Mingyu (Ben) Kim

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RESEARCH INTEREST

My main research interests focus on the modeling, analysis, estimation, and control of **Multi-Agent Robot Operation Systems**, including sensor networks, unmanned aerial vehicles (UAVs), underwater vehicles, and sensor networks with an emphasis on real-time centralized and distributed optimization. These interests have significant potential applications in the field of robotics and control systems, where they can be used to improve the efficiency of robot deployment for tasks such as target detection, path planning, environmental monitoring, and surveillance. In particular, my work on developing algorithms for optimal multi-agent robots coordination and stochastic target trajectory prediction/modelling can enhance the capabilities of autonomous robots in dynamic and uncertain environments. These methods also are essential for improving mission efficiency, energy conservation, and system resilience in various robotic applications.

EDUCATION

Virginia Tech, Blacksburg, VA
Ph.D. in Electrical and Computer Engineering — Graduated in May 2025

- *Dissertation: "Toward Optimal Deployment of Multi-Agent Robots for Detection of Poisson Distributed Targets"*
- Supervised by Prof. Daniel J. Stilwell

Georgia Institute of Technology, Atlanta, GA
M.S., in Electrical and Computer Engineering — Graduated in Dec 2020
Accelerated M.S. program: Spring 2017/ Fall 2020 — (Military service in South Korea: 2018~2020)

- *Research Project: "Resilience Improvement in Optimal Power Flow using Interior Point Method with Dual-Simplex Initialization"*
- Supervised by Prof. Santiago Carlos Grijalva

Georgia Institute of Technology, Atlanta, GA
B.S., in Electrical and Computer Engineering, — Graduated with High Honor in Dec 2016

JOURNAL PUBLICATIONS

M. Kim, H. Yetkin, and D. Stilwell, "Suboptimal spatial-temporal multi-robots mission scheduling when sensing performance is stochastic and time-varying," in preparation for submission to *IEEE Sensors Journal*.

J. Jimenez, E. Evans, M. Bays, D. Stilwell, **M. Kim**, and H. Yetkin, "Optimal unmanned underwater vehicles (UUV) surfacing in uncertain environments with spatio-temporal maritime traffic," *IEEE Journal of Oceanic Engineering* (2025).

S. Shrestha, N. Stark, B. Green, D. Stilwell, and **M. Kim**, "Assessing the importance of sediment characterization on seabed embedment predictions of cylindrical objects," *Elsevier-Applied Ocean Research Journal* (2024).

M. Kim, H. Yetkin, D. Stilwell, J. Jimenez, S. Shrestha, and N. Stark, "Toward optimal placement of spatial sensors to detect Poisson-distributed targets," *IEEE Access* (2023).

CONFERENCE PUBLICATIONS

M. Kim, H. Yetkin, and D. Stilwell, "Decentralized multi-robot system for Poisson distributed targets detection in real-time," in preparation for submission to *IEEE-IROS.*

M. Kim, D. Stilwell, and J. Jimenez, "Outlier Detection of Poisson-Distributed Targets Using a Seabed Sensor Network," *IEEE-OCEANS* (2025).

M. Kim, D. Stilwell, H. Yetkin, and J. Jimenez, "Improved approximation of sensor network performance for seabed acoustic sensors," *IEEE-OCEANS* (2025).

M. Kim, H. Yetkin, D. Stilwell, and J. Jimenez, "Barrier coverage problem for suboptimal multi-robots deployment for monitoring of Poisson distributed intruder trajectories," submitted to *IEEE-SysCon* (2024) (under review).

M. Kim, H. Yetkin, D. Stilwell, and J. Jimenez, "On the role of uncertainty in Poisson target models used for placement of spatial sensors," *IEEE-SPIE* (2023).

J. Jimenez, M. Bays, D. Stilwell, H. Yetkin, and **M Kim**, "Optimizing unmanned underwater vehicle surfacing using a Poisson process," *IEEE-OCEANS* (2023).

