using SpaCy and NLTK.
– Integrated data sources from different platforms (Twitter, Facebook, Instagram, Gab) into a single dataset using Pandas.
– Collected more than 12M tweets related to foreign influence using the Twitter API. [github]

Brookhaven National Laboratory   **Upton, NY**
Intern, Advisor: Dr. David Jaffe   *June 2016 - August 2016*

Developed software for simulation and statistical analysis of radioactive sources considered for calibration of the PROSPECT experiment antineutrino detector.

Primary deliverables:

– Bash scripts to run batch parallel Monte Carlo simulations of alpha particle transport in SRIM.
– NumPy and SciPy code to adaptively resample the detector geometry.
– CERN ROOT modules for interpolation of Monte Carlo data and calculation of alpha energy deposition spectrum.
– Two presentation given to PROSPECT collaborators detailing feasibility and accuracy of volumetric calibration using alpha particle sources. [report]

Massachusetts General Hospital   **Boston, MA**
AAPM Undergraduate Fellow, Advisor: Dr. Alexei Trofimov   *June 2015 - August 2015*

Prototyped a gaze tracking interface for use in proton radiotherapy treatment of ocular melanoma:

– Performed calibration of optical and infrared sensors for gaze tracking.
– Developed computer vision software for segmentation and pupil tracking using OpenCV
– Embedded gaze tracking sessions in a PyQt GUI which allows a physician to easily view and modify pupil segmentation parameters, view deviations from treatment plan in real time, and automatically save raw optical and segmented data.
– Worked with physicians and medical physicists to guide the design of the application.
– Wrote documentation and instructions for use of the GUI.

Technical Skills:

Languages/Libraries: Python, C, Bash, BLAS, TeX, CUDA C, MATLAB, Mathematica

Software:

    Python: Pandas/Dask, NumPy, PyTorch, JAX, PyG, Jraph, scikit-learn, statsmodels, SpaCy, NLTK, Gensim, Selenium, Beautiful Soup

    Linux/SWE/HPC: Git, SSH, Vim, Conda, Slurm, SQL, Elasticsearch, cloud computing

ML/AI: Transformers, physics-informed neural networks, neural operators, graph neural networks, message passing neural networks, graph learning

Mathematics/Statistics: Differential Geometry, Numerical Analysis, Functional Analysis, Partial Differential Equations, Timeseries Analysis, Graph Theory

Invited Presentations:

1. **The George Washington University** (ENIGMA seminar, 45m presentation) [slides]
   "Multiscale Operator Learning for complex social systems", 10/4/2023

2. **Brown University** (CRUNCH group meeting, 40m presentation) [slides] [video]
   "Multiscale Operator Learning for complex social systems", 9/15/2023

3. **IC2S2 2022** (Conference talk, 15m presentation) [slides]
   "Automated Detection of Information Operations Using Graph Neural Networks", 7/21/2022

4. **Brookhaven National Laboratory** (PROSPECT group meeting, 20m presentation) [report]
   "Mass calibration for PROSPECT", 8/10/2016