Preliminary 4th year Project Proposal  
(Team proposal)

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| Project title | Autonomous Driving Sensor Fusion – Camera / LIDAR / RADAR |
| Student names | Maksym Bolotov, Maxim Chu, Catherine Wu, Rebecca Chen |
| Supervisor | Matt Ritchie |
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# Topic and aims

This project explores sensor fusion for autonomous vehicles (AVs) using three different sensors: RADAR (AWR1642), LiDAR (RPLIDAR A2) and Camera (Intel RealSense D435). Radio detection and ranging (RADAR) sensors operate by emitting radio waves that reflect off the surfaces of objects. These reflected waves are received by the sensor to calculate the objects' distance and velocity [1]. The distance to an object is influenced by the time it takes for the radio waves to return. The velocity of the object is determined using the Doppler effect. RADAR is a high-accuracy, low-cost sensor that operates reliably in all lighting and weather conditions. RADAR sensors have low resolution, making it difficult for them to distinguish between different objects.

Light detection and ranging (LiDAR) is a sensor technology that employs an emission spectrum of electromagnetic waves ranging from 750 nm to 1.5 µm. These waves are reflected back to the sensor and based on the time of flight (ToF) of the electromagnetic wave a position can be established [2]. LiDAR is a high-precision and high-accuracy sensor that functions well in various lighting environments. Due to the nature of the sensor array and the ToF calculations, it is particularly weak at calculating ranges in harsh weather conditions like rain. Electromagnetic waves are reflected by the droplets, resulting in malicious readings.

Depth cameras provide both depth and contextual information about the environment. The principle behind capturing depth is that two images are captured simultaneously with stereo infrared cameras, which are compared to identify corresponding points. By calculating the disparity, the depth of each point is determined, allowing for a depth map to be created [3]. A key strength is the ability to provide detailed colour and depth information. It will be useful for identifying and classifying objects using machine learning algorithms. However, depth cameras have a more limited range, and the performance is reliant on good lighting conditions [4].

By employing sensor fusion, a more accurate representation of the surrounding environment can be captured. The sensor stack enhances robustness against noise and disruptions like rain, crucial for the safety of AVs. This is achieved by leveraging each sensor's strengths: the camera's spatial resolution, LiDAR's distance estimation, and RADAR's velocity estimation. However, integrating multiple sensors presents challenges such as optimal placement, calibration, and data fusion methods.

Calibration involves aligning the sensors’ intrinsic and extrinsic parameters and will depend on the vehicle design itself, making fusion techniques a more compelling research area. The current state-of-the-art approach for sensor fusion is employing deep learning methods [5], creating fusion networks. These networks handle different sensor combinations like Camera-LiDAR or Camera-Radar, using diverse data and perspectives. There are a few metrics to evaluate the success of various methods including network speed (as the AV must react to its environment), object classification and mapping accuracy.

The aim of the project is to:

* Combine camera, LiDAR and RADAR sensors in AVs to perform operations like trajectory planning and object classification.
* Create an optimal fusion network for maximising mapping accuracy and robustness.

# Proposed task breakdown and team allocation

The proposed task breakdown is divided by sensor, with one student assigned to each: camera, LiDAR, and RADAR. The tasks for each sensor are similar and include physical setup, using the sensor firmware, and preparing and preprocessing data for fusion.

The remaining student will be assigned to work on the fusion of the sensors. This involves gathering appropriate training data, creating an architecture, and training a network to integrate the results from all the sensors.

Any outstanding work or extensions to the base of the project, such as trajectory planning and designing an interface to visualise the results, will be undertaken based on each team member's availability.

Preliminary Task Allocation:

Maksym: LiDAR

Rebecca: Camera

Catherine: RADAR

Maxim: Sensor Fusion

Microsoft Teams will be used for project management, and GitHub will be used to maintain the project codebase.

# References

[1] D. Parekh, N. Poddar, A. Rajpurkar, M. Chahal, N. Kumar, G. P. Joshi, W. Cho, “A Review on Autonomous Vehicles: Progress, Methods and Challenges,” Electronics, 11, (2022), doi: 10.3390/electronics11142162.

[2] Y. Li and J. Ibanez-Guzman, “Lidar for autonomous driving: The principles, challenges, and trends for Automotive Lidar and Perception Systems,” IEEE Signal Processing Magazine, 37, pp. 50–61 (2020), doi:10.1109/msp.2020.2973615.

[3] V. Tadic, Á. Odry, I. Kecskes, E. Burkus, Z. Király, and P. Odry, “Application of Intel RealSense Cameras for Depth Image Generation in Robotics,” WSEAS Transactions on Computers, 18, pp. 107–112 (2019).

[4] Y. W. Kuan, N. O. Ee, and L. S. Wei, “Comparative Study of Intel R200, Kinect v2, and Primesense RGB-D Sensors Performance Outdoors,” IEEE Sensors Journal, vol. 19, no. 19, pp. 8741–8750, (2019), doi: 10.1109/JSEN.2019.2920976.

[5] R. Ravindran, M. J. Santora and M. M. Jamali, "Camera, LiDAR, and Radar Sensor Fusion Based on Bayesian Neural Network (CLR-BNN)," IEEE Sensors Journal, 22, pp. 6964-6974 (2022), doi: 10.1109/JSEN.2022.3154980.