PROFESSIONAL EXPERIENCE

Hanwha Qcell, Seoul, South Korea July 2020- Sep 2020

S/W Product Planning & Management Team, Intern

- *Optimization of Home Energy Management Systems and Competitor Strategy Analysis for Energy Storage and Distributed Energy Resources*
    - Problem: The energy storage and distributed energy resources (DER) industry faced challenges in optimizing efficiency and compliance with varying ESS tariff policies across different countries, while competitors' strategies required careful analysis to stay competitive.
    - Action: Conducted in-depth research on incentive programs and competitor strategies for ESS and DER installations, and proposed new Home Energy Management System (HEMS) modes tailored to country-specific ESS tariff policies. Additionally, developed a front-end load management system using Time-of-Use (TOU) rate plans and demand response (DR) contracts.
    - Results: Optimized efficiency and compliance for HEMS, while delivering a profitable load management product. Regular presentations on trends and financial policies helped the team stay informed on global ESS and software platform developments.

Military Service, *Republic of Korea Army*

1. *Military Science & Technology Soldier*, The Air Defense School, Sejong, South Korea July 2019- July 2020
    - Non-technical:
        - Researched as a visiting student at Smart Microgrid Lab (Korea University, Seoul, South Korea) supervised by *Prof. Choi, Sungyeon*, from Sep 2019 to May 2020.
        - Wrote a monthly trend journal about technologies empowered by renewable energy resources.
        - Interpreted both for Saudi Arabian Army and ROKA in English to support their meeting.
    - Technical: Authored a review paper titled "A Review: Microgrids and Their Feasibility in Military Applications," providing a comprehensive analysis of microgrid technology and its potential military benefits.
        - Problem: The military faces challenges in ensuring energy security, operational readiness, and resilience in the face of disruptions, with heavy reliance on fossil fuels and centralized energy systems being a significant vulnerability.
        - Action: Conducted a comprehensive review of microgrid technologies and their potential applications for military purposes. This included examining distributed energy resources (DER), real-world military microgrid projects, and the implementation of Vehicle-to-Grid (V2G) systems to enhance energy resilience and operational flexibility.
        - Result: The review highlighted the economic, environmental, and operational benefits of microgrids in military settings. It demonstrated how microgrids can improve energy security, reduce reliance on external fuel supplies, and provide a sustainable, resilient energy source for military operations.
2. *US 8th Army Korean Augmentation To the United States Army (KATUSA), Camp Henry, USA* Nov 2018- July 2019

Smartgrid Lab, Yonsei University, Seoul, South Korea Dec 2017- Oct 2018

Research Intern (Supervisor: Prof. Hur, Kyeon)

- Research
    - Problem: The integration of photovoltaic (PV) systems with power electronic converters poses challenges in modeling, control, and optimization, especially in achieving efficient energy conversion and maximizing system performance under varying environmental conditions.
    - Action: Developed a detailed methodology for simulating and controlling PV systems integrated with converters, including the design and implementation of Maximum Power Point Tracking (MPPT) algorithms, boost converters, and three-phase DC/AC inverters using MATLAB/Simulink. The approach also addressed the need for precise control strategies like current control and phase-locked loops (PLL) for inverter systems.
    - Results: Successfully built and validated simulation models for PV systems with enhanced control mechanisms that improved energy conversion efficiency and system stability. The research demonstrated the effectiveness of MPPT algorithms in optimizing power output, and the integration of control techniques in DC/AC inverters to maintain stable operation in grid-connected environments.
- Tools/Methods:
    - Utilized MATLAB/Simulink to create high-fidelity models of PV systems and power converters. Key methods included modeling PV cells with equivalent circuits, designing MPPT algorithms for optimal energy extraction, and implementing current control systems for inverters. The research also provided insights into debugging and optimizing complex power electronics systems for enhanced reliability.

