PORTFOLIO

2019 - 2024

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I am a 24 year-old Italian engineer recently graduated from the **MSc Robotics** programme at TU Delft, in the Netherlands. I did my bachelor's in **Automation Engineering** at Alma Mater Studiorum University in Bologna, also participating in a double degree programme with Tongji University in Shanghai.

I am **hardworking**, with good **problem-solving** and **communication** skills that make me a proficient **team player**.

Other than the scientific world, I am fond of **cinema** and **photography**. I also love **travelling** and visiting new places to discover different fascinating cultures and meet interesting people.

A more complete overview of my past project can be found at: https://github.com/GioeleBuriani/past_projects

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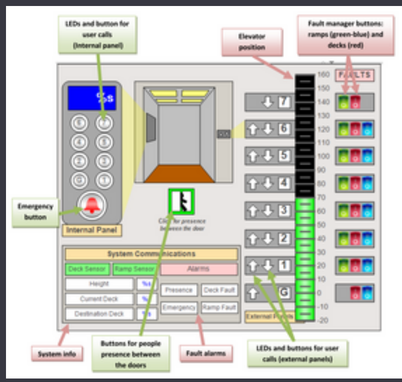
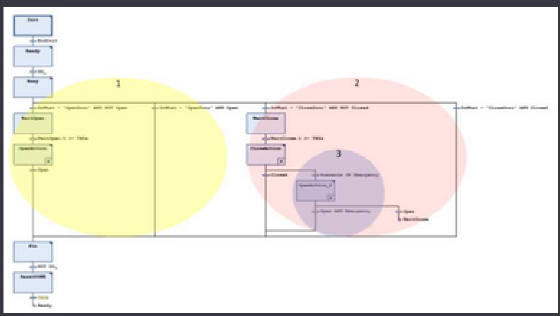
PLC Control for an elevator

Project Goal:

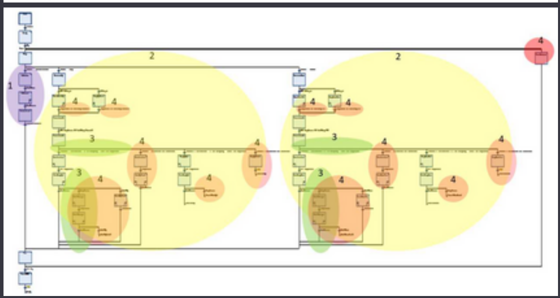
The project aimed to develop a control system for a simulated elevator using the CoDeSys environment. Key objectives included initializing the elevator, efficiently managing user calls from both inside and outside the cab, and considering simultaneous calls. The focus was on crafting a control policy that demonstrates a high degree of efficiency in handling calls and elevator functions.



The solution employed Sequential Function Chart (SFC) for mapping out control sequences, Structured Text (ST) for detailing specific actions within those sequences, and Function Block Diagram (FBD) for structuring the logic of Generalized Actuators (GAs). This blend of languages enabled a detailed control mechanism for both the elevator's hardware and software aspects.

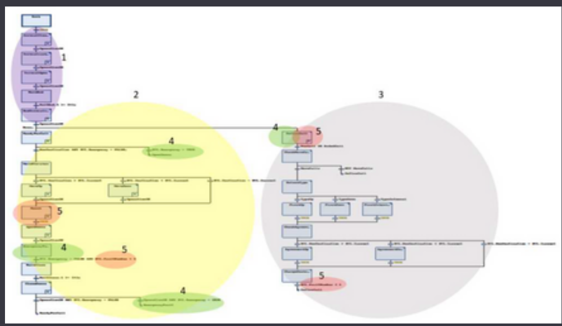


The DOORS GA, designed using inputs from the door sensors and controlling its actuators, facilitated the operation of elevator doors under normal and exceptional circumstances. This GA included logic to detect obstructions and manage door states during emergencies.



