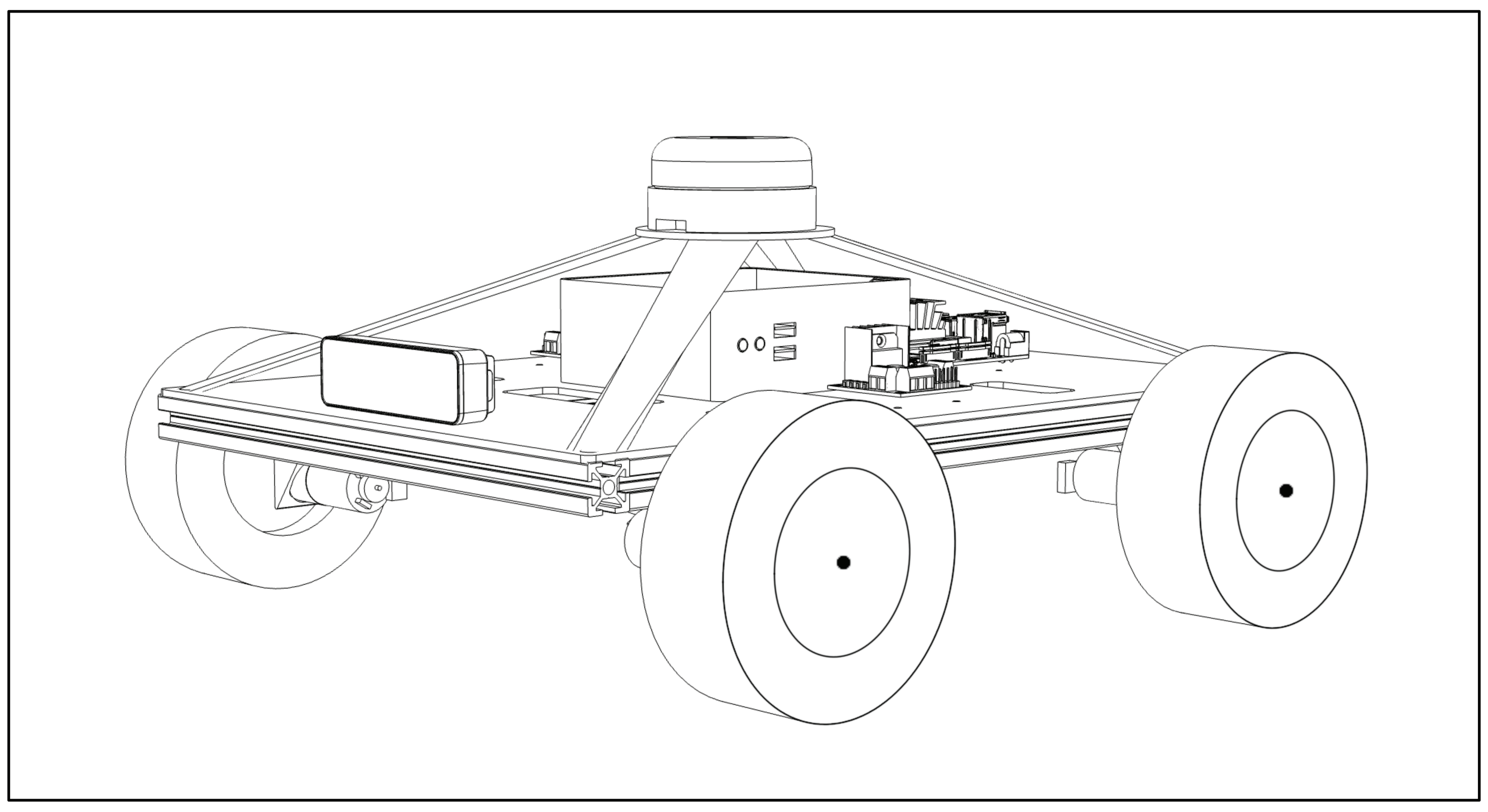
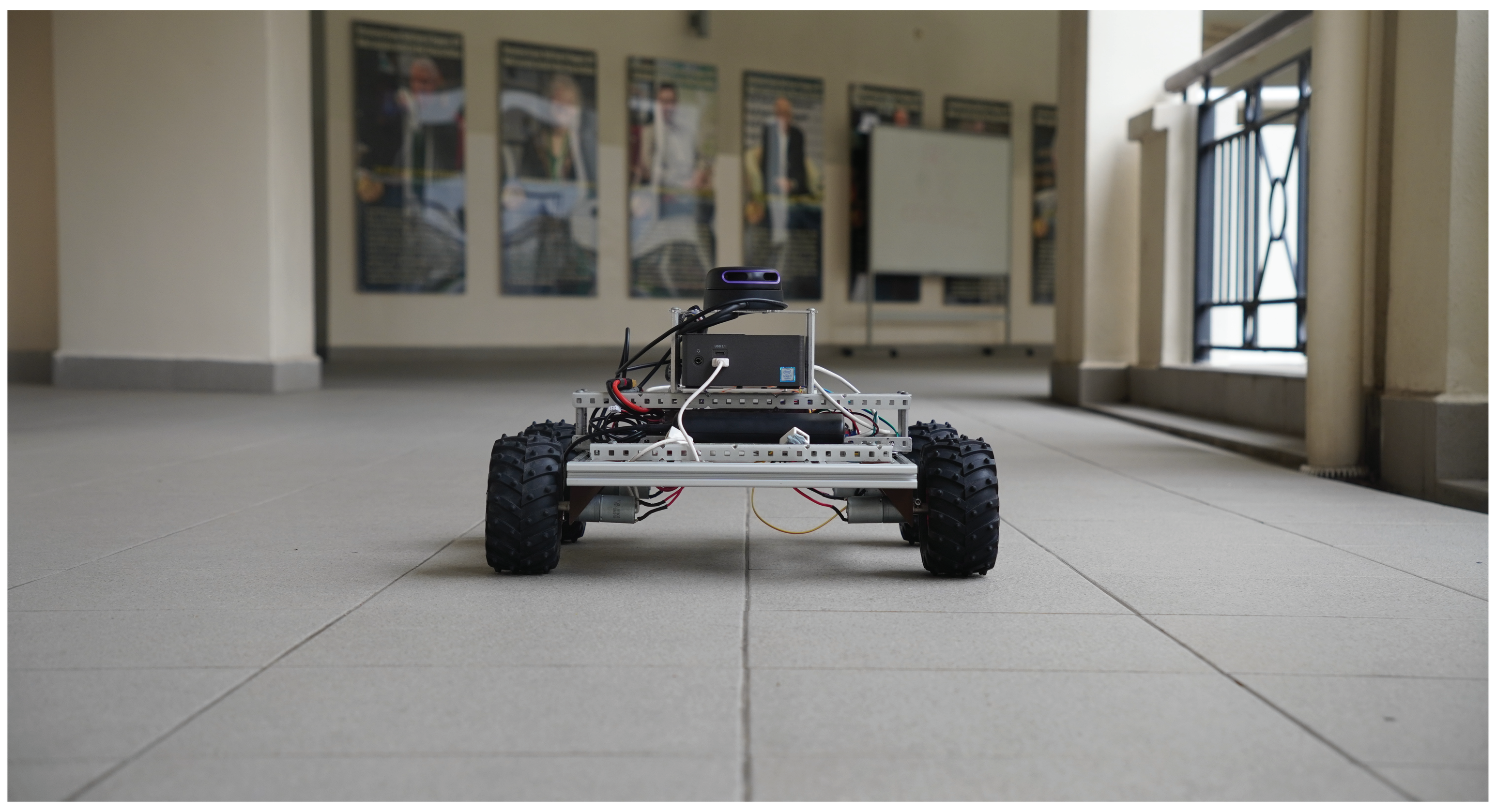
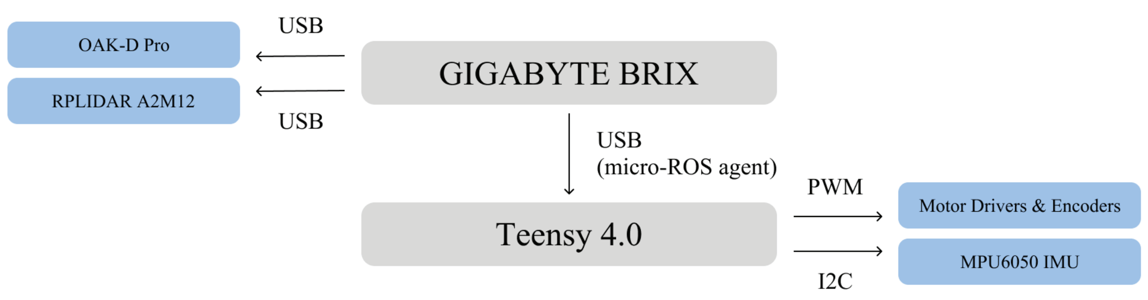
DEVELOPMENT OF A LOW-COST ROBUST AUTONOMOUS APPROACH TO MODERN CAMPUS SECURITY