RESEARCH PROJECT

1. Assessment of Potential Value of Uncertainty in Target Arrival Model for Optimal Mult-Robots Deployment for Detection

- Research
  - Problem: Estimated uncertain intensity functions in a point process model, which represent a 1-dimensional (1-D) target arrival prediction model, need to be evaluated to determine if accounting for uncertainty in target arrivals outperforms deterministic models in the optimal sensing robot deployment problem.
  - Action: Led the project by conducting extensive numerical simulations to estimate a doubly stochastic Poisson point process model from historical target data. Evaluated the model by analyzing the target detection performance of robots, strategically placed based on the model's predictions, to assess its effectiveness in optimizing robot deployment.
  - Results: Through extensive simulations, the uncertain intensity function demonstrated improved sensing robot network performance in approximately 85% of the trials, outperforming the deterministic intensity function in optimizing sensor deployment.
- Tools/Methods:
  - Developed extensive numerical simulations using Monte-Carlo sampling to evaluate the performance of sensing robot networks based on uncertain intensity functions. MATLAB was used to assess the probability of perfect detection, while R Studio was employed for estimating the sampling distributions.

2. Real-Time Suboptimal Placement of Spatial Sensing Robots to Detect Poisson Distributed Targets

- Research
  - Problem: a) Computing the optimal solution for sensing robot placement to detect uncertain 1-D target arrivals is NP-hard, making it computationally prohibitive and unsuitable for real-time applications.
    b) Additionally, while the literature provides approximate solutions for deterministic target models, the difference between these approximations and the optimal solution has not been thoroughly analyzed.
  - Action: Led the project by: a) Proposing an approximation algorithm for real-time applications based on Jensen's inequality, which provides a guaranteed lower bound. b) Conducting an upper bound analysis of Jensen's gap to quantify the difference between the approximated and optimal solutions.
  - Results: a) The proposed approximated objective function guarantees 63.3% optimality of the lower bound by leveraging the property of submodularity, with a computational time of less than 0.01 seconds when deploying 100 sensing robots.
    b) Numerical simulations show that the maximum upper bound of Jensen's gap is small, and the actual difference between the approximated and optimal solutions is even smaller.
- Tools/Methods:
  - Developed simulations in MATLAB to measure the computational time of each run with the proposed online algorithm. Additionally, the simulations demonstrate the upper bound of the difference between the optimal and approximated solutions, validating the efficiency and accuracy of the approach.

3. Suboptimal Sensing Robot Deployment for Barrier Coverage of Poisson Distributed Target Trajectories in 2-D

- Research
  - Problem: Developing an uncertain two-dimensional (2-D) linear target trajectory model is challenging due to the complexities of the original domain. Moreover, accurately representing the interaction between the uncertain linear target trajectory and the sensing performance function adds further difficulty to the modeling process.
  - Action: Led the project by utilizing a bijective transformation to map linear target trajectories to unique points in a different domain. Similarly, the sensing performance function was also mapped to this domain, enabling a clear representation of the interaction between the target trajectory and the sensing performance..
  - Results: The optimal sensing robot placement problem was redefined in the transformed domain, enabling the application of a similar algorithm to the one I developed for the 1-D sensing robot placement problem. This redefinition allows for more efficient solutions while maintaining the effectiveness of the original approach.
- Tools/Methods:
  - Developed simulations in MATLAB to search for optimal sensing robot locations for detecting uncertain linear target trajectories in a transformed domain. The intensity of the target trajectory was estimated using R-Studio, enabling accurate modeling of the uncertain trajectories.

4. Suboptimal Spatial-Temporal Scheduling of Sensing Robots for Uncertain Target Detection

- Research
  - Problem: a) In the detection of uncertain target arrivals, robots are not only optimally deployed but also scheduled to operate on/off due to limited resources, such as battery life, to maximize mission efficiency.
    b) As robots are deployed for target detection, their stochastic and sensing performance can vary over time due to environmental factors (e.g., sensor burial), impacting overall detection capabilities.