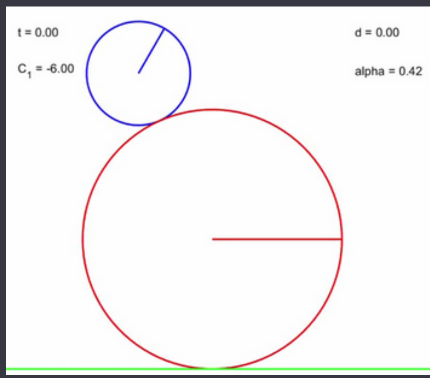
For vertical movement, the MOVE GA was central. It utilized sensors regarding the elevator's position and controlled the ascent and descent actuators. The GA featured an initialization phase to establish a baseline elevator position, followed by logic to adjust speed and direction based on real-time user input.

A Policy Algorithm orchestrated the overall system operation, integrating the DOORS and MOVE GAs. This algorithm initiated the system, handled user calls, and managed priorities. It was crucial for ensuring the system's adaptability, responding to user calls and system status to direct elevator movement efficiently.



Emergency and fault handling were integral to the system design, with protocols to maintain operation during sensor malfunctions and emergency stop conditions. The system's architecture facilitated robust responses to operational anomalies, ensuring continued service and safety.

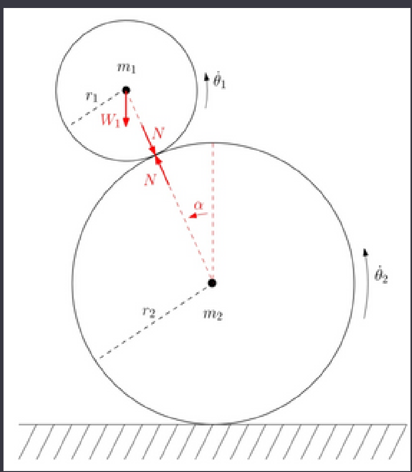
BSc thesis: 2D modelling and control of a ball-balancing robot



Project Goal:

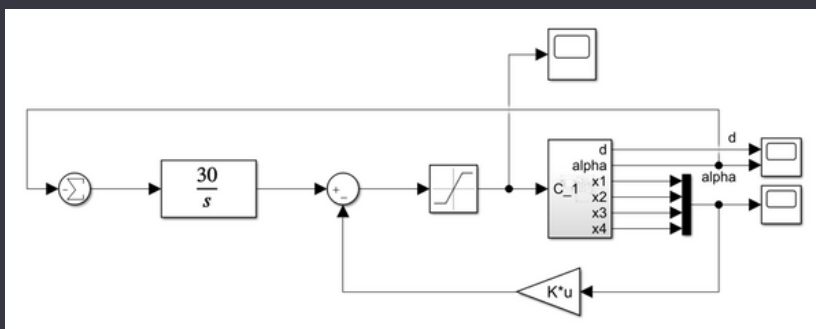
This project aimed to develop a 2-D model of a Ball-Balancing Robot, consisting of a wheel balancing on a cylinder. This required understanding the dynamics and interactions at the contact interface, primarily focusing on friction dynamics. The objective was to create a foundational model to guide the design of a more complex 3-D version of the robot, leveraging insights into the rolling and sliding behaviors at play.

The solution entailed two primary facets: modelling and control strategies for the ball-balancing robot in a 2-D plane.



The modelling phase explored the dynamics between the wheel and cylinder, focusing on rolling actions with both fixed and moving axes. It involved an analysis of contact dynamics, studying rolling friction and forces from applied torque. Equations described the system’s response in scenarios like pure rolling versus sliding, incorporating aspects like the tangential weight component and forces from normal interactions. For scenarios with moving axes, the modelling addressed how relative rotation and linear shifts influence the interplay between angular movements and forces exerted on the wheel.

In controlling both fixed and moving axes, the strategy involved stabilizing dynamics through tailored techniques. For fixed axes, controllers using anticipatory networks and prefilters aimed to enhance response times and manage overshoots, adjusting to load changes and input saturation. Moving axes control utilized state-space representation for linearization, with pole placement and LQR techniques ensuring stability and optimized response. Additionally, compensation for steady-state errors and an anti-windup network addressed input saturation, ensuring the system's robust performance under various conditions.



This project established a technical foundation for predicting robot behavior and designing robust, responsive control systems. It provides insights into ball-balancing robot dynamics, paving the way for the development of 3-D models.

Pedestrian recognition by means of multiple sensors

Project Goal:

The objective of this project was to develop algorithms for detecting pedestrian locations in 3D space from vehicular sensor data. Using a combination of camera, LiDAR, and radar inputs, the aim was to accurately identify and position pedestrians within the vehicle's environment, leveraging both single-camera and multi-sensor approaches.