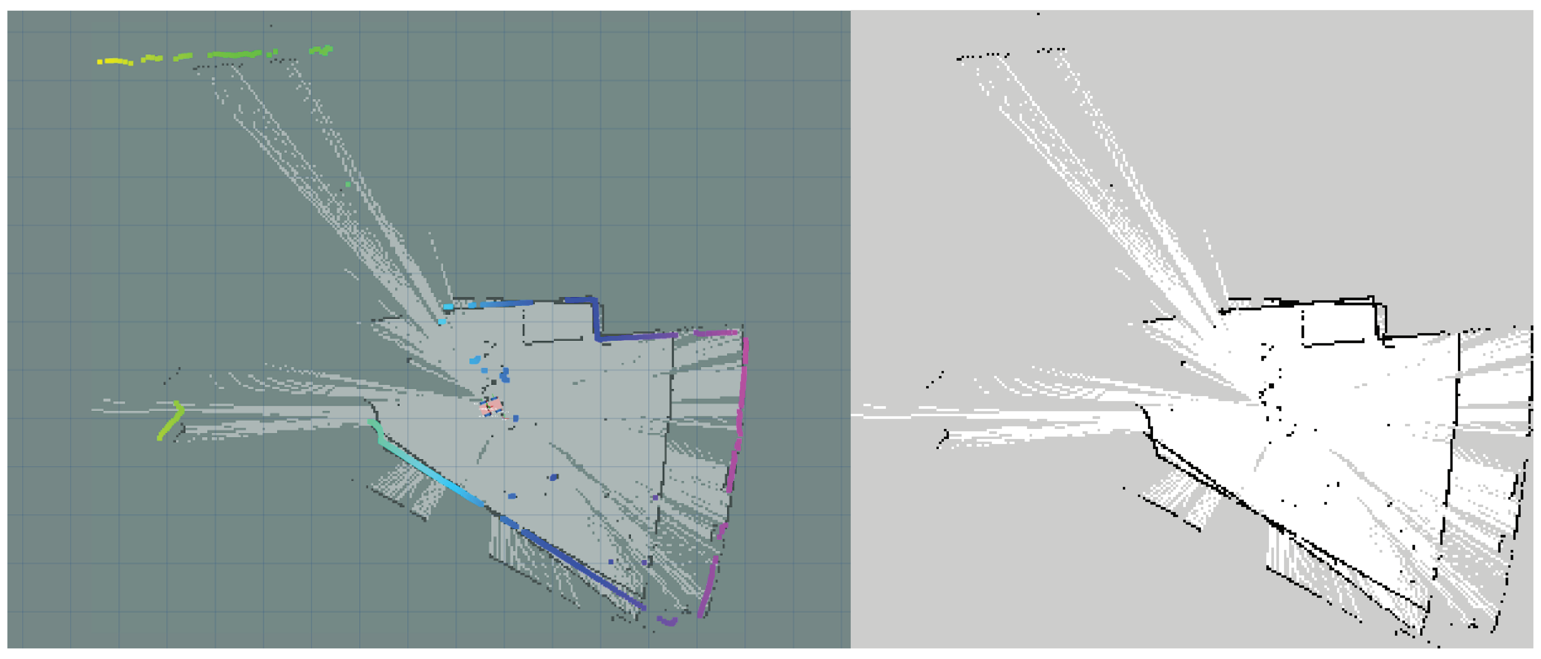
Introduction

Unmanned Ground Vehicles (UGVs) provide a novel alternative to conventional campus surveillance methods, including manual patrol and camera surveillance. This project aims to develop a low-cost, robust, and modular UGV for campus surveillance, allowing campus security to remotely monitor different areas efficiently. The UGV, through the usage of a Simultaneous Localisation and Mapping algorithm, is able to map and self-navigate. Through testing, we have determined optimal planning and locomotion controllers for the UGV to operate in urban environments. Afterwards, the UGV conducts computer vision (CV) tasks locally, in order to detect any potential intruders in its line of sight, through the usage of a pose estimation model. Images of detected intruders would then be passed through another pose classification model, to determine any further suspicious movement.



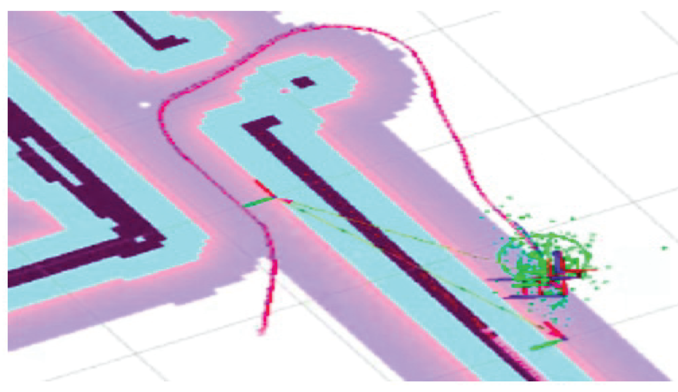