    - Action: Leading the project by: a) Formulating a novel problem that simultaneously computes suboptimal robot locations and on/off scheduling for detecting uncertain target arrivals. b) Incorporating a time-varying sensor performance function into the problem, accounting for dynamic changes in sensor effectiveness over time.
    - Results: a) Utilizing an uncertain spatial-temporal target arrival model, both suboptimal robot locations and their on/off temporal schedules are computed. b) Incorporating a stochastic and time-varying sensing performance model results in better performance compared to not accounting for these factors.
- Tools/Methods:
    - Developed simulations in MATLAB to suboptimally search for the locations of a set of robots and their respective on/off scheduling. The spatial-temporal target arrival intensity was estimated using R-Studio code, enhancing the accuracy of the deployment and scheduling strategy.

5. Decentralized Mult-Robots System for Uncertain Target Detection in Real-Time

- Research
    - Problem: Once robots are deployed for detecting targets, they begin collecting target data and adjust their locations based on informed decisions. However, making centralized decisions in real-world scenarios becomes challenging due to limited communication between robots, often caused by physical distance.
    - Action: Leading the project by implementing a decentralized approach for estimating the intensity function, where each robot utilizes its own collected data and partially shared information from other robots. This allows the robots to make decisions locally, significantly reducing the reliance on centralized control and communication.
    - Results: The decentralized system demonstrated improved scalability and robustness compared to centralized methods. Each robot's local decision-making, supported by partial information sharing, led to faster adaptation and higher detection rates in scenarios with limited communication. This approach reduced computational load and achieved more efficient real-time target detection, particularly in environments with restricted communication.
- Tools/Methods:
    - Developed in MATLAB to test the distributed system. These simulations incorporated real-time target movement and stochastic arrival models, allowing each robot to adapt to its local environment. The system was evaluated by comparing the detection accuracy and decision-making efficiency of decentralized versus centralized models.

6. Resilience Improvement in Optimal Power Flow (OPF) using Interior Point Method with Dual-Simplex Initialization

- Research
    - Problem: In the event of a disruption, power systems operating in islanded mode must quickly find an optimal operating point to maintain resilience and prevent system failures or equipment damage. Commonly used linear programming (LP) solvers, such as the simplex method and the interior point method (IPM), each have drawbacks: the simplex method is slow for large systems, while the IPM can suffer from delays due to starting at an ill-conditioned point.
    - Action: As the project lead, I addressed this issue by proposing a novel approach that combines the dual-simplex method with the IPM. The dual-simplex method is used to find a suitable initial feasible point for the IPM, allowing it to bypass ill-conditioned starts and significantly reduce computational time. This hybrid approach enhances the computational efficiency of solving optimal power flow (OPF) problems in islanded systems, especially those with ill-conditioned step lengths.
    - Results: The proposed method was validated on a modified IEEE 3-bus system. Iterative testing, with up to 5,000 iterations, demonstrated that the dual-simplex initialization improved the speed of the IPM solver by 1.31 to 2.44 times compared to using the methods individually, depending on the number of iterations. This confirmed the robustness and effectiveness of the solution.
- Tools/Methods:
    - The implementation was carried out using MATLAB, and the experiments were run on a system equipped with an Intel Xeon CPU E5-2680 v4 processor.

