

MIT THINK 2024-25 Finalists

Neural Radiance Fields for Precise Odometry Calibration in Autonomous Path-Following Systems

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Abstract: Autonomous vehicles have become increasingly significant in today's world - from drones for disaster recovery to self-driving car systems created by Waymo and Tesla. As the world starts to lean on driverless technology, the importance of robust and accurate path-following skyrockets – and with it, the importance of precise sensor feedback. Sensor feedback is the backbone of all path following algorithms – Pure Pursuit, MPC, etc. all need precise odometry retrieved from sensors in order to perform their functions optimally. A quite important problem in the field of sensor integration is ensuring noisy and inaccurate outputs are filtered properly – the proposed method aims to develop a novel, efficient way to calibrate an autonomous agent's odometry. I propose calibrating an autonomous agent with its environment through the use of Neural Radiance Fields (NeRFs). Neural Radiance Fields are leveraged to synthesize a detailed and high-fidelity 3D reconstruction of the agent's environment - given a preconstructed NeRF, by comparing the camera view from the autonomous robot and a synthesized camera view in the NeRF at the robot's estimated position, the deviation between the robot's actual and estimated position can be calculated through 3D-3D point alignment calculations. This method would only require the agent to utilize a camera and a proximity sensor like LiDAR, significantly reducing the variability in sensor noise. This approach enables the agent to align its odometry with its environment, allowing it to follow its trajectory more accurately and mitigate errors caused by noisy sensors or other adverse conditions.

Bug-Eyes: Autonomous Bug-Mimicking Robots Optimizing Computer Vision for Species Monitoring and Conservation

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Abstract: The rapid loss of biodiversity—up to 150 species disappearing daily—threatens ecosystem stability and global sustainability. Traditional methods of species monitoring are usually time-consuming, resource-consuming, and mostly inaccessible in remote areas, constraining conservation efforts badly. So, Bug-Eyes combines the power of computer vision to automate the identification and tracking of insect species for ecological monitoring at scale. Bringing the most up-to-date autonomous vehicle technology together, Bug-Eyes merges machine learning, robotics, and solar-powered autonomy in a slimmed-down system built to navigate fragile ecosystems. That way, it collects and analyzes ecological data in real-time, offering one crucial tool for conservationists to understand population dynamics, track endangered species, and make informed choices backed by real-time data. The project was placed with accessibility in mind, using open-source tools and modular, low-cost hardware, so it would be feasible even for researchers or organizations working in resource-restricted settings. Bug-Eyes shows how technological innovation can contribute to advancing ecological preservation in a period of unprecedented environmental change when there is a critical need for monitoring and protection of biodiversity.

MoML-CA: A Hybrid Molecular Modeling and Machine Learning Framework for PFAS Contaminant Analysis

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Abstract: Per- and polyfluoroalkyl substances (PFAS) pose a persistent threat to water safety due to their stability, toxicity, and lack of natural degradation pathways. Conventional methods (e.g., granular activated carbon and reverse osmosis) often struggle to remove novel short-chain PFAS, while time-intensive laboratory experiments and traditional molecular modeling alone can be costly and limited in scalability. We propose MoML-CA (Molecular Modeling & Machine Learning for Contaminant Analysis), a hybrid computational framework that integrates molecular modeling with multi-scale graph neural networks (MGNNs) and long short-term memory (LSTM) networks to predict PFAS behavior and fate in water treatment systems. Our pipeline leverages OpenMM for molecular dynamics (MD) simulations, coupled with an iterative feedback loop between MGNN, MD, and LSTM components. Through this process, we aim to achieve greater than 90% predictive accuracy of PFAS properties while reducing simulation time by at least 30% compared to standard MD approaches. Real-world water quality data from Cedar Falls and Waterloo utilities will be used for validation. By adjusting parameters like pH and residence time, MoML-CA will recommend cost-effective, eco-friendly PFAS removal strategies. Our work directly supports Sustainable Development Goals #6 (Clean Water and Sanitation) and #14 (Life Below Water), providing an open-source framework to address emerging contaminants in drinking water globally.

Toxic Traits in Microgravity: Exploring *Microcystis aeruginosa* Genome Sequencing and Toxin Production in Simulated Microgravity Using a 3D Clinostat

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Abstract: *Microcystis aeruginosa* is a bloom-forming cyanobacterium that produces the hepatotoxin microcystin. Although extensively studied in aquatic environments, its growth rate and toxin production in space have not been well explored. Understanding how *M. aeruginosa* responds to microgravity is crucial, as cyanobacterial toxins may contaminate drinking water in space and pose a more lethal risk. Previously, we assessed toxin production, cell count, photosynthetic activity, and macroscopic variations through ELISA bioassays, flow cytometry, and AquaPen readings. The experimental groups were subjected to horizontal and vertical rotation on a 2-D clinostat, with a static ground control. We also reviewed literature comparing 2-D clinostats to other microgravity simulators like parabolic flight and 3-D clinostats. This information is essential for evaluating the validity of clinostats in simulating microgravity. By studying how simulated microgravity impacts *M. aeruginosa*, this research contributes to our understanding of cyanobacterial biology in space and explores practical methods for future space-based microbial research. This study advances the understanding of the potential risks of toxin production in space environments and supports the development of life-support strategies for long-term space missions. Ideally, we hope to utilize more accurate microgravity simulations models such as a 3- D clinostat and use CRISPR-Cas9 to minimize microcystin production