Hardware Design and Component Integration

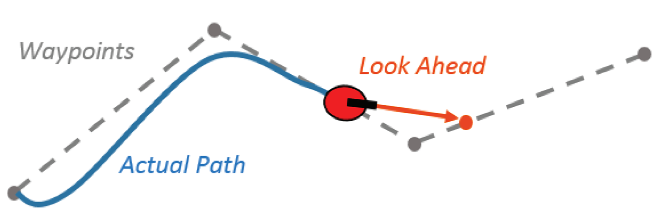
- 2020 T-slot aluminium chassis is lightweight yet sturdy, exhibiting excellent load handling in normal use
- UGV runs on ROS2 on the BRIX, to which most high-level mission-critical components are connected for data processing
- Velocity data is then piped to an external Teensy 4.0 through the micro-ROS interface in order to control the motors on the pulse-width modulation (PWM) interface



Simultaneous Localisation and Mapping (SLAM)

- A2M12 provides a 2D point cloud of the area surrounding the robot
- Sparse graph optimization with loop closure detection is used to generate maps and perform localisation
- Odometry data from encoders and an IMU is also recorded to improve accuracy of localisation data
- Allows the robot to semi-autonomously map and gather information about an area as intended
- Robot can be controlled by a remote operator by inputting desired waypoints based on the SLAM map





