Reactive and Proactive Autonomous Driving Techniques

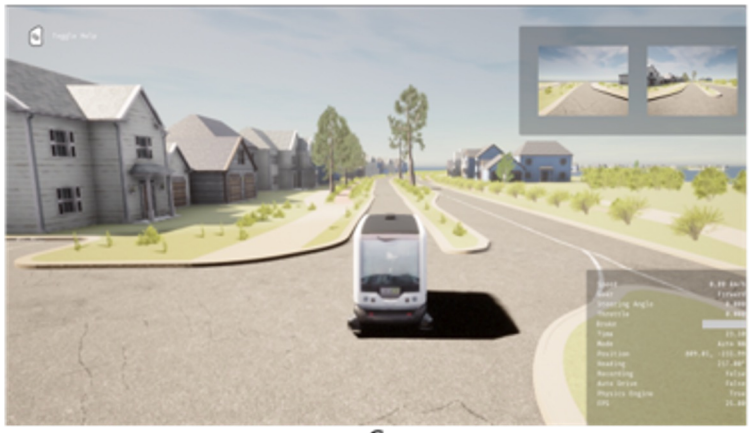
Kieran Quirke-Brown

nUWAy Shuttle Bus

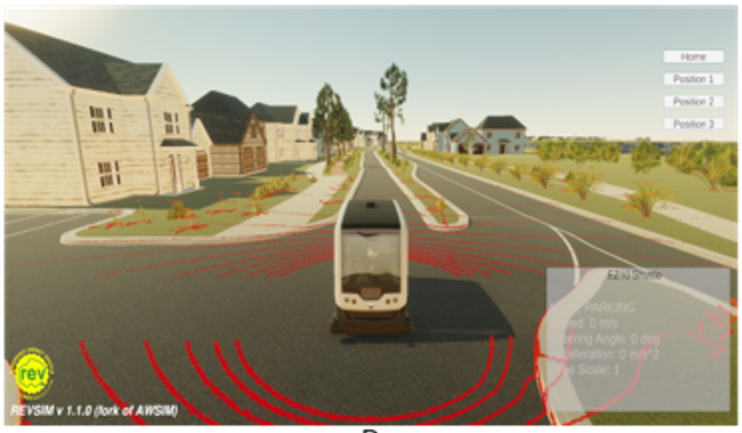
Simulation

A

B

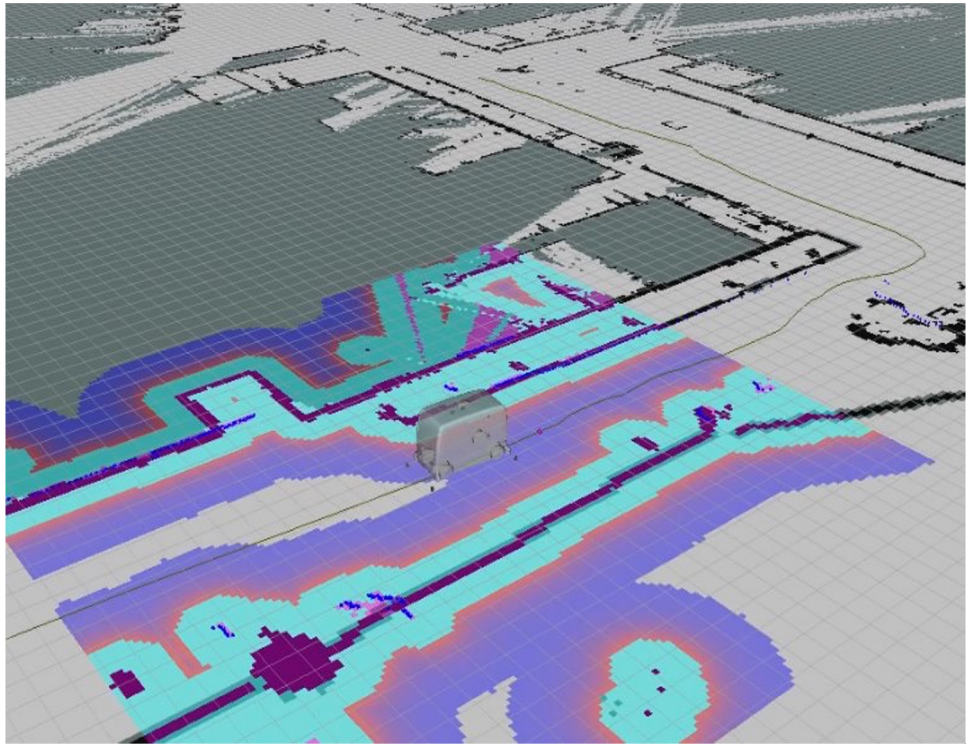


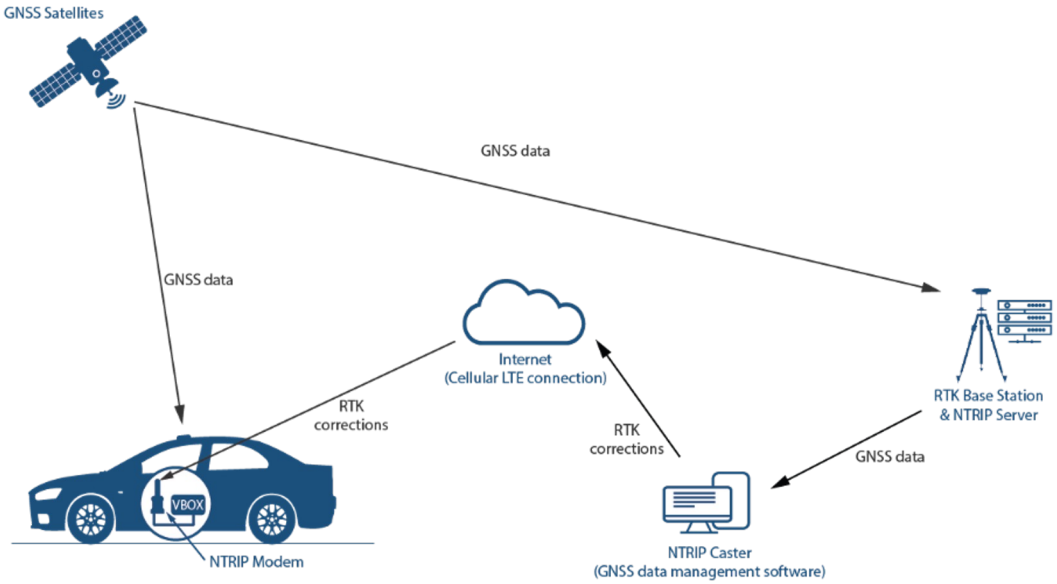