The project adopted two distinct methodologies for pedestrian detection, starting with a mono-camera system. This approach utilized ground plane information and camera perspective to generate proposal boxes for potential pedestrian locations. By analyzing the camera's visual data, the system crafted intelligent proposals that improved pedestrian position estimation over traditional methods. The classification phase relied on pre-trained classifiers to discern pedestrians within these boxes, highlighting the system's reliance on robust image processing techniques.

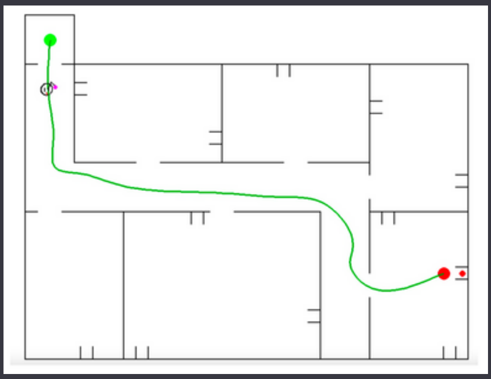
Transitioning to a multi-sensor approach, the project integrated LiDAR and radar data with camera imagery to enhance detection capabilities. This method employed LiDAR point clouds for initial pedestrian shape identification, utilizing clustering algorithms to pinpoint potential subjects. Radar data provided additional verification, helping to refine the detection process in adverse weather conditions or when the camera's visual cues were insufficient.

A significant part of the solution involved fusing data from the different sensors to create a cohesive detection framework. For the camera-only setup, the emphasis was on exploiting geometric relationships and implementing advanced image processing algorithms. Meanwhile, the multi-sensor strategy focused on the synergistic use of LiDAR's depth precision, radar's object detection under variability, and the camera's detailed visual information. By combining these diverse data streams, the project aimed to produce a more reliable and accurate pedestrian detection system.

Path planning and control for a mobile manipulator

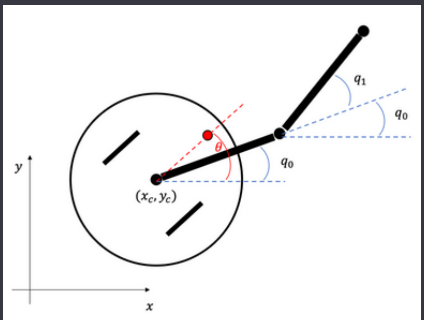
Project Goal:

This project aimed to create an advanced motion planner for a differential drive robot with a 2-degree-of-freedom planar manipulator in a simulated hospital setting, focusing on generating a path from a specific start to a randomized goal, navigating rooms and avoiding obstacles. The project emphasized smart, efficient solutions tailored for a simple simulated environment.

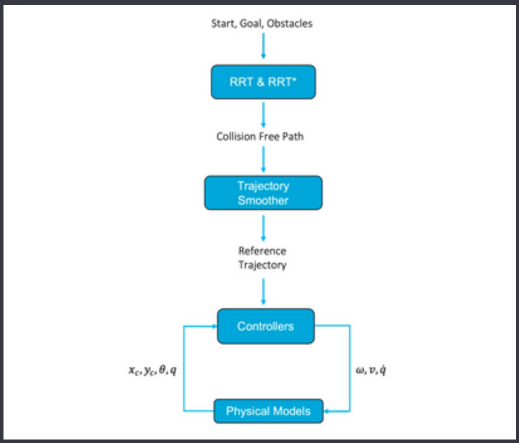


The solution hinges on integrating several algorithms to devise a motion planner capable of navigating a robot through complex hospital environments. Initially, the project utilized a Rapidly-exploring Random Tree (RRT) algorithm, chosen for its efficacy in sparse environments. However, to enhance path optimality, an Informed-RRT* algorithm was incorporated, focusing on areas of interest by sampling points within an ellipsoidal region defined by the start and goal positions.

The robot's kinematics were designed to account for the differential drive's non-holonomic nature by imposing a non-slipping constraint, thus ensuring precise control over the robot's movement. This included deriving expressions for the robot's linear and angular velocities based on the independent velocities of the wheels, which were crucial for navigating the robot in the planned environment.



