Project Preferences: CS6953 Name Anthony Le (u1368721)

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1. (Most Desired) Reinforcement Learning for Road Sign Detection and False Positive Elimination

This project aligns closely with my interests in leveraging reinforcement learning (RL) in robotics to optimize systems for complex decision-making tasks. My research involves developing adaptive control strategies using data-driven (and potentially RL) approaches for a robotic system to replicate physiological gait motion in cadaveric lower limb specimens for preclinical foot and ankle orthopedic applications. This approach improves the accuracy in replicating gait and reduces the need for manual tuning in the robotic system. Similarly, this road sign detection project focuses on fine-tuning detection systems with RL to optimize performance in varying and uncertain real-world conditions while reducing the need for manual corrections in detection systems. While my current research does not yet incorporate RL, I recognize its potential and have built foundational experience through online coursework, including courses from Udacity/Georgia Tech. This project offers an exciting opportunity to expand my hands-on experience with RL, which will be valuable in my future career in industry. RL is a powerful tool for tackling many practical challenges, and deepening my expertise in this field will enable me to apply it effectively.

Qualifications and Background:

- Completed coursework in sequential decision-making in robotics and reinforcement learning and integrated complex control systems with advanced algorithms for biomechanical modeling
- Extensive experience designing data-driven control algorithms to accurately replicate motion patterns in robotic systems for cadaveric simulations
- Implemented deep learning models (CNNs, LSTMs, transformers) and uncertainty quantification methods for various applications, including predicting biomechanical forces, modeling variability in gait analysis, and quantifying risk in soft tissue manipulation for robotic surgery
- Directly addressed real-world variability and noise in biomechanical and clinical datasets, paralleling the challenges of enhancing detection systems under different environmental conditions
- Strong Python programming skills and practical expertise in developing deep learning models using PyTorch and Tensorflow, coupled with advanced statistical analysis

Proposed Strategy:

1. Research
   - Study existing road sign detection models and identify opportunities for RL optimization
   - Familiarize with advanced RL methods like Proximal Policy Optimization (PPO) and their applications to object detection
2. Develop
   - Incorporate RL into the feedback loop of the pre-trained deep learning detection models, using a reward function to minimize false positives
   - Simulate varied conditions (e.g., weather, lighting) for model refinement before testing on real-world data
3. Evaluate
   - Benchmark the RL-enhanced system against baseline models using precision-recall and F1 score
   - Perform iterative improvements based on performance metrics and user feedback
4. Document
   - Document model architecture, RL integration, and key findings
   - Provide recommendations for scalability and potential applications to other autonomous systems

2. Deep Learning for Estimating Lane Line Quality Using Retroreflectometer Ground Truth

This project combines hands-on field experimentation with deep learning applications, which I find especially appealing. I'm excited by the challenge of training models to assess lane quality using practical, real-world data. The use of retroreflectometer measurements as ground truth aligns with my interest in working with high-quality datasets to solve tangible problems. Additionally, I've noticed the poor visibility of lanes while driving around Salt Lake City, and I would find it rewarding to address this issue, ultimately contributing to safer driving conditions for everyone.

Qualifications and Background:

- Skilled in deep learning with experience designing CNNs and transformer-based models for sequence and spatial data analysis
- Practical experience processing time-series data for biomechanical applications, analogous to training models on datasets for lane line quality
- Strong statistical background for analyzing retroreflectometer data and aligning predictions to ground truth measurements
- Familiarity with real-world data collection and experimental design, including the use of motion capture and force sensors

Proposed Strategy:

1. Research
    - Understand retroreflectometer technology and its dataset characteristics
    - Review existing methodologies for assessing lane line quality
2. Develop
    - Collect retroreflectometer data to serve as ground truth for lane line quality
    - Develop preprocessing pipelines for images and retroreflectometer data, ensuring data integrity
    - Train a CNN or transformer-based regression model to predict lane line reflectivity from images, leveraging data augmentation and transfer learning for robustness
3. Evaluate
    - Validate the model by comparing predictions to retroreflectometer measurements using regression metrics like MAE and RMSE
    - Test robustness across varied environmental conditions and iteratively refine the model
4. Document
    - Provide a dataset of images with corresponding retroreflectometer measurements
    - Deliver a model capable of accurate reflectivity predictions
    - Compile a comprehensive report detailing data processing, model performance, and opportunities for improvement

3. (Least Desired) Deep Learning-Driven 3D Reconstruction, Data Synthesis, and Size Estimation for Road Signs

This project is particularly intriguing to me because of its dual focus on leveraging deep learning for both 3D reconstruction and dataset generation. Its hands-on nature complements my skills in robotics and deep learning. The integration of Blender to create synthetic datasets adds a creative layer that appeals to my engineering background.

Qualifications and Background:

- Experience with 3D reconstruction through medical imaging, including CT and MRI scans, to generate 3D bone models for biomechanical modeling
- Proficient in deep learning methods, including CNNs and transformer-based architectures, which align well with image-to-3D modeling and parameter prediction
- Strong Python programming skills and experience in data synthesis and preprocessing

Proposed Strategy:

1. Research
    - Explore Blender scripting for 3D modeling and investigate relevant datasets for training the size estimation model
    - Understand parameterization techniques to generate diverse and realistic 3D models
2. Develop
    - Develop a Python pipeline integrating Blender for parameterized synthesis of 3D road sign models, including shape, size, and texture adjustments
    - Train a CNN or transformer model to predict sign dimensions using both synthetic and real-world data
    - Combine the dataset generation pipeline with the prediction model, ensuring real-time estimation capabilities
    - Explore extensions like Optical Character Recognition (OCR) for detecting textual elements on signs
3. Evaluate
    - Test model performance using datasets with known ground truth for dimensions, reporting metrics like RMSE and accuracy
    - Validate the integration system by evaluating its ability to generalize across varying sign types and environmental conditions
4. Document
    - Deliver an integrated tool combining 3D synthesis, dimension estimation, and OCR capabilities
    - Create user-friendly documentation detailing model development, integration, and practical applications