C



D

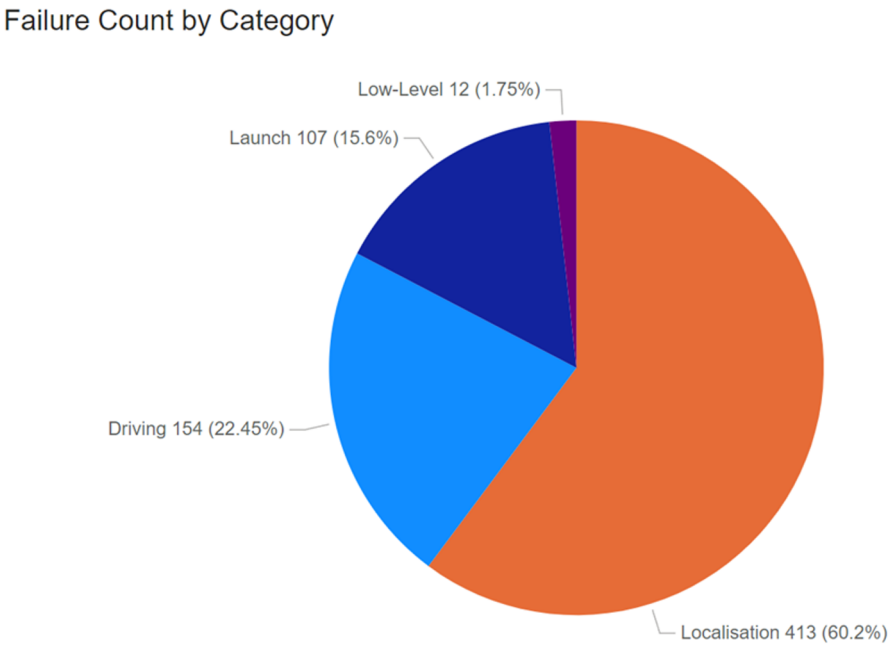
Deterministic Driving Techniques

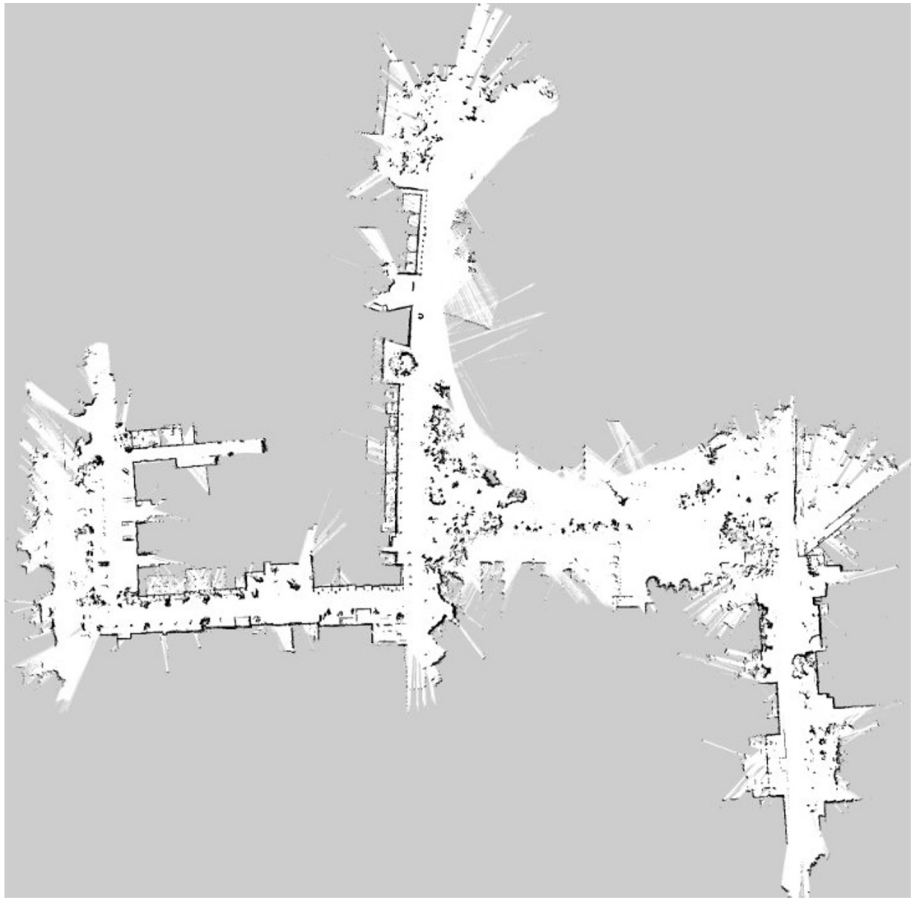




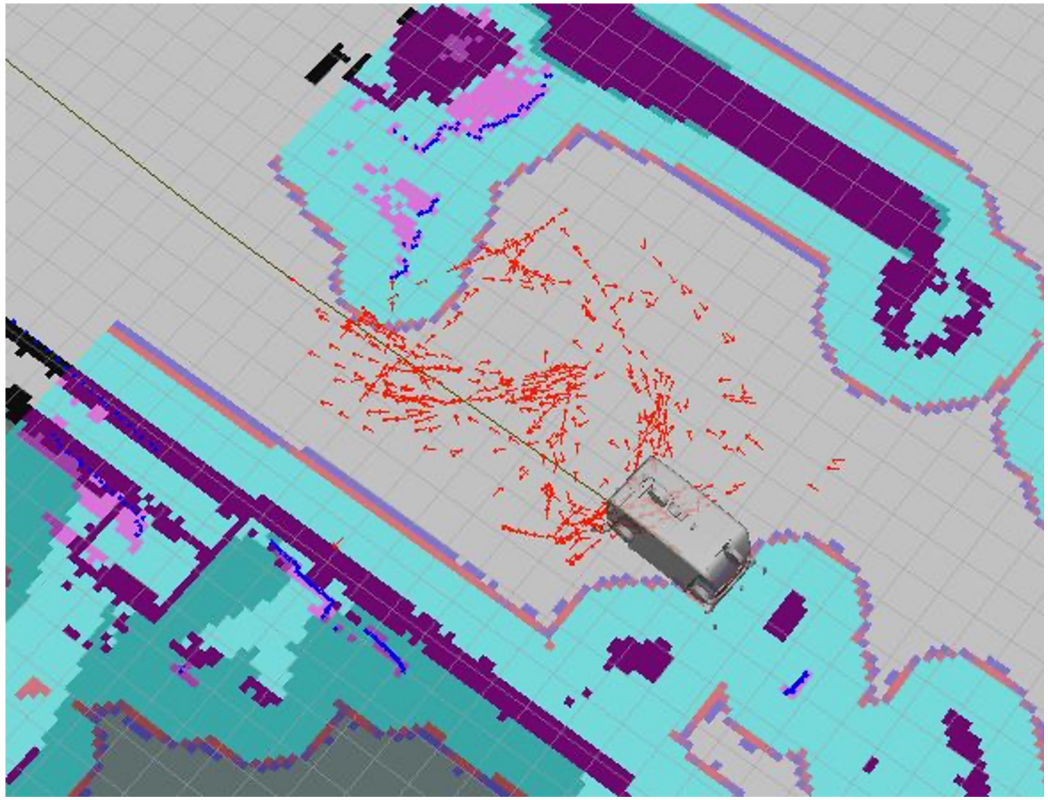
VBOX Automotive NTRIP https://www.vboxautomotive.co.uk/index.php/en/how-does-it-work-rtk

