COMP7705 Project
Detailed Project Proposal

Project Title.	Parallel Balanced Wheel-Leg Robot Based on Deep Reinforcement Learning
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Aim

The main goal of this project is to improve the adaptability and movement efficiency of wheel-legged robots in complex terrain, with the following specific objectives:

1. Design and build wheel-legged robots:
Develop an innovative wheel-legged robot with a 5-link balanced wheel-leg structure to improve its stability and agility. The design will take into account the needs of multiple terrains to ensure that the robot can effectively respond to different environmental challenges.

2. Development of efficient control systems:
Design and implementation of a deep reinforcement learning based control system that enables a wheel-legged robot to autonomously learn and optimize its locomotion strategy. The system will use environmental feedback to adjust the robot's behavior to achieve better walking capabilities on diverse terrains.

3. Enhancing terrain adaptation:
By training the robot to move through different environments (e.g., uneven ground, ramps, obstacles, etc.), its ability to adapt to complex terrain is enhanced. The goal is to enable the robot to maintain stable walking under different physical conditions and avoid obstacles effectively.

4. Deploying control systems in edge computing environments
Enabling edge computing deployment of control systems on wheel-legged robots to reduce latency and improve real-time responsiveness. Enhance the autonomy and responsiveness of the robot by performing data processing and decision making locally on the robot, thereby improving overall performance.

By achieving the above goals, this project aims to advance the wheel-legged robots control of to make them more efficient and reliable in real-world applications, especially in complex and dynamic environments.

Brief Literature Review

Overview of wheel-legged robots:
Wheel-legged robots are a new type of robot that combines the characteristics of wheeled and legged robots. They are able to move flexibly over different terrains through the combination of wheels and legs. Compared with traditional four-wheeled robots, wheel-legged robots are more adaptable in complex environments and can effectively deal with obstacles and uneven ground.

Control methods:
Traditional control methods (e.g., PID algorithms and LPC algorithms, etc.) perform well when dealing with simple environments, but often fail to respond effectively in complex dynamic environments. In recent years, more and more studies have begun to employ deep and reinforcement learning techniques to improve the adaptability of robots in complex environments. For example, certain literature demonstrates successful cases of using deep reinforcement learning to optimize robot motion strategies, showing the potential of this approach in improving robot autonomy and intelligence

Deep reinforcement learning:
Deep Reinforcement Learning (DRL), as an emerging control method, has been widely used in the research of wheel-legged robots.DRL is capable of effectively handling complex dynamic environments by learning optimal control strategies through interaction with the environment. It has been shown that using deep algorithms such as), wheel-legged robots are able to learn autonomously from simple movements to complex tasks.Q-network (DQN) and proximal policy optimization (PPOThe introduction of DRL not only improves the efficiency of robot movement, but also opens up new directions for its application in the real world.

Existing tools and resources:
Several open source projects and tools provide valuable resources for researchers in wheel-legged robotics research:
Wheel-Legged-Gym: a reinforcement learning-based simulation platform dedicated to motion control and strategy optimization for wheel-legged robots. The platform provides a variety of environments and tasks to support researchers in testing and validating various control algorithms.
legged_gym: This project provides researchers with a flexible simulation environment focused on the control and optimization of leg movements. It integrates a variety of physics engines to provide support for the application of deep learning algorithms.
rsl_rl: This is a library focusing on deep reinforcement learning, aiming to provide efficient algorithms and tools for wheel-legged robot control. The project facilitates the comparison and evaluation of different algorithms, providing researchers with a basis for selecting appropriate control strategies in real-world applications.

While the combination of wheel-legged robots and deep reinforcement learning shows great potential, a number of challenges remain, including:

High-dimensional state spaces: state spaces in complex environments are often very large, increasing the difficulty of learning.
Training efficiency: deep reinforcement learning usually requires a lot of training time and computational resources, how to improve training efficiency remains a key issue.
Real-time control: applying the trained model in real-time control to ensure its fast response and stability is also the focus of future research.
Transformation of Simulation to Reality: Migration from simulation to reality is still a challenge in practical applications. There are many unpredictable factors in real environments, such as lighting variations, ground friction, etc., which may not be fully modeled in simulation.

Proposed Methodology

The research methodology of this project will be centered on the design of the wheel-legged robot, the development of the control system, and Deep Reinforcement Learning (the application of). The specific steps include the following main components:DRL
1. Robot design and construction
Mechanical structure design:
A is usedfive-link balanced wheel leg structure , and its stability and maneuverability on different terrains are considered during the design process.
Modeling and the strength and stiffness of the structure was verified.was performed using Solidworks.
Hardware selection and integration:
Selecting the right motors, sensors, and controllers ensures that the hardware is capable of meeting motion and control needs.
When integrating hardware, ensure that the electrical and mechanical parts work together effectively to ensure overall performance.
2. Control system development
Use the ROS platform:
Builds control systems on Linux systems, utilizing the functional libraries and tools provided by ROS (Robot Operating System).
Develop sensor data processing module to acquire environmental information in real time and perform data fusion.
Control Algorithm Design:
Design of a model-based control algorithm as a baseline control strategy.
Control strategy optimization using deep reinforcement learning.
3. Deep and intensive learning training
Simulation environment construction:
Use simulation platforms such as Wheel-Legged-Gym to simulate different terrain and environmental conditions to create diverse training scenarios.
Design reward functions to encourage robots to move efficiently, avoid obstacles and maintain balance in complex terrain.
DRL algorithm selection:
Select suitable for this projectDRL algorithms , such as Deep Q Network (DQN), Proximal Policy Optimization (PPO), etc., and train and optimize the policies based on these algorithms.
Implementing domain randomization techniques to enhance the generalization of training

models to real-world environments.
4. Transformation from simulation to reality
Transfer Learning:
After training is completed in the simulation environment, the learned strategies are applied to the real robot using transfer learning techniques.
Adjusting model parameters to adapt to changes in the real environment ensures that the robot can operate stably in a realistic scenario.
Step-by-step testing:
Start in a controlled environment, gradually increase the complexity, and continuously optimize the control strategy through feedback in the real environment.
Record test data, analyze robot performance and make necessary adjustments.
5. Experimentation and evaluation
Performance Evaluation:
A series of experiments were designed to evaluate the performance of the robot in different terrains and environments, including metrics such as speed, stability and energy consumption.
Experimental results were analyzed using quantitative and qualitative methods to assess the effectiveness of deep reinforcement learning algorithms.
Optimization and Iteration:
Optimization of algorithms and hardware is performed based on the experimental results, forming a feedback loop to continuously improve the robot performance.
Regular summaries of results and technical debriefings are conducted to ensure transparency and traceability of the project.

Milestones

Tasks		*Estimated completion time*	*Estimated number of Learning hours*
1	Robot design and construction	4.1	20
2	Control system development	4.15	40
3	Deep reinforcement learning training (simulation)	5.20	80
4	Deploying control systems to edge computing environments	5.25	40
5	Deep reinforcement learning training (realistic)	6.8	40
6	Experimentation and evaluation of different algorithms	6.13	40

7	Project page	7.12	20
8	reporting	7.15	20
9			
10			
			Total: 300

Deliverables

Items	
1	Robot Simulation Results
2	Robot Mechanical 3D Drawing
3	physical robot
4	Robot Hardware Systems
5	Robot Control System
6	Project web pages and reports
7	
8	
9	
10	