Nibraas Khan

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Nashville, TN - USA

Education

- **Vanderbilt University** — *Aug 2020 - Dec 2025 Expected*
  Ph.D. Computer Science — Nashville, TN
- **Middle Tennessee State University** — *Aug 2017 - May 2020*
  B.S. Computer Science — Murfreesboro, TN

Experience

- **Vanderbilt University - Robotics and Autonomous Systems Lab** — *May 2020 - Present*
  Research Assistant — Nashville, TN
  - **Tiered eXplainable AI (xAI) Framework**
    - Engineering a Python library for xAI designed to translate black-box model predictions into actionable insights for diverse stakeholders.
    - Automating the discovery of interpretable features with a built-in, semi-supervised pipeline that uses kernel-based change point detection and HDBSCAN to learn a vocabulary of motion primitives from raw, unlabeled data.
    - Architecting the library's core API to deliver tiered, multi-level interpretations, providing both granular model-debugging data for developers and simplified explanations for non-technical end-users
  - **End-to-End Wearable System for Biomechanical Analysis**
    - Leading the full-stack development of a wearable biomechanics analysis platform, integrating custom on-body hardware, a cloud-based ML pipeline, and a mobile application to provide athletes with corrective feedback.
    - Engineering the on-body data capture system, using an ESP32 microcontroller to stream 100Hz kinematic data from 10 IMUs (9-axis) over I2C to a React Native mobile application.
    - Architecting the cloud analysis pipeline on an AWS EC2 instance that preprocesses kinematic data using change point detection and Dynamic Time Warping before a PyTorch Siamese network generates expert comparisons, achieving a full analysis-to-feedback loop in under 5 seconds.
    - Developing the 3D avatar visualization within the React Native app, using forward kinematics to animate feedback, and now working on an initiative with Vanderbilt's Wond'ry to explore its application as a medical device for orthopedics.
  - **Real-Time Precursor Detection System (REACT)**
    - Architecting and deploying a novel, end-to-end system for real-time prediction of behavioral precursors, achieving an 84.6% F1-score in a challenging low-data clinical environment.
    - Engineering the complete data lifecycle, building a multi-modal Python pipeline to process raw sensor and audio streams into over 50 predictive features.
    - Implementing a PyTorch few-shot learning model with a custom medoid-based loss function and automating hyperparameter optimization with Optuna.
    - Building a companion iOS app for data collection and the delivery of real-time alerts to clinicians through an Apple watch.
    - Developing a full-loop MLOps pipeline to ingest multi-modal sensor data from iOS devices via a Kafka-based streaming system on an AWS EC2 instance, validate data quality using Great Expectations, and orchestrate a weekly retraining workflow with Airflow to automatically train a PyTorch model within a Docker container and deploy the updated artifact to the iOS fleet for on-device inference.
  - **Deep Learning for Digital Biomarker Discovery**
    - Leading a digital biomarker discovery project to aid in the assessment of Mild Cognitive Impairment, which involves automatically detecting sub-tasks of Instrumental Activities of Daily Living from wearable sensor data and identifying kinematic features within each task to serve as biomarkers.
    - Managing a 4-person data annotation team while engineering a data pipeline for a noisy dataset of 150 sessions from 30 participants, which involves programmatically correcting for unsynchronized IMU start times and misaligned timestamps.