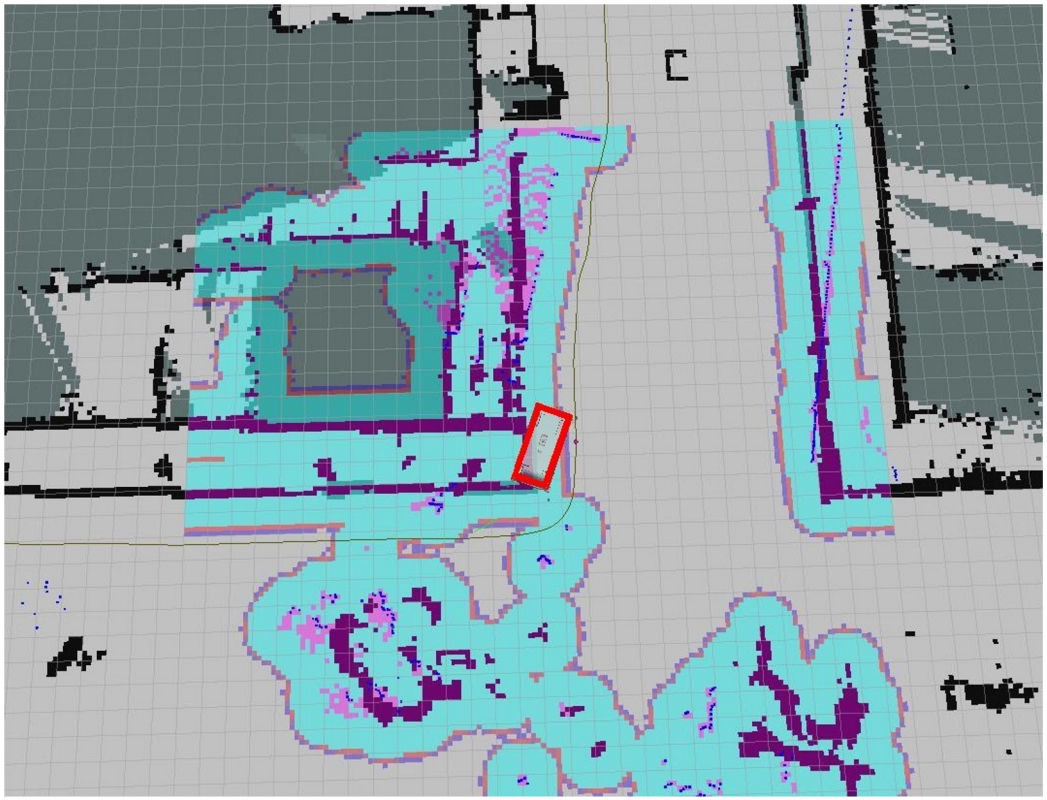
Reliability and SLAM issues





Driving issues





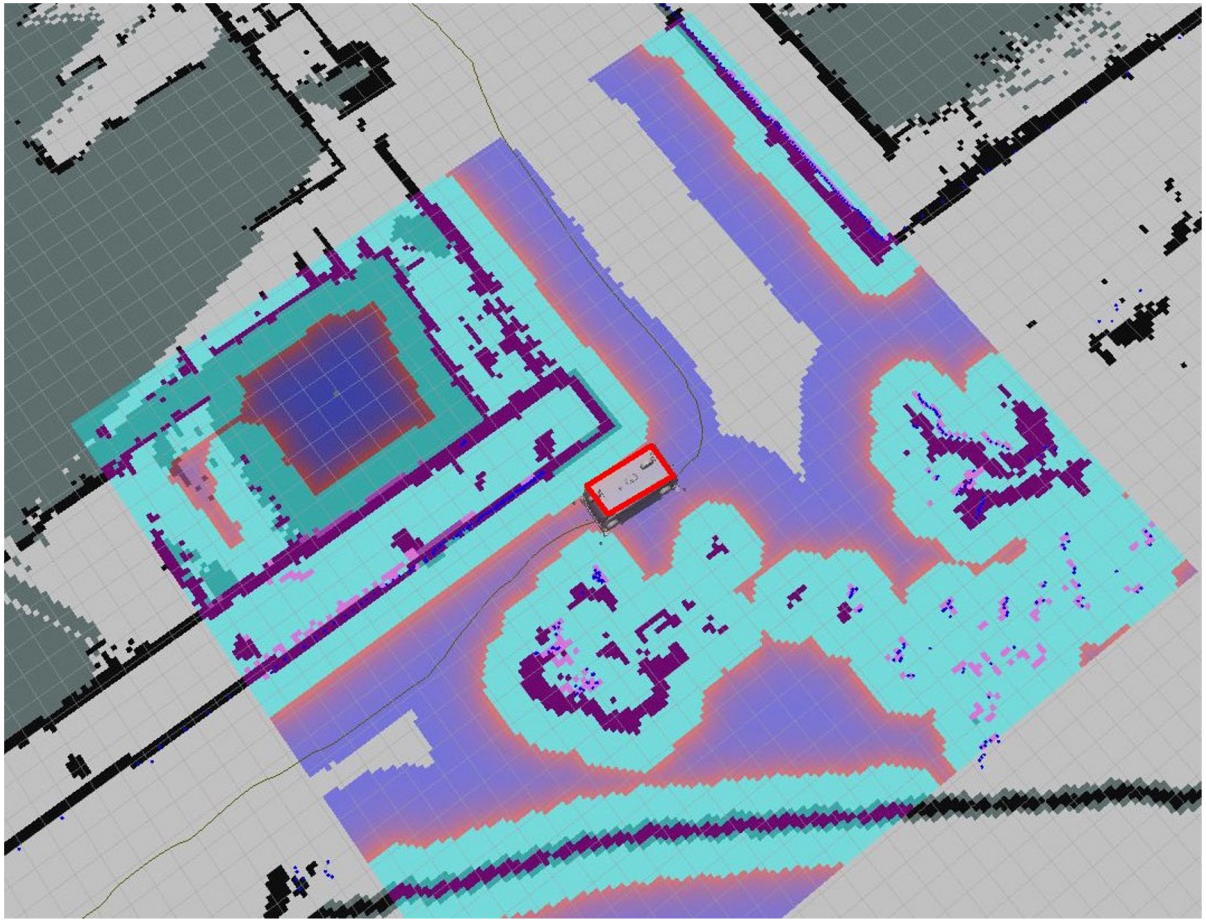
Safety systems - Heartbeat

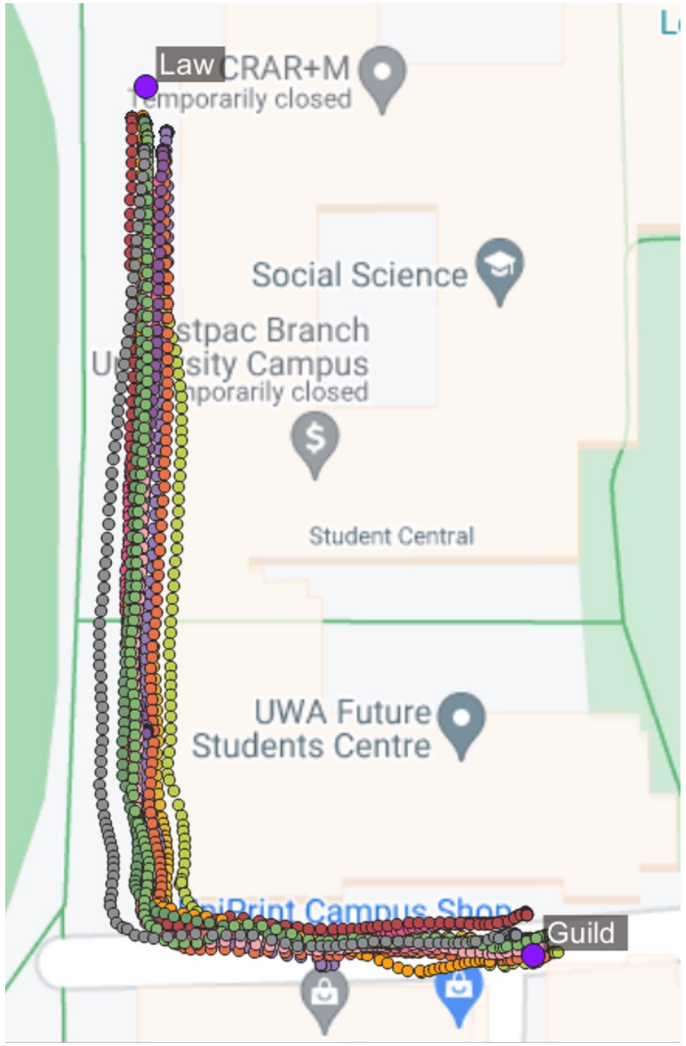
MTBF (minutes)	Level	Initial	Final
Severity	Low	23	25
	Medium	7	123
	High	284	615
Failure Source	Low-level	284	615
	Launch	32	1230
	Localisation	8	56
	Driving	22	33