To address the challenge of navigating the robot with an attached manipulator, the motion planning process was augmented with a trajectory smoothing algorithm. This algorithm, inspired by Noreen's work on B-Splines for smooth path generation, was adapted to ensure the path was suitable for the robot's differential drive and manipulator's joint angle configurations, ultimately ensuring a collision-free trajectory.

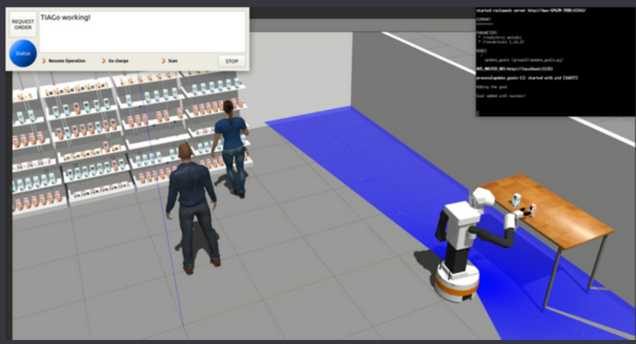


The control strategy employed a PID controller for the robot's base angular velocity and a proportional regulator for its linear velocity, alongside another PID controller for the manipulator. This comprehensive control approach was essential for managing the complex interactions between the robot's movement and the manipulator's operations, thereby optimizing the robot's performance in navigating the planned paths within the hospital environment.

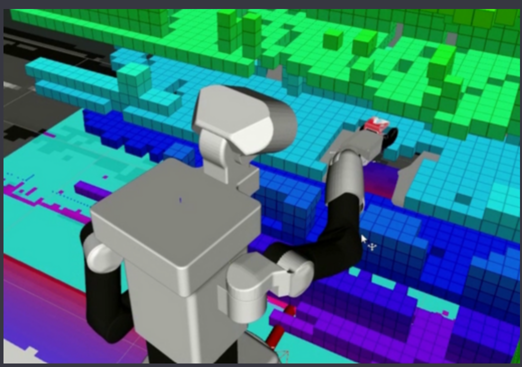
Software to make a TIAGo robot help supermarket employees

Project Goal:

The project aimed to enhance the TIAGo robot's abilities, allowing it to autonomously collect, identify, and restock products at supermarket checkouts. This effort sought to lessen staff workload during peak times by introducing advanced robotics into retail, thus improving operational efficiency.



Central to the project's success was the creation of a complex software framework built on the Robot Operating System (ROS), which allowed for complex interaction between the robot and its surroundings. This framework consisted of various modules responsible for navigation, interaction with humans, detection of objects, and the management of unforeseen errors, each contributing to the robot's autonomous functionalities.



The navigation and planning module was pivotal, enabling the robot to move through the supermarket efficiently, avoiding obstacles and minimizing any inconvenience to people. Adaptability was a key feature, achieved through the integration of Planning Domain Definition Language (PDDL) and ROSPlan, which allowed the robot to modify its goals in response to immediate tasks and detections.

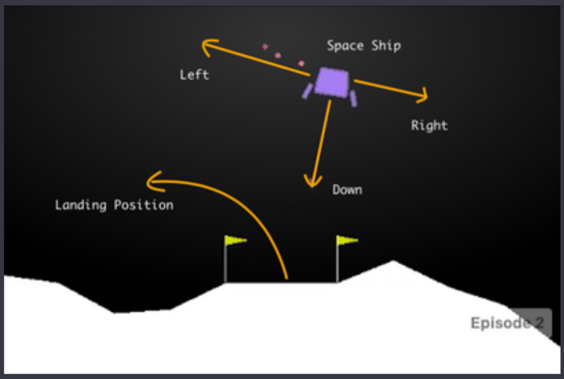
A significant aspect of the project was the development of a seamless interface for staff to interact with the robot, alongside a robust detection system capable of identifying both people and products. Through the use of visual and auditory signals for communication and the application of cameras and machine learning for object recognition, the robot was equipped to navigate human presence and accurately identify products, greatly enhancing its autonomous capabilities

Ensuring the robot could handle unexpected situations was essential for smooth operation. An elaborate error-handling strategy was implemented, enabling the robot to tackle challenges such as absent products or navigation impediments. Precise control over object manipulation, crucial for executing pick-and-place operations, was achieved through advanced motion control algorithms.

