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人形機器人騎乘電動機車
Humanoid Robot Riding an E-Scooter

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Abstract—This project aims to develops the necessary tools for control, motion-planning and perception to achieve two world-firsts: (a) Driving an e-scooter and (b) successfully passing the Taiwan driving license test, using anunmodified 1.4m tall humanoid robot.

Introduction

The experimental platform used comprises a **Gogoro scooter** and a **Thormang3** humanoid robot

Figure 1. Thromang3 riding a Gogoro scooter

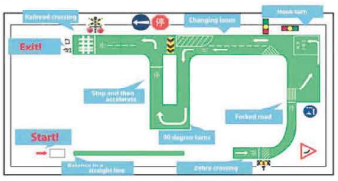

Figure 2. Taiwanese scooter license test diagram

The primary challenge of this research is the **simulation-to-reality** gap, which was addressed through rigorous simulation testing before real-world implementation.

Simulation

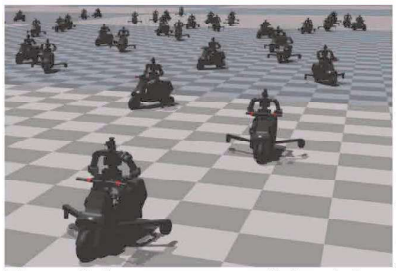

Figure 3. Isaac gym parallel training

NVIDIA's Isaac Gym parallel simulations used for testing various control strategies and fast training of neural networks. Every neural networks learns to control a **different version of the scooter** with a set of different parameters such as weight, speed, delay, ect. This makes the network more robust

Control Methods

Different advanced methods were tested and used to solve the difficult "**sim to real**" problem.

Inverse kinematics

To avoid breaking the robot the neural network can control the robot thought a carefully made inverse kinematics that can automatically **determine the seating position** of the robot and computes the joints position for a given steering angle.

Neural networks

IsaacGym training using **2048 simultaneous simulations** resulting in a Model trained in **30 seconds**.

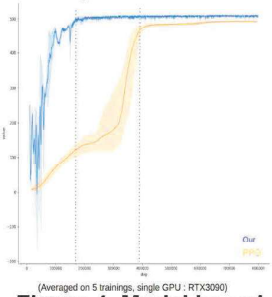

Figure 4. Model based training results

Extensive **domain randomisation** and state of the art **PPO** were used to train a well performing neural network. Different **model based** approaches are currently tested, allowing the use of real data in the training loop making sim to real easier. This approach works in simulation and will be tested soon on the real robot.

Results

Simulation-to-reality gap crossed resulting in the **world first** humanoid robot driving a scooter

Figure 5. Fully autonomous driving in straight line (PPO)

Our system is able to control a electric scooter in difficult **low speed** conditions and fully **maintain control** over the systems, allowing to perform right and left turns unlocking simple path planning in the future.

Figure 6. Robot performing a left turn (PPO)

Future work

Refining the controls for **prolonged driving** and adding a **VSLAM** in view of passing the taiwanese **scooter licence test**.