ECE Graduate Research Seminars-Summer 2024

In Person Sessions: June 3-4, 2024

Remote Sessions: June 17-18, 2024

June 3, 2024-Afternoon Session

Name: Koami Soulemane Hayibo
Area of Research: Power Systems
Name of Supervisor: Joshua Pearce

Vertical free-swinging photovoltaic racking energy modeling: A novel approach to agrivoltaics

To enable lower-cost building materials, a free-swinging bifacial vertical solar photovoltaic (PV) rack has been proposed, which complies with Canadian building codes and is the lowest capital-cost agrivoltaics rack. The wind force applied to the free-swinging PV, however, causes it to have varying tilt angles depending on the wind speed and direction. No energy performance model accurately describes such a system. To provide a simulation model for the free-swinging PV, where wind speed and direction govern the array tilt angle, this study builds upon the open-source System Advisor Model (SAM) using Python. After the SAM python model is validated, a geometrical analysis is performed to determine the view factors of the swinging bifacial PV, which are then used to calculate the solar irradiation incident on the front and back faces of the bifacial PV modules. The findings reveal that free-swinging PV generates 12% more energy than vertical fixed-tilt PV systems. Free-swinging PV offers the lowest capital cost and the racking levelized cost is over 30% lower than the LCOE of other agrivoltaics racks including the LCOE of commercial fixed-tilt metal racking, optimized fixed-tilt wood racking PV, and seasonally adjusted wood racking PV.

Name: Muhammad Umair Danish
Area of Research: Software Engineering
Name of Supervisor: Katarina Grolinger

HyperForecasting: Leveraging Kernelized Hypernetworks for Short Term Load Forecasting Across Diverse Consumers

Load forecasting plays a crucial role in energy system management and planning, directly impacting operational efficiency, cost reduction, grid stability, and environmental sustainability. While deep learning methods, notably LSTMs and transformers, have demonstrated significant success in load forecasting, they often struggle to capture complex and abrupt variations and are typically evaluated on specific consumer types, such as offices or schools. To address these challenges, this research introduces HyperForecasting, a novel load forecasting approach that utilizes hypernetworks to model complex patterns across diverse consumers. Hypernetworks are employed to predict the parameters of the primary prediction network, specifically LSTM in our case. Additionally, a learnable adaptable kernel by incorporating polynomial and radial basis function kernels, is introduced to enhance performance. The effectiveness of HyperForecasting is evaluated across various consumer types, including student residences, detached homes, a home with electric vehicle charging, and a townhouse. Across all consumer categories, HyperForecasting consistently outperforms 10 other techniques, including state-of-the-art models such as LSTM, AttentionLSTM, and transformers, demonstrating its efficacy and versatility in load forecasting applications.

Name: Qiaomei Han
Area of Research: Communication Systems and Data Networking
Name of Supervisor: Xianbin Wang and Weiming Shen

Distributed Link Heterogeneity Exploitation for Attention-Weighted Robust Federated Learning in 6G Networks

The integration of cutting-edge 6G networks and distributed machine learning particularly federated learning (FL) technologies is expected to be the cornerstone of developing the next generation of collaborative integrated networks. However, the distributed heterogeneous links among devices impose an adverse impact on FL, which could become severe when the devices are distributed in dynamic environments or among links with higher-performing latency, reliability, and data rate promised by 6G. To tackle this issue, we proposed a novel FL framework to characterize and mitigate the impact of heterogeneous communication links through an attention-weighted model aggregation method. Specifically, link heterogeneity in terms of latency, reliability and data rate is quantified, then an attention weight matrix is generated to guide the distributed links to provide connections for model aggregation, thereby effectively mitigating the adverse impacts of link heterogeneity on FL. Experimental results demonstrated the superiority of this framework and approach compared to other baseline methods in terms of global FL model performance.