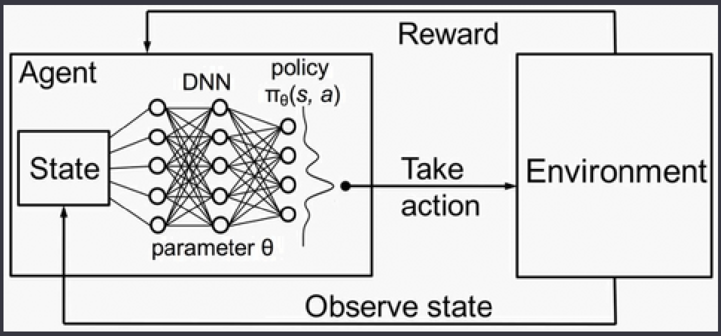
Control of OpenAI Gym Lunar Lander with Deep Q-learning

Project Goal:

The objective of this project was to apply deep reinforcement learning techniques for controlling a lunar lander in a simulated environment. Specifically, the goal was to navigate and successfully land the lunar lander within a designated zone, utilizing the principles of Q-Learning to achieve precise control and maneuvering.



In tackling the complex task of lunar landing, a Deep Q-learning approach was adopted, integrating a neural network to approximate the Q-function. This enabled the learning agent to evaluate and select actions based on the current environment state and receive rewards. The simulated environment provided by OpenAI Gym's LunarLander-v2 was chosen for its dynamic and challenging nature, offering a realistic backdrop for the application of reinforcement learning algorithms.



The project's implementation phase began with the development of a reward mechanism, crucial for guiding the agent's learning process. Rewards were structured to reflect the lander's performance, encouraging behaviors that would lead to a successful landing. Alongside this, a neural network architecture was designed, serving as the function approximator for the Q-learning algorithm. This network was crucial for managing the continuous state space of the landing scenario, transforming inputs into actionable decisions.

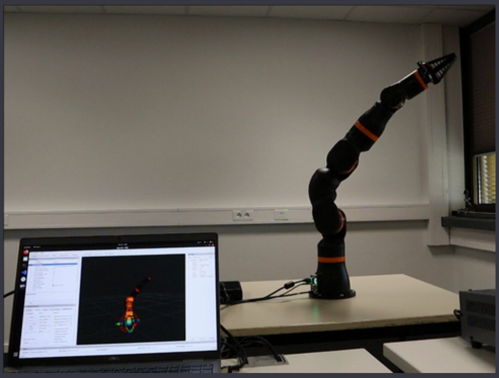
Enhancements such as experience replay and a target network were incorporated to address the challenges of stability and efficiency. Experience replay broke the correlation between consecutive learning samples, while the target network contributed to a stable learning process by providing a consistent target for the Q-function updates. Hyperparameter tuning, including adjustments to the learning rate and discount factor, played a pivotal role in optimizing the learning process.

Through iterative training and refinement, the project successfully demonstrated the application of deep reinforcement learning to a complex control task. The learning agent progressively improved its landing accuracy and control, showcasing the potential of neural networks in enabling sophisticated decision-making and control strategies in simulated environments.

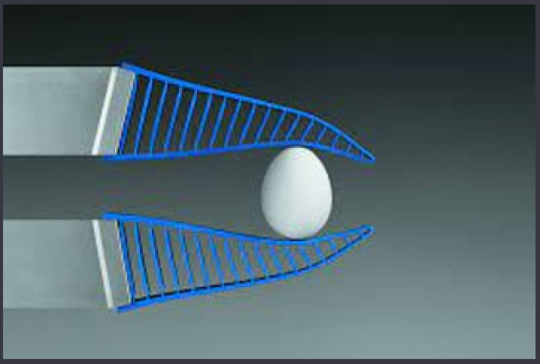
Soft gripper as end-effector of a cobot mounted on top of a quadruped robot

Project Goal:

The project embarked on enhancing quadruped robot functionalities by integrating a soft gripper onto a collaborative robot (cobot). This setup would empower the robot to autonomously identify, approach, and manipulate objects with diverse shapes and materials, thereby broadening its interactive and operational capabilities within various environments.