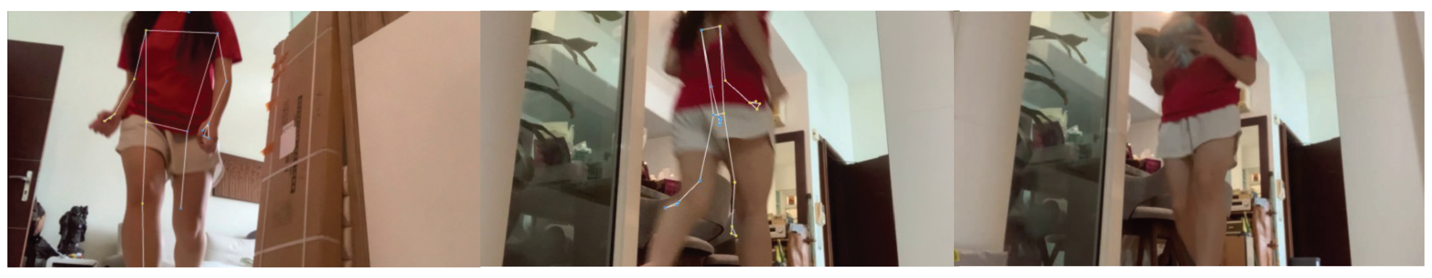
Navigation

- Dijkstra's algorithm was used to find an obstacle-free path for the robot to follow
- A Pure Pursuit controller enabled the robot to stay on the computed path, even amidst unfamiliar and changing terrain
- The robot can thus navigate tight spaces in urban compounds with a low chance of accidental collisions

Human Detection & Classification

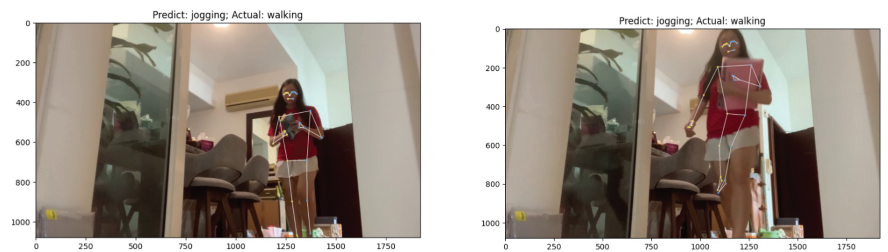
- Using BlazePose, humans and their landmarks could be accurately spotted
- This was combined with the depth sensing capabilities of the OAK-D Pro to accurately determine the distance between the robot and any identified humans

- BlazePose was still largely able to identify landmarks, even under partial occlusion, the subject holding an object, or in blurry images



- However, the model was less accurate when faces were occluded, as BlazePose uses the face as a proxy for pose detection to improve robustness against false positives
- Face occlusion led to misidentification of landmarks and the model being unable to identify humans in frame

- The pose classification model was tested on the KTH test dataset, and our custom dataset.
- On the KTH dataset, the model had a mean 90.9% accuracy. The model generally over-classified images to the jogging class, with the walking class having a greater precision than the jogging class and the jogging class having a higher recall.
- On the custom dataset, the accuracy fell to a mean of 74.0%, with the over-classification of the walking class as jogging continuing to a stronger extent.



- The model was found to rely heavily on arm position to classify an image, with the model classifying an image as "jogging" when the subject's arms are raised and bent. Conversely, the model classifies an image as "walking" when the subject's arms are lowered and straight.

Conclusion & Future Work

- Working UGV prototype has been created at less than 2% of the average cost required to rent a similar surveillance system for a year
- UGV is equipped with the ability to autonomously navigate in foreign environments, minimising initial time cost before it can begin patrolling new areas
- A novel, reliable, and accurate trespass detection system also allows it to survey large areas effectively
- Future work include the development of human-in-the-loop interfaces to allow security to designate patrol routes, be notified of anomalies detected, and to decide if the robot should follow and chase down the intruder, which will greatly benefit integration of UGV into existing human security systems

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YDSP Young Defence Scientists Programme
DSTA Defence Science & Technology Agency
DSO National Laboratories