Safety systems - SLAM

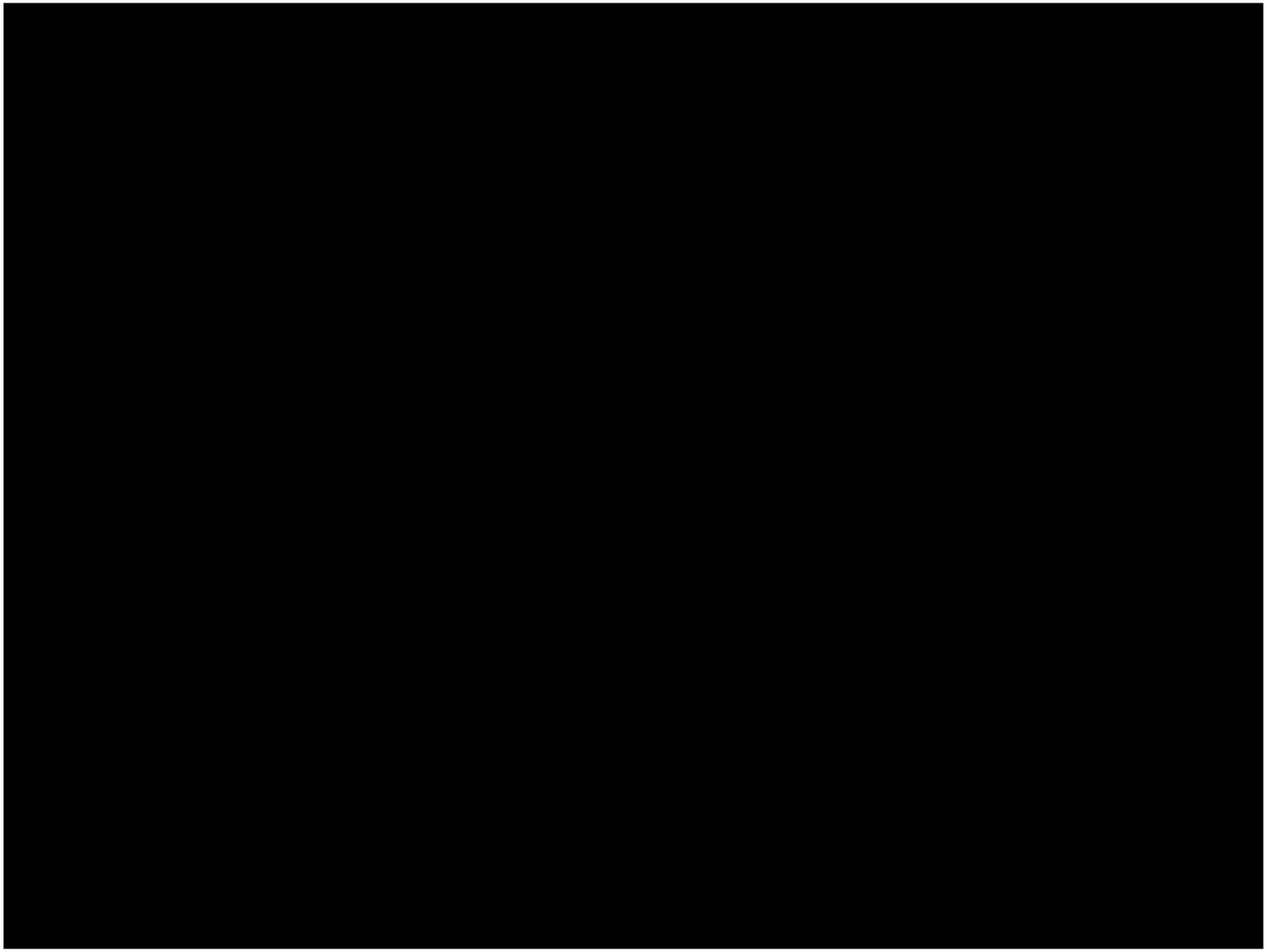
	SLAM Toolbox		AMCL	
Operation	Failure	Success	Failure	Success
Map Loads (per hour)	5.727	2.009	0.098	3.610
Pose Estimation (per hour)	1.004	2.132	0.293	6.244
MTBF (minutes)	8.24		55.91	