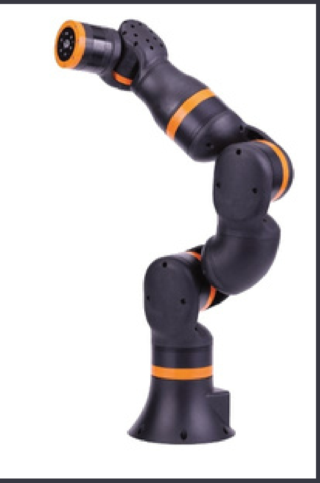
The core of this project revolved around crafting a soft gripper, inspired by the FinRay® effect. This innovation led to the design of a gripper capable of conforming to various object shapes. The implementation involved 3D-printed fingers made from TPU-90A filament, chosen for its balance between flexibility and resilience. Precision in movement and control was achieved using micro servos.



Key to managing the system's interactive dynamics was leveraging the Robot Operating System (ROS). A tailored ROS package was developed to ensure smooth communication and coordination between the gripper, the cobot, and the quadruped robot. This setup featured dedicated nodes for processing sensor data, controlling the gripper, and executing commands within a unified software framework.

The hardware aspect saw the integration of a Raspberry Pi Zero W as the single-board computer (SBC) for the gripper, selected for its compactness and processing capability. Yet, challenges like sensor delays prompted considerations for employing an Arduino for direct servo management to enhance responsiveness.

An Igus ReBeL® cobot was chosen for its agility and compatibility with the quadruped robot, thanks to its six degrees of freedom and light construction. Modifications to the ROS package and hardware were necessary to ready the cobot for deployment, enabling precise movements as dictated by the overarching ROS-driven framework, marking significant strides in robotic interaction and manipulation.



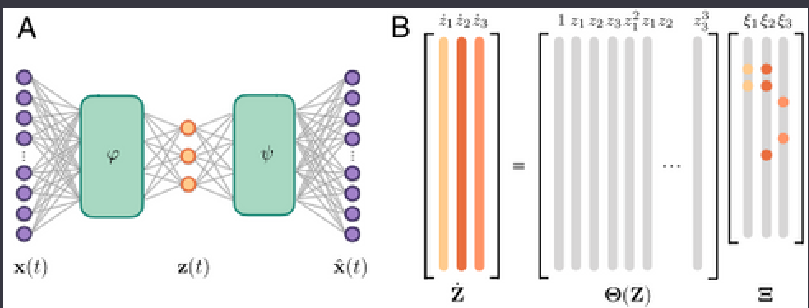
The solutions mentioned mark only the initial part of the project, laying the groundwork for further development in autonomous robotic manipulation.

MSc thesis: Learning interpretable reduced-order models for jumping quadrupeds

Project Goal:

The thesis presents a novel method for learning simplified yet interpretable models of jumping quadruped robots from data, combining Symbolic Regression with autoencoders. The goal is to accurately describe the dynamics of jumping motions in quadruped robots, providing a foundation for advancing legged robotics with efficient and understandable models.

This project pioneers an innovative algorithm for generating interpretable, simplified dynamic models of jumping quadruped robots, by effectively reducing the system's complexity into a comprehensible latent space using linear autoencoders. This transformation captures the essential dynamics, facilitating the creation of symbolic equations for the models, thereby enhancing interpretability and adjustability.



The development process was methodically executed in two primary stages: the initial phase focused on training the autoencoder with diverse jump phase data, ensuring accurate dynamic representation. The subsequent phase refined the decoder, aiming for precise jump sequence reconstruction from the latent representations. This comprehensive training approach underscores the robustness of the developed models.

Incorporating Symbolic Regression, specifically through the Sparse Identification of Nonlinear Dynamical Systems (SINDy) algorithm, further optimized the models by distilling complex dynamics into interpretable, mathematical expressions. This step emphasized model simplicity and clarity, reinforcing the utility and accessibility of the resulting dynamic models.

Experimental validation on both simulated and actual quadruped robots underscored the efficacy of the proposed models in capturing the intricate dynamics of jumping motions. This project significantly advances the modelling of legged robotics, offering a nuanced understanding of dynamic behaviors through simplified, interpretable models.