1. Project ID: 1803679 Padlock and Safe Cracking with Machine Learning

Project description:

This is a practical project and the student should have hands-on experience with Raspberry Pi/Arduino interfaces, and a keen interest in Machine Learning (and doing lots of experiments).

1. Project ID: 1803816 Pet health monitoring

Project description:

This research project aims to adapt contactless health sensors, originally developed for humans, for use in small animals. The student will evaluate the feasibility of modifying these vital signs monitoring devices to work effectively with cats and dogs. Working alongside veterinary research collaborators and our technical team at the Imperial Next Generation Neural Interfaces Lab, the student will conduct a small study to collect health data from these animals. The project involves adapting the sensors, gathering vital signs data, analysing these results, and comparing them against traditional veterinary monitoring methods. This research could potentially advance veterinary care technology by introducing more sophisticated, non-invasive monitoring tools for small animals.

1. Project ID: 1803831 Control for active suspension systems of road vehicles

Project description:

This project will design robust control systems for the Series Active Variable Geometry Suspension (SAVGS) and the Parallel Active Link Suspension (PALS) for road vehicles that simultaneously improve ride comfort and road holding (high frequency dynamics) and body attitude motions (low frequency dynamics).

1. Project ID: 1803832 Control of dual-motor electric vehicles

Project description:

This project will investigate the energy management control of dual-motor electric vehicles using offline optimal control and online predictive control strategies, to improve their energy efficiency.

1. Project ID: 1803837 Computer Vision and State Estimation of a Parrot Minidrone

Project description:

This project focuses on the development of a state estimation framework for a Parrot quadrotor vehicle. The vehicle is designed for indoor operation, which complicates the problem of position estimation due to the inability to use GPS as a means of correcting for estimator drift. Instead, the quadrotor must process images generated by its onboard camera alongside the data produced by its ultrasonic sensor, inertial measurement unit (IMU), and pressure sensor into a single state estimate that is reliable enough to enable indoor navigation.

The project entails building upon the rudimentary optical flow implementation currently used on the drone and designing a filter framework to combine all of the sensor measurements. Areas of focus include implementing more recent computer vision techniques to improve the quality of the image-based velocity estimation, incorporating loop-closure for position estimation as part of the vision pipeline, and deriving a Kalman filter from the vehicle and sensor dynamics. Work will begin inside a realistic Simulink simulation environment then proceed to deployment and testing on real hardware. As such, any approach developed is expected to work within the constraints of the limited computational power available onboard the quadrotor.

Anyone interested in taking this project should be familiar with MATLAB and Simulink, as well as with the basics of modern computer vision and state estimation.

1. Project ID: 1803895 Learning-based safe control of aerial robots

Project description:

Aerial robots have been widely used in critical applications such as search and rescue, surveillance, and infrastructure inspection. Operating in complex and dynamic environments requires robust control systems that can adapt to disturbances and changes in the environment. Traditional control methods may struggle to handle this, while purely data-driven approaches may lack safety guarantees. This objective of this project is to develop a new strategy that integrates data-driven method with control-theoretic safety assurances, enabling aerial robots to adaptively synthesize safe control policies. The candidate will be asked to (i) conduct a literature review on the topic; (ii) develop efficient data-driven MPC for safe aerial robots; and (iii) validate the approach via simulations and experiments.

1. Project ID: 1803893 Probabilistic modelling of human driving behavior for safe motion planning

Project description:

Understanding and predicting human drivers’ actions is critical to ensuring safe and smooth integration of autonomous vehicles into mixed-traffic environments. Traditional motion planning approaches often rely on deterministic models, which fail to account for the inherent uncertainties in human driving behavior. By using probabilistic modelling techniques, one can capture the range and likelihood of possible human driving actions, enabling the AV to anticipate and respond more effectively to unpredictable maneuvers. This project aims at developing a probabilistic framework to model human driving behavior for safe motion planning of autonomous vehicles. In detail, the candidate will be asked to (i) conduct a literature review on the topic; (ii) model the probabilistic behavior in a data-driven way; (iii) apply known control techniques to develop an efficient prediction and safe motion planning strategy for ego vehicle; and (iv) validate the approach via simulations.

1. Project ID: 1803890 Design of an open-source electric drive system for wheelchairs

Project description:

Electric wheelchairs are key for the autonomy and the quality of life of millions of people with mobility impairments. However, their cost is a big problem for low-income population in less developed countries. One of the things that make them expensive is that they are often oversized to carry large weight on steep slopes; however, there could be opportunities to make them less expensive if they were tailored to the specific, and perhaps less demanding, needs of the user. The aim of this project is to develop an open source drive system for an electric wheelchair for anyone to use and adapt. The idea is to design something that can be integrated into existing non-powered wheelchairs and to pay great attention to the cost and the robustness of the design. The project is suitable for students interested in hardware and hands-on design and prototyping. Candidates are expected to design, build and test PCBs as well as use 3D-printers to create wheel motor couplings, etc..

1. Project ID: 1803905 SmartPower4Good: control for wireless charging of robot wheelchairs

Project description:

Description

Powered wheelchair users (similar with electric cars users), suffer from range anxiety; people with disabilities heavily rely on assistive systems, for example power wheelchairs (PWCs [2]), for completing activities of daily living. However most of these assistive technology users still rely on plug-in chargers, which is both inconvenient and limiting, as PWC users regularly have limitations in their physical abilities, thus relying to a caregiver for this crucial task. Relevant literature [1] still reports that as a result, PWC users travel 3.6 times less than an average person walks, and around 30% less than those that use manual wheelchairs; at least 50% of PWC users have been stranded at least once, causing the user to experience issues of charging anxiety, and feeling of lack of independence. We would like to improve the use of wireless chargers for smart wheelchair users, along the lines of existing work with electric scooters.