Name: Davoud Gholamiangonabadi
Area of Research: Software Engineering
Name of Supervisor: Katarina Grolinger

Mitigating Overestimation of Model Accuracy in Clustered Federated Learning with Non-IID Data through Separate Hold-out Model Selection and Evaluation

Federated learning (FL) is emerging as a promising method for enhancing security and privacy in distributed learning, as it allows clients to train models without sharing their local data. However, the challenge of non-IID (non independent and identically distributed) data, which can lead to degraded model performance and convergence issues, remains a significant hurdle. Clustered FL attempts to address this by grouping clients with similar data and training separate models for each cluster. Despite its potential, clustered FL struggles with the complexities of cluster determination without data sharing and with accurate model evaluation. The conventional approach of selecting the best cluster for a test client based on their data often leads to an overestimation of model accuracy, as it conflates model selection with model evaluation. This paper introduces an approach within the FL framework that separates the processes of selecting a cluster and evaluating model accuracy. It involves using a portion of a target client's data to choose a cluster, while the remaining data is reserved for evaluating the model's accuracy. Additionally, to avoid the pitfalls of high-dimensional data clustering, such as the curse of dimensionality and decreased accuracy, the paper employs a dimensionality reduction strategy. Our experiments reveal that the typical method of evaluating by best-fit cluster notably overestimates model accuracy, underscoring the importance of the proposed separate evaluation approach. The findings also indicate that dimensionality reduction is effective for clustering clients in FL settings.

Name: Sergio Alexander Salinas
Area of Research: Biomedical Systems
Name of Supervisor: Ana Luisa Trejos and Katarina Grolinger

Mixed-Reality Technology to Support Shoulder Rehabilitation Exercises: Accuracy Test

Shoulder disorders are common musculoskeletal complaints that limit a patient's range of motion and daily activities. Recently, serious games and mixed reality technologies, such as the HoloLens, have been proposed for shoulder rehabilitation. However, the accuracy of this technology to track 3D hand movements for reporting therapy-related kinematic metrics is still unknown. Therefore, accuracy and repeatability tests of the HoloLens 2 in tracking hand movements and its potential for shoulder rehabilitation assessment were performed. Comparisons were made between the HoloLens 2 and an Aurora electromagnetic system, which was used as the ground truth. A mixed-reality environment was developed to capture static and dynamic hand positions. The results show that the HoloLens 2 hand-tracking system is accurate to within a median of 10.2 mm and has repeatability comparable to the Aurora system. The HoloLens 2 data are suitable for computing kinematic metrics for shoulder rehabilitation assessment, achieving accuracies above 86.9% for all of the tested metrics.

Name: Riya Roy
Area of Research: Power Systems
Name of Supervisor: Joshua Pearce

Is Small or Big Solar Better for the Environment? Comparative Life Cycle Assessment of Solar Photovoltaic Roof-top vs. Ground-mounted Systems

This study conducts a comprehensive life cycle assessment (LCA) to compare the environmental impacts of rooftop and utility-scale solar photovoltaic (PV) systems. Focusing on a representative 7.4 kWp rooftop system and a 3.5 MWp utility-scale system, particular attention is given to analyzing the LCA of racking/mounting systems, which represent a significant point of differentiation between the two system types. Sensitivity analyses are also conducted across various factors, including PV module types, ground-mounted system footings, and geographic locations spanning different U.S. states. Results indicate that rooftop PV systems exhibit 21%–54% lower embodied energy per kWp compared to utility-scale ground-mounted systems. Despite their potential sub-optimal orientation, rooftop systems consistently demonstrate lower energy payback times. Greenhouse gas emissions are 18%–59% lower for rooftop systems, with water consumption reduced by 1%–12% per kWp. Furthermore, it is worth noting that rooftop solar systems exhibit energy payback periods that are roughly 51%–57% shorter compared to ground-mounted systems in all geographical areas. In contrast, ground-mounted PV systems demonstrate CO2 payback periods that are 378%- 428% longer for identical modules, and 125%-142% longer for the most frequently utilized modules in both scenarios. Significantly, the water usage for ground racks designed for utility purposes greatly surpasses that of rooftop mounting structures, with a factor of around 260 (rack a) and 6 (rack b). In summary, this research underscores the environmental benefits of rooftop PV systems compared to utility-scale ground-mounted systems, particularly in terms of energy demand, greenhouse gas emissions reduction, and water usage. These findings emphasize the necessity of integrating LCA into the development and implementation of solar PV systems to advance sustainable energy solutions.