    - Architecting an analysis framework in TensorFlow/Keras that automates a 30-fold Leave-One-Participant-Out cross-validation, integrating Optuna for hyperparameter tuning and SHAP for model explainability; this framework produced a Bi-GRU model with a 4-head attention layer achieving an 86% F1-score.
  - **Socially Assistive Robot - Virtual Reality (SAR-VR) System**
    - Engineering a therapeutic SAR-VR gaming system to mitigate cognitive decline and social isolation in older adults by using a robot to facilitate collaborative, dyadic activities.
    - Developing the core software in Unity/C# for 7 research-backed activities, using a 35-state FSM to manage participant interactions while helping architecting its transition to a Q-learning agent for dynamic engagement.
    - Architecting the system's robot-agnostic protocol (WebSockets & JSON API with 55+ commands) proven on 3 robotics platforms, and engineering the pipeline to process 2.26 TB of multi-modal data (Kinect, E4 sensors) from 150+ participants.
    - Managing the complete deployment lifecycle across 10 care facilities, delivering 20+ software updates, providing on-site staff training, and authoring documentation that resulted in a 95%+ reduction in weekly system errors.
  - **Mentorship & Guidance**
    - Mentoring 30+ students in advanced research topics, providing direct technical guidance on using machine learning to estimate biomechanical parameters, advanced prompt engineering techniques, and developing core software components for the SAR-VR therapeutic system.

- **MTSU's Phillip Lab** *August 2018 – May 2020*
  Research Assistant Murfreesboro, TN
  - Architected the SBFBWMtk, a novel hierarchical reinforcement learning framework that combines Sensory-Based and Feedback-Based task-switching mechanisms to solve complex, Non-Markovian problems. The model synthesizes the TD-learning-based Working Memory Toolkit with n-task learning and uses Holographic Reduced Representations for efficient state encoding.
  - Engineered a dynamic transfer learning method that enables the model to retain and transfer its learned value function to a larger neural network as task complexity grows. This novel approach, not present in prior toolkits, was shown to reduce overall training time for agents in dynamic environments.
  - Implemented a novel Abstract Task Representation switching mechanism that utilizes both positive and negative TD error signals, boosting model accuracy on complex combined tasks from a baseline of 38.33% to 96.88% after tuning. This research was published at the 2020 IEEE International Conference on Tools with Artificial Intelligence.

PROJECTS

- **JumpStart** *Jan 2023 – Present*
  Co-Founder Nashville, TN
  - Co-founded a community-focused organization that prepares students for tech careers through a dual-focus program: building pro-bono software for clients while providing technical workshops and direct connections to industry mentors and hiring partners.
  - Led the technical architecture and mentorship for a real-time UAV ground control station for NEXUS. Guided students in integrating a multi-component computer vision pipeline, featuring a YOLOv8 model fine-tuned on the VisDrone dataset for object detection and a DeepSORT algorithm for real-time tracking, all streamed with low-latency via WebRTC.
  - Guided the development of a clinical analysis tool for Vanderbilt's TRIAD. Mentored students in building and deploying an XGBoost model that predicted a therapist's ability to control behavioral escalations, trained it on data from the REACT clinical study, and designed it with an online learning component to continually improve its F1-score as therapists input new session data.
  - Oversaw the architecture and development of an interactive 3D virtual thrift store for Vanderbilt's Wond'ry, utilizing React Three Fiber to create a navigable user experience; the project is hosted on GitHub Pages and currently serves as instructional material for a Vanderbilt course.

SKILLS

- **Languages:** Python, Typescript, C#, Kotlin
- **ML Frameworks & Data Science:** PyTorch, TensorFlow, Scikit-learn, Pandas, NumPy
- **Cloud & MLOps:** AWS (EC2, S3, SageMaker), Firebase, GCP, Docker, Git / GitHub Actions, Git LFS
- **Data Engineering & Orchestration:** Kafka, Airflow, Great Expectations, N8N
- **Databases:** MongoDB, SQLite
- **ML Specializations:** Explainable AI (xAI), Reinforcement Learning (Hierarchical RL, Policy Transfer), Deep Learning (LSTMs, GANs, Siamese Networks), Computer Vision (Object Detection & Tracking), Time-Series Analysis (Wearable Sensor Data), LLM Fine-Tuning
- **Developer Platforms & Tools:** Unity, React, React Native, Android / iOS Development, Pytest

PUBLICATIONS

C=CONFERENCE, J=JOURNAL, S=IN SUBMISSION, I=IN PRESS, A=ARTICLE, X=ARXIV, M=MANUSCRIPT

[C.S] **Khan, N.**, Wang, D., Ghosh, R., Tauseef, M., Mion, L., Ma, M., Sarkar, N. 2025. *Decoding Human Motion: A Scoping Review of Explainable AI Methods in Movement Analysis*

[M] **Khan, N.**, Cole, K., Sarkar, N. 2025. *Explainable Deep Learning for IADL Activity Prediction in Mild Cognitive Impairment using Wearable Sensors*

[M] **Khan, N.**, Shragge, I., Zilinskaite, G., Plunk, A., Staubitz, J., Rajaraman, A., Weitlauf, A., Sarkar, N. 2025. *Interpretable Deep Few-Shot Learning for Prediction of Precursors to Challenging Behaviors in Individuals with Intellectual and Developmental Disabilities*

[J] Tate, J., Mion, L., Migovich, M., Ghosh, R., **Khan, N.**, Kilpatrick, A., Scharre, D., Newhouse, P., Maxwell, C., Tan, A., Sarkar, N. 2025. *A multi-site randomized clinical trial of socially assistive robots on engaging older adults with cognitive impairment residing in long-term care settings: A protocol paper*

[C] **Khan, N.**, Haan R., Shragge, I., Zilinskaite, G., Plunk, A., Staubitz, J., Rajaraman, A., Weitlauf, A., Sarkar, N. 2025. *A Universal Web-Based Tool for Multimodal Data Synchronization and Labeling*

[J] Tate J., Maxwell, C., Migovich, M., **Khan, N.**, Ghosh, R., Colopietro, K., Kilpatrick, A., Sarkar, N. 2025. *Factors Affecting Implementation of Socially Assistive Robots in Long-Term Care Facilities*

[C.S] Weitlauf, A., **Khan, N.**, Plunk, A., Sargent, A., Staubitz, J., Dieffenderfer, J., Sarkar, N. 2024. *Autistic User Input on Wearable Technology: Preliminary Feedback to Inform System Design*

[J.I] **Khan, N.**, Plunk, A., Zhaobo, Z., Adiani, D., Staubitz, J., Weitlauf, A., Sarkar, N. 2024. *Pilot Study of a Real-time Early Agitation Capture Technology (REACT) for Children with Intellectual and Developmental Disabilities*

[J.S] Ghosh, R., **Khan, N.**, Migovich, M., Tate, J., Maxwell, C., Latshaw, E., Newhouse, P., Scharre, D., Tan, A., Colopietro, K., Mion, L., Sarkar, N. 2024. *User-Centered Design of Socially Assistive Robotic Combined with Non-Immersive Virtual Reality-based Dyadic Activities for Older Adults Residing in Long Term Care Facilities*

[C] Wang, H., **Khan, N.**, Chen, A., Sarkar, N., Wisniewski, P., Ma, M. 2024. *MicroXercise: A Micro-Level Comparative and Explainable System for Remote Physical Therapy*

[C] **Khan, N.**, Tauseef, M., Ghosh, R., Sarkar, N. 2024. *A Novel Loss Function Utilizing Wasserstein Distance to Reduce Subject-Dependent Noise for Generalizable Models in Affective Computing* HCI

[A] Maxwell, C., Ghosh, R., **Khan, N.**, Migovich, M., Tate, J., Latshaw, E., Lorraine, M., Sarkar, N. *User-Centered Design for Socially Assistive Robotic Activities with Older Adults in Long Term Care* Innovation in Aging

[J] Wagner, L., Corona, L., Hooper, M., **Khan, N.**, Dixon, A., Lavanderos, A., Sarkar, N., Zheng, Z., Sarkar, N., Warren, Z. *Development of a Patient-Facing Mobile Health App to Track Family Access and Engagement with Early Intervention Services in Underserved Communities* INSAR

[J] Adiani, D., Breen, M., Migovich, M., Wade, J., Hunt, S., Tauseef, M., **Khan, N.**, Colopietro, K., Lanthier, M., Swanson, A., Vogus, T., Sarkar, N. *Multimodal Job Interview Simulator for Training of Autistic Individuals* RESNA