EDUCATIONAL EXPERIENCE

Created Lab Textbook titled *"Three-Phase DC/AC Inverter for PV Systems using MATLAB/Simulink"* June 2018-Oct 2018

- Non-technical:
  - Developed a graduate-level lab textbook providing practical insights into renewable energy systems and power electronics, bridging theory and real-world applications for hands-on, applied learning purpose.
  - Objective: The primary goal of this lab is to teach students how to model and control power electronic converters integrated with photovoltaic (PV) systems. Through four labs, students will gain hands-on experience in building, simulating, and controlling PV systems using MATLAB/Simulink, emphasizing practical applications of theory in renewable energy systems.
- Technical:
  - Learning outcomes: students will
    - Learn the fundamentals of PV energy generation and integration with power systems.
    - Understand the operation and control of power electronic components, including boost converters and inverters.
    - Develop skills in building and debugging complex simulation models in MATLAB/Simulink.
    - Learn key concepts such as Maximum Power Point Tracking (MPPT), pulse-width modulation (PWM), and current control techniques.
  - Summary of chapters
    - Introduction: Provides an overview of the lab's focus on PV system modeling and control using MATLAB/Simulink, highlighting the importance of mastering simulation tools.
    - Lab 1: Teaches students to model a basic PV cell in Simulink, focusing on fundamental circuit components and generating I-V and P-V characteristic curves.
    - Lab 2: Covers the integration of a PV system with a boost converter, including MPPT for optimizing energy output and voltage control.
    - Lab 3: Introduces single-phase DC/AC inverters, focusing on current control using a PI controller and pulse-width modulation (PWM) techniques.
    - Lab 4: Explores three-phase inverter control using dq-frame transformations and active/reactive power control in a PV system.

Teaching Assistant

- Virginia Tech, ECE 2514: *Computational Engineering* Aug 2024- Present
  - Non-technical:
    - Held with an office hours of 8 hours per week, provided feedback for the homework/assignment for further improvement, and proctored exams.
    - Led weekly lab sessions, explained core concepts, and guided students through coding exercises.
  - Technical:
    - Main learning objective: To teach students to develop software solutions for electrical and computer engineering applications by focusing on abstract thinking, modeling, simulation, and data analysis, alongside software design, implementation, and testing through team-based projects.
    - Tools: Visual Studio Code, GCC, CMake, Github, and Autograde
- Georgia Tech, MGT 2250 - *Management Statistics* Aug 2016- Dec 2016
  - Non-technical:
    - Assisted with office hours, responded to the questions via email, and proctored exams.
  - Technical:
    - Main learning objective: To equip students with a solid foundation in statistics for business decision-making by covering key concepts such as variation, probability, statistical inference, and linear regression, with a focus on applying these tools to real-world business scenarios like profitability assessment and forecasting.
  - Tool: Microsoft Excel

ACTIVITIES & AWARDS

Competition: CityLearn Challenge (*Our Team ROLEVT Wins 1st Place/ led by : Prof. Jin, Ming*) May 2020-Aug 2020

- Formulated optimization models for storage management to reduce electricity consumption and emissions
- Evaluated our reinforcement learning (RL) method across diverse and unknown scenarios, ensuring robustness and adaptability of the approach.

Institute of Electrical and Electronics Engineers (IEEE), Georgia Tech Chapter, Vice President May 2017-July 2017
Institute of Electrical and Electronics Engineers (IEEE), Georgia Tech Chapter, Treasurer Oct 2016-May 2017
Out-of-State Tuition Waiver at Georgia Tech Summer and Fall 2016

- Awarded based upon academic performance and participation in activities to help internationalize campus

Outstanding Academic Performance of Scholarship (*ranked 1st in the class*) Nov 2012
Awarded by Electrical Engineering Technology Department at Oklahoma State University

REFERENCES

Dr. Daniel J. Stilwell, Professor, Electrical and Computer Engineering, Virginia Tech
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Dr. Harun Yetkin,
Assistant Professor, Mechatronics Engineering, Bartin University (Turkey),
Research Assistant Professor, Electrical and Computer Engineering, Virginia Tech
Email: hyetkin@bartin.edu.tr / yetkinh@vt.edu / Phone: +90 (378) 501 10 00

Dr. Ryan K. Williams, Assistant Professor, Electrical and Computer Engineering, Virginia Tech
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