In this project, you will work towards a (shared) control system that will help robot wheelchair users to navigate their wheelchair to align with a wireless charging system (WCS, developed in collaboration with Prof Mitcheson's group). Such WCS can be installed in bus stops, trains etc. Given that powered wheelchairs users might find difficult to dock with such installations, we would like to help them by developing motion control systems that assist in alignment to maximise charging. (Imagine that your mobile phone move could move by itself through motors to align better with a Qi charger).

You should be interested in signal processing, computer vision, control and robotics, and be happy with interfacing electronics (sensors, control and power systems) and writing control algorithms (typically in C/C++ under Linux). You must be interested in implementing and seeing your algorithms working on real robots. You should maintain a regular working pattern throughout the year, and start early, since working with real robots is not compatible with last minute work cramming.

Times for further information at my office EEE\_1011:

-- Tuesday, 19th November, 13:00-14:00

-- Tuesday, 26th November, 12:00-13:00

Please email me if you cannot make any of the above in case I can meet you on other slots (not guaranteed before the end of November)

[1] C. Teeneti et al, “System-Level Approach to Designing a Smart Wireless Charging System for Power Wheelchairs”, IEEE Trans Industry Applications, 2021

[2] See robot wheelchairs (e.g. ARTY/ARTA -- we constantly experiment with new ones too) here: https://www.imperial.ac.uk/personal-robotics/robots/

1. Project ID: 1803895 Learning-based safe control of aerial robots

Project description:

Aerial robots have been widely used in critical applications such as search and rescue, surveillance, and infrastructure inspection. Operating in complex and dynamic environments requires robust control systems that can adapt to disturbances and changes in the environment. Traditional control methods may struggle to handle this, while purely data-driven approaches may lack safety guarantees. This objective of this project is to develop a new strategy that integrates data-driven method with control-theoretic safety assurances, enabling aerial robots to adaptively synthesize safe control policies. The candidate will be asked to (i) conduct a literature review on the topic; (ii) develop efficient data-driven MPC for safe aerial robots; and (iii) validate the approach via simulations and experiments.

1. Project ID: 1803935 AI-driven smart control of vehicle-to-grid flexibility for grid service provisions

Project description:

To achieve the net-zero target, electric vehicles (EVs) have recently received a prominent interest in electrifying the transportation sector due to their advantages of mobility and flexibility. Previous works have focused on vehicle-to-grid (V2G) technology that allows for an increased utilisation of EVs to make arbitrage by the temporal differentials of electricity prices. Nevertheless, the economic potential of EV flexibility may not be fully exploited, lacking an appropriate business model. This work aims to address this challenge by optimising the provision of multiple inter-dependent services, including charging service, demand management service, carbon intensity service, and balancing service. To solve this problem, a model-free and data-driven reinforcement learning (RL) method is proposed to learn the smart charging and discharging behaviours of EVs for multi-service provisions.

1. Project ID: 1803823 Advanced Velocity Control for a Robot Arm Using the RRMC Approach:

Project description:

develop and implement an advanced velocity control system for a robotic arm using the Resolved-Rate Motion Control (RRMC) approach. This involves designing a control algorithm that translates desired end-effector velocities into joint velocities, ensuring precise motion control.

Suggested Steps

1. Define the Application Environment

· Identify and define the specific application environment for the robotic arm, such as pick-and-place operations in manufacturing facilities, or sorting and packaging in logistics.

· Understand the operational requirements and constraints specific to the chosen industry.

2. Robot simulation · Simulate a robot from the available list in the Robotics System Toolbox Library · Import the robot’s rigid body tree model using the importrobot function

3. Kinematic Modeling

· Use the Robotics System Toolbox to model the kinematics of the robotic arm, including forward and inverse kinematics.

· Develop equations that relate end-effector velocities to joint velocities using the Jacobian matrix, and compute the pseudo-inverse for solving the inverse velocity kinematics problem.

4. Design of the RRMC Algorithm

· Define the desired velocity vector for the robot's end-effector in task space. This includes both linear and angular velocities that the end-effector should achieve.

· Compute the Jacobian matrix for the robotic arm, which relates joint velocities to end-effector velocities. This matrix is essential for converting task-space velocities into joint-space velocities.

· Use the pseudo-inverse of the Jacobian matrix to calculate the joint velocities required to achieve the desired end-effector velocities. This step involves solving the inverse kinematics problem in a differential manner.

· Derive the joint velocity commands from the pseudo-inverse operation. These commands specify how each joint should move to accomplish the task-space objectives.

· Implement a low-level joint-space controller to execute the computed joint velocity commands accurately.

· Enforce joint limits, prevent collisions, and handle dynamic constraints to ensure safe and reliable robot operation.

5. Visualize the robot and its task using Sim3D

Advanced project work:

1. Add null space projection terms to manage redundancy and optimize secondary objectives, such as obstacle avoidance or joint limit avoidance.

2. Prototype efficient algorithmic solutions for computing the Jacobian pseudo-inverse and Hessian terms needed for advanced controllers.

Background material

- Robotics System Toolbox

- Robotics library

- Robotics arm control examples

- Sim3D example