[A] Lorraine, M., Latshaw, E., Lin, Y., Migovich, M., Ghosh, R., **Khan, N.,** Sarkar N., Tate, J. *Participatory Design: An Essential Process For Socially Assistive Robotic Activities In Long-term Care Settings* Innovation in Aging

[X] **Khan, N.,** Sarkar N. 2022. *Semi-Supervised Learning for Stress Detection Using Physiological Data for Partially Labeled Data*

[C] **Khan, N.**, Ghosh, R., Migovich, M., Johnson, A., Witherow, A., Taylor, C., Schroder, M., Vongpanya, T., Sarkar, M., Sarkar, N. 2022. *Data Collection and Annotation Tool for Asynchronous Multimodal Data.*

[C] Ghosh, R., **Khan, N.**, Migovich, M., Wilson, D., Latshaw, E., Tate, J., Mion, L., Sarkar N. 2022. *Iterative User Centered Design of Robot-Mediated Paired Activities for Older Adults with Mild Cognitive Impairment (MCI).* Human Aspects of IT for the Aged Population. Technology in Everyday Living

[C] Migovich, M., Ghosh, R., **Khan, N.**, Tate, J., Mion, L., Sarkar, N. 2021. *System Architecture and User Interface Design for a Human-Machine Interaction System for Dementia Intervention*

[C] **Khan, N.**, Phillips, J. L. 2020. *Combined Model for Sensory-Based and Feedback-Based Task Switching: Solving Hierarchical Reinforcement Learning Problems Statically and Dynamically with Transfer Learning.*

[X] **Khan, N.**, Haan, R., Boktor, G., McComas, M. and Daneshi,R. 2020. *Steganography GAN: Cracking Steganography With Cycle Generative Adversarial Networks.*

[X] **Khan, N.**, Phillips J. 2020. *Combined Model for Partially-Observable and Non-Observable Task Switching: Solving Hierarchical Reinforcement Learning Problems Statically and Dynamically with Transfer Learning.*

POSTERS

[1] Bullard, E., **Khan, N.**, Sarkar, N. 2025. *Enhancing Athletic Performance Through AI: An Iterative Prompt Engineering Approach for LLM-Based Coaching Feedback*. Gothenburg, Sweden

[2] Shragge, I., Rajaraman, A., Staubitz, J., **Khan, N.**, Plunk, A., Zilinskaite, G., Weitlauf, A., Sarkar, N. 2024. *Using Sensors to Predict Precursors to Severe Behavior Displayed by Autistic Children*. Nashville, TN

[3] **Khan, N**., Ghosh, R., Migovich, M., Johnson, A., Witherow, A., Taylor, C., Schroder, M., Vongpanya, T., Sarkar, M., Sarkar, N. 2022. *Developing an Asynchronous Multimodal Data Data Collection and Annotation Tool*. Remote

[4] Ghosh, R., **Khan, N**., Migovich, M., Wilson, D., Latshaw, E., Tate, J., Mion, L., Sarkar N. 2022. *Designing Iterative User Centered Design of Robot-Mediated Paired Activities for Older Adults with Mild Cognitive Impairment*. Remote

[5] Migovich, M., Ghosh, R., **Khan, N**., Tate, J., Mion, L., Sarkar, N. 2021. *Dementia Intervention System Architecture and User Interface Design*. Remote

[6] Haan, R., Boktor, G., **Khan, N.**, Barbosa, S. 2020. *CookieBox- Fake News Classifier*. Remote

[7] **Khan, N.** and Phillips J. 2020. *Combined Model for Partially-Observable and Non-Observable Task Switching: Solving Hierarchical Reinforcement Learning Problems Statically and Dynamically with Transfer Learning* . Murfreesboro, TN

[8] **Khan, N.** and Phillips J. 2019. *Working Memory for Fully Autonomous Systems (Combined Model for partially observable and non-observable task switching*. Murfreesboro, TN