Campus based driving

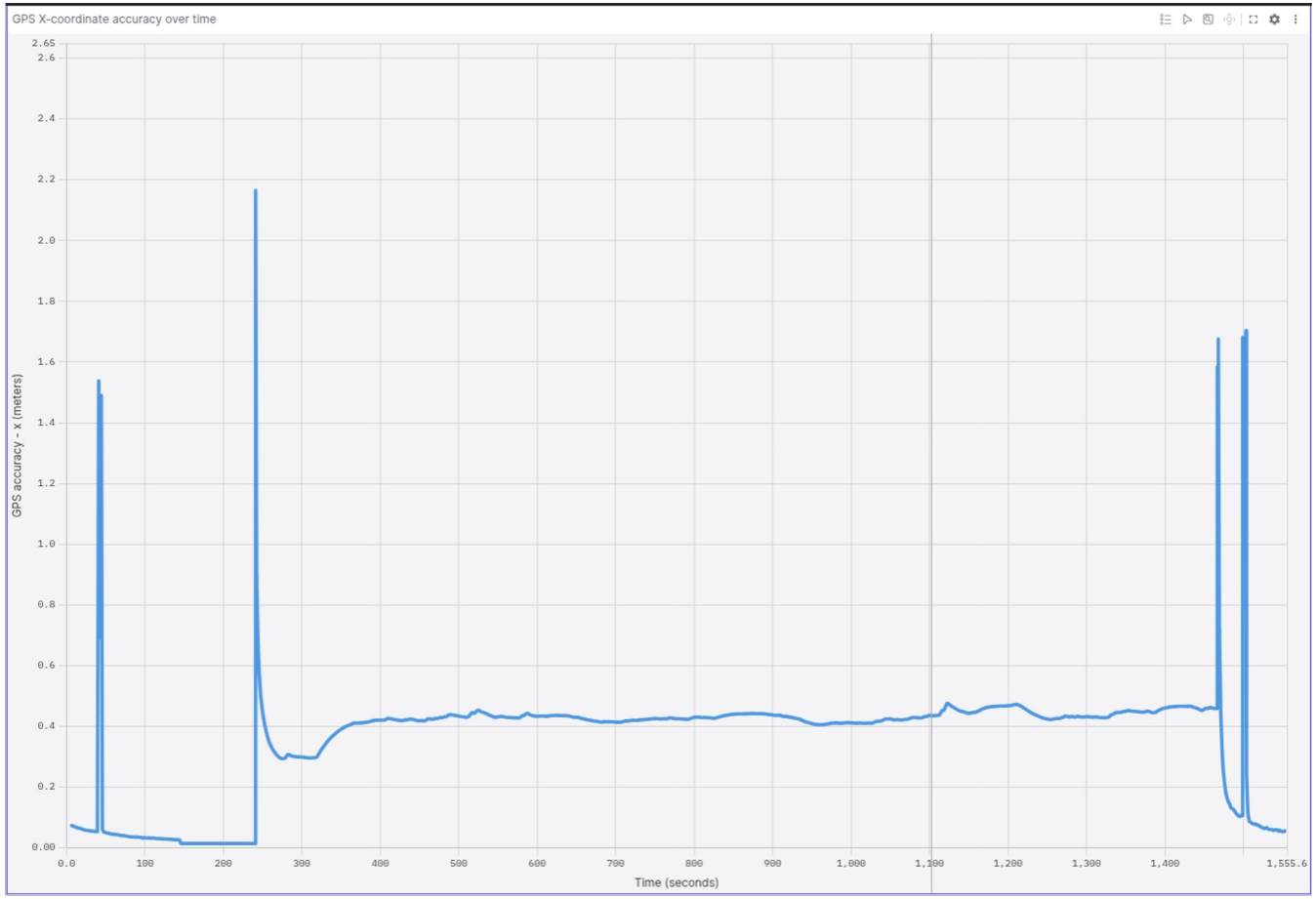




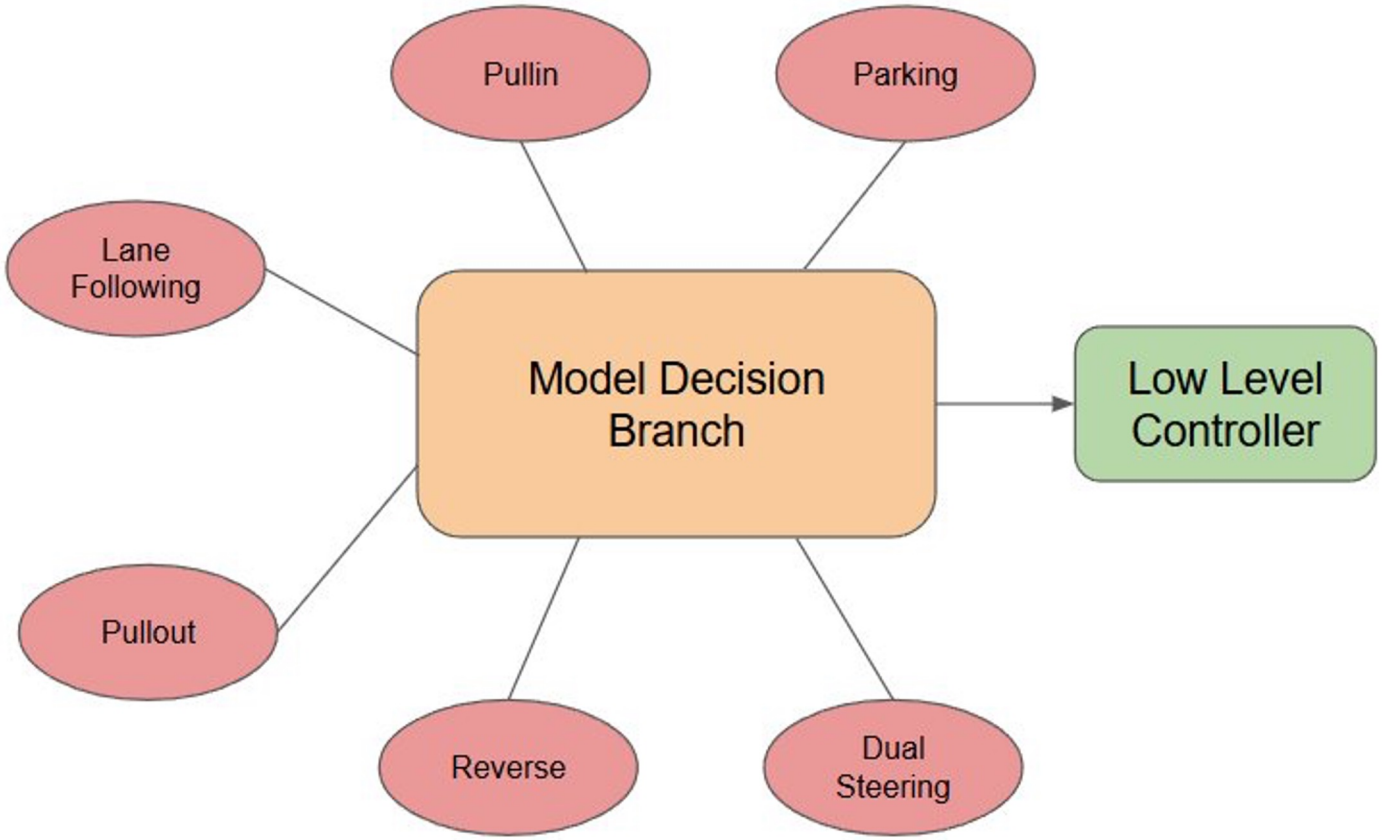
On road autonomous driving



GNSS + RTK accuracy

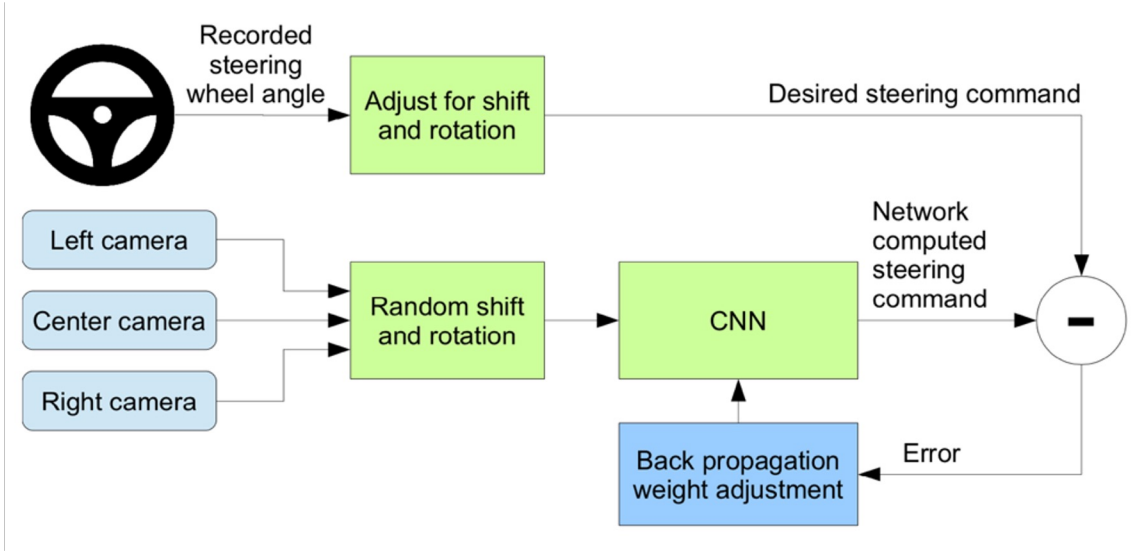


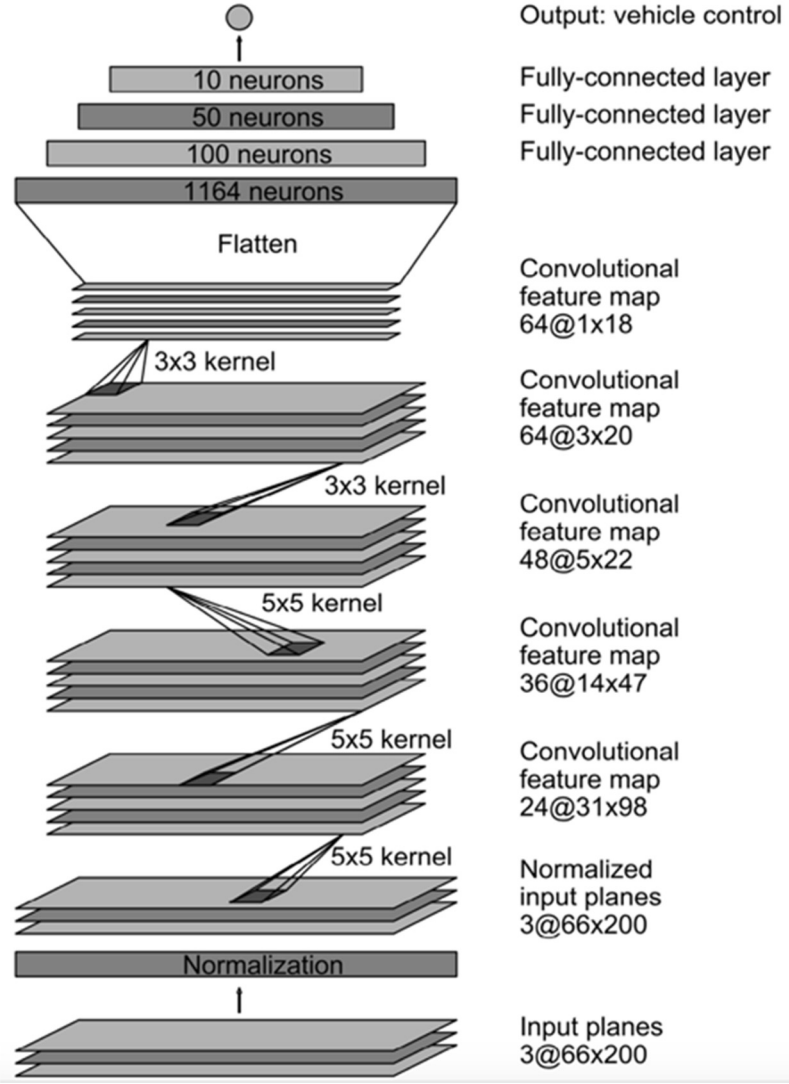
Modular based system design



On road design considerations

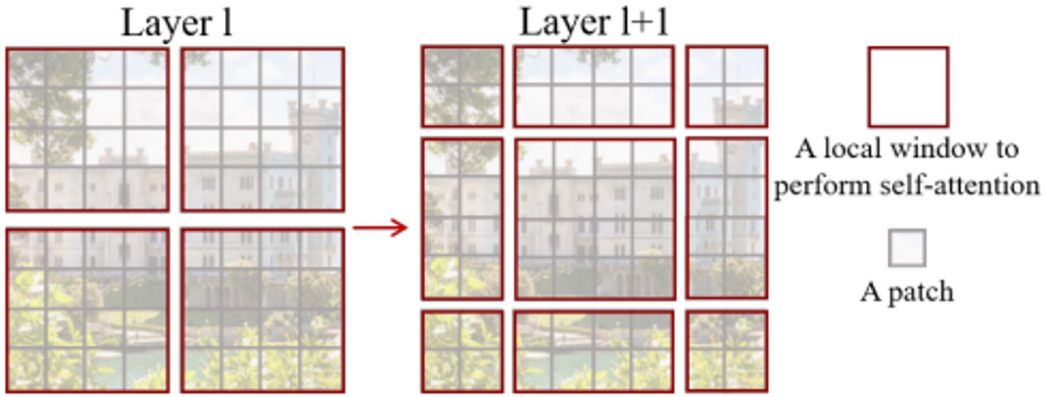
Using CNN models similar to PilotNet and EfficientNet



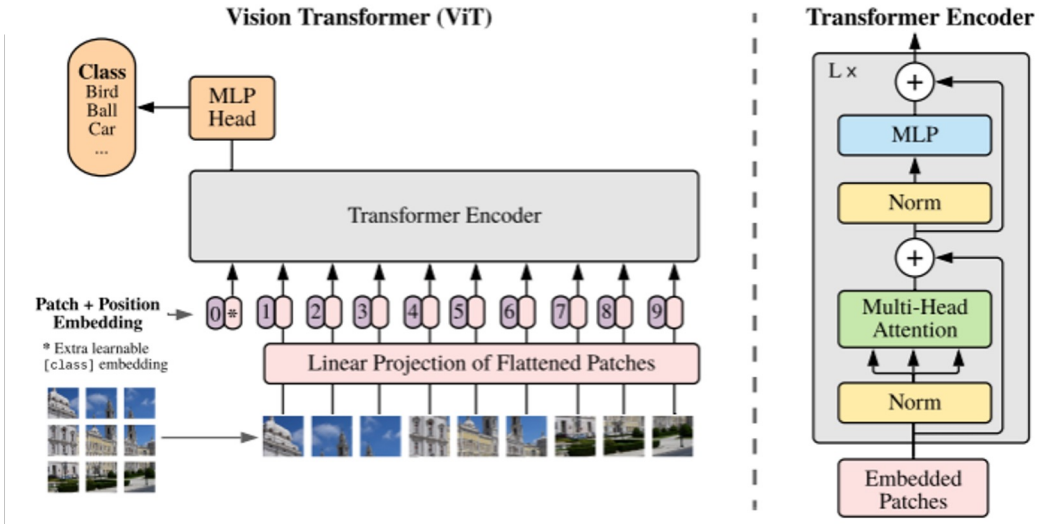


Bojarski et al., "End to End Learning for Self-Driving Cars," 2016

Explore sequence based model architectures

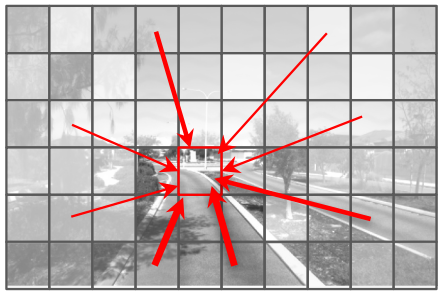


Attention(Q, K, V) = softmax($QK^T/sqrt(d_k)$)V

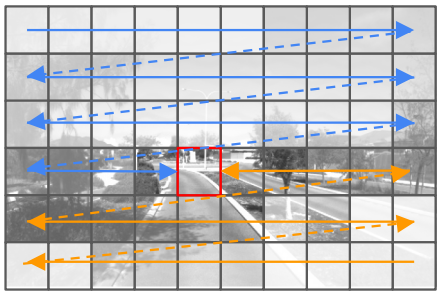


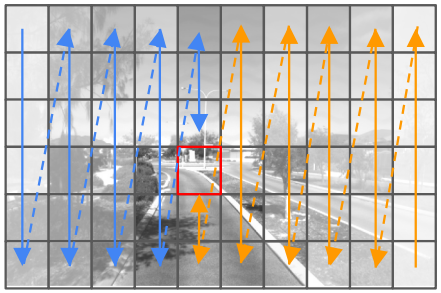
Dosovitskiy, A; Beyer, L; AN IMAGE IS WORTH 16X16 WORDS:TRANSFORMERS FOR IMAGE RECOGNITION AT SCALE
Liu, Z; Lin, Y; et al. Swin Transformer: Hierarchical Vision Transformer using Shifted Windows

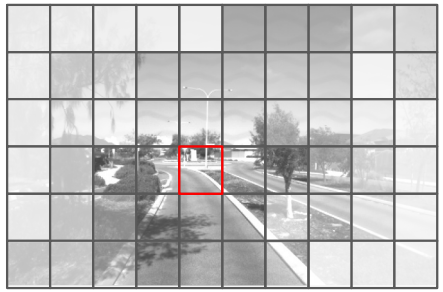
Explore sequence based model architectures



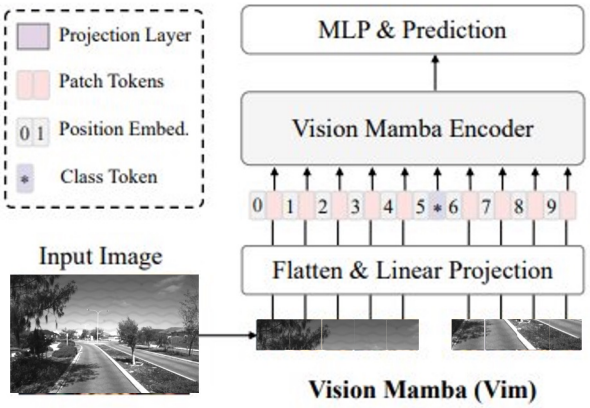
Transformer self attention
(all inputs are related to current sequence target)

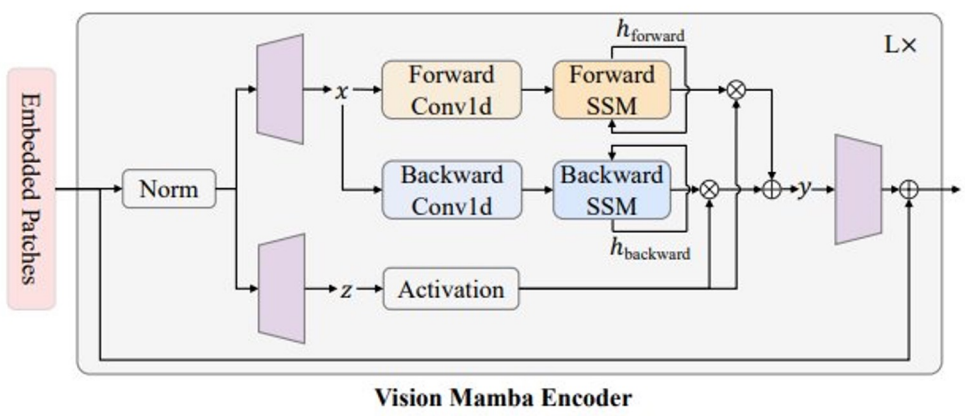






Mamba State space models use selective scanning to relate only the key details in the sequence to the current target, typically focusing on areas closer to the target token.





$$h_t = \overline{A}h_{t-1} + \overline{B}x_t \quad (2a)$$

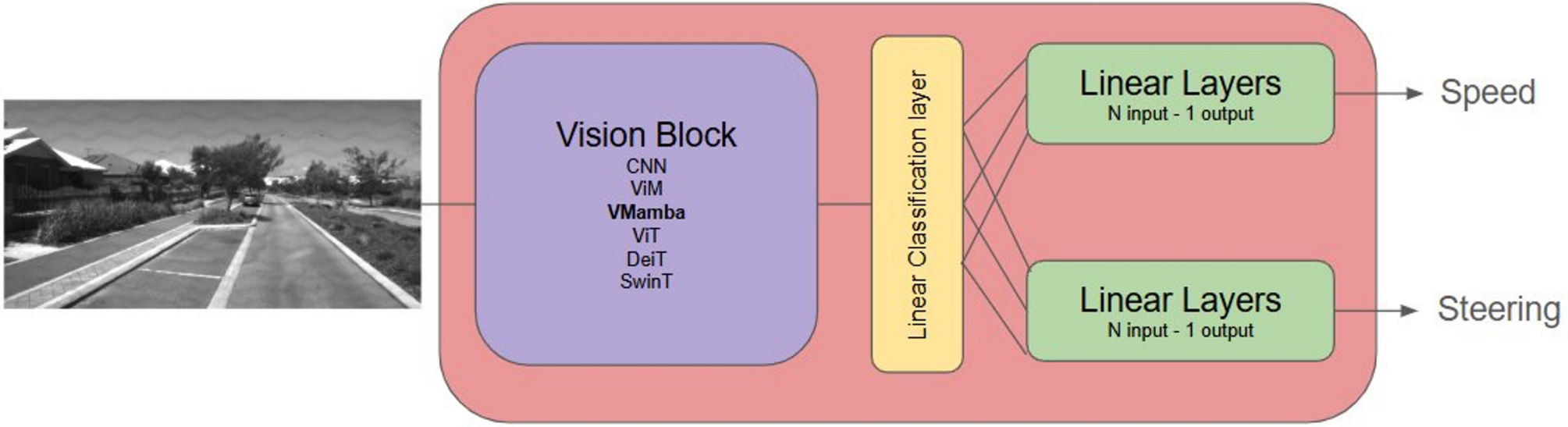
$$y_t = Ch_t \quad (2b)$$

Visuals adapted from following papers in content of autonomous driving problem nUWAy is solving.

Y. Liu, Y. Tian, Y. Zhao, H. Yu, L. Xie, Y. Wang, Q. Ye, and Y. Liu, "Vmamba: Visual state space model," arXiv preprint arXiv:2401.10166, 2024.

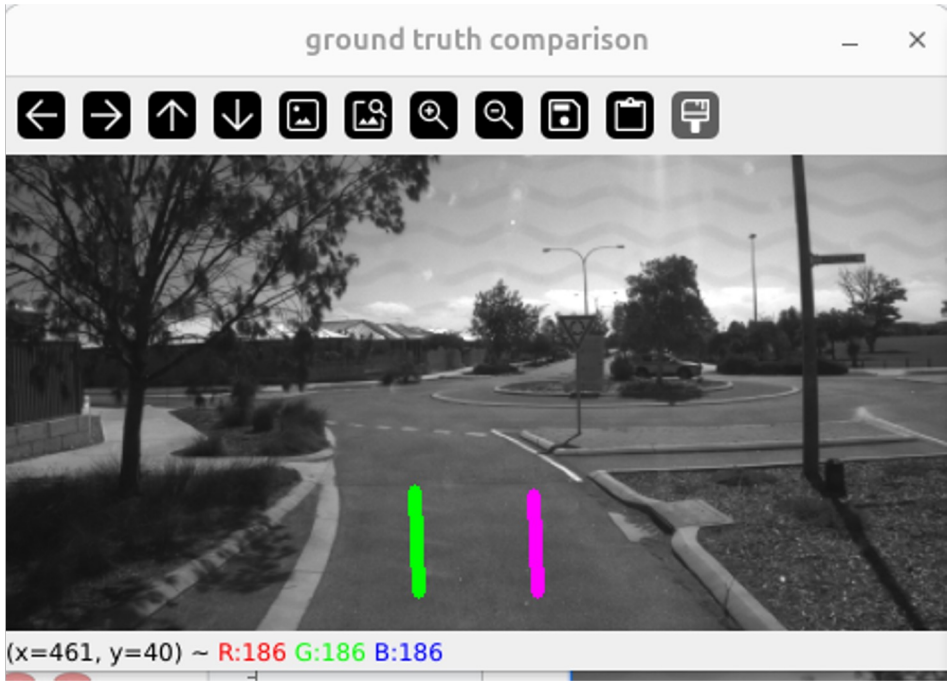
L. Zhu, B. Liao, Q. Zhang, X. Wang, W. Liu, and X. Wang, "Vision mamba: Efficient visual representation learning with bidirectional state space model," in Forty-first International Conference on Machine Learning.

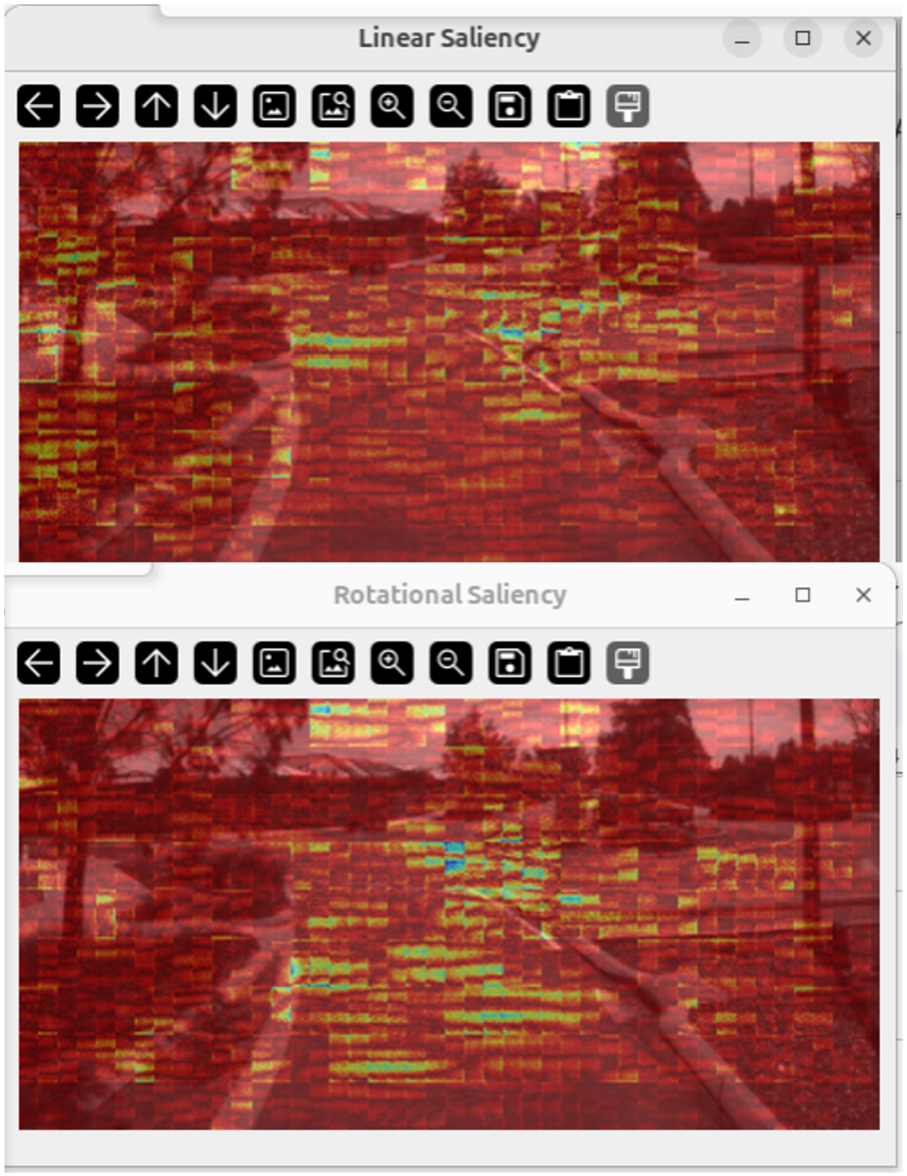
Exploring modern NN architectures in visual tasks



Performance evaluation

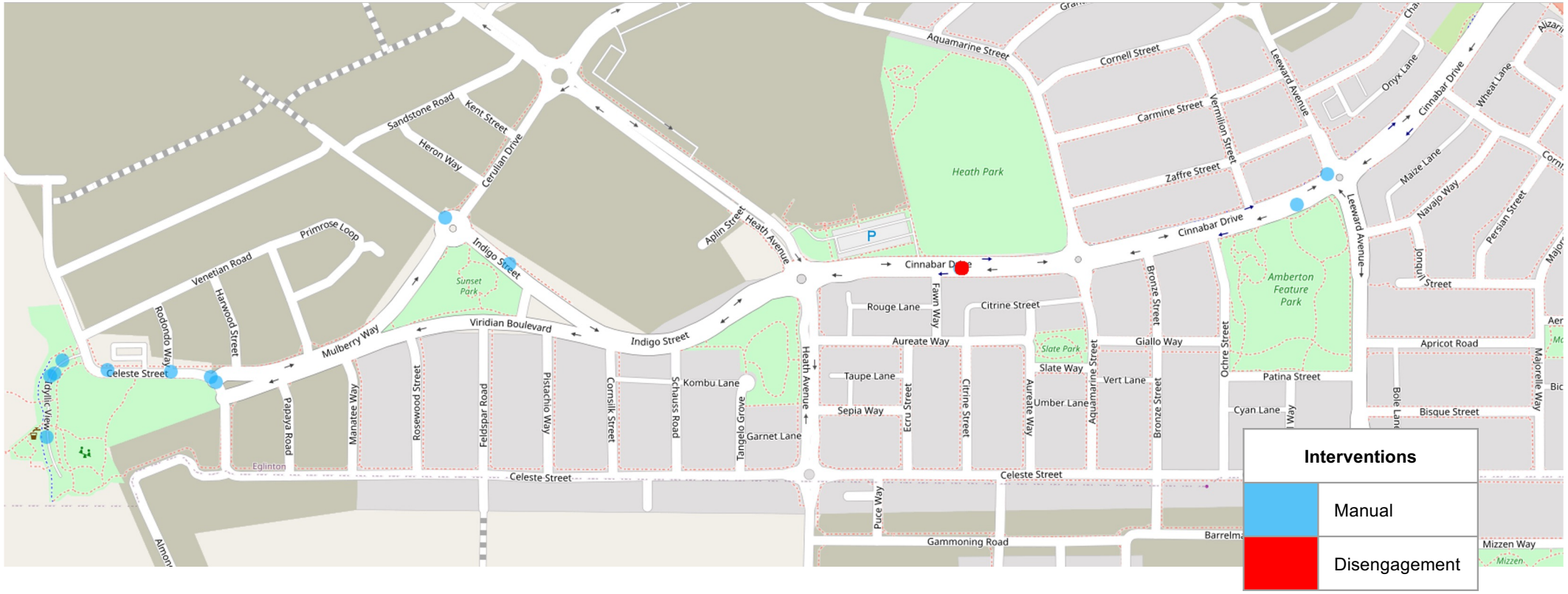
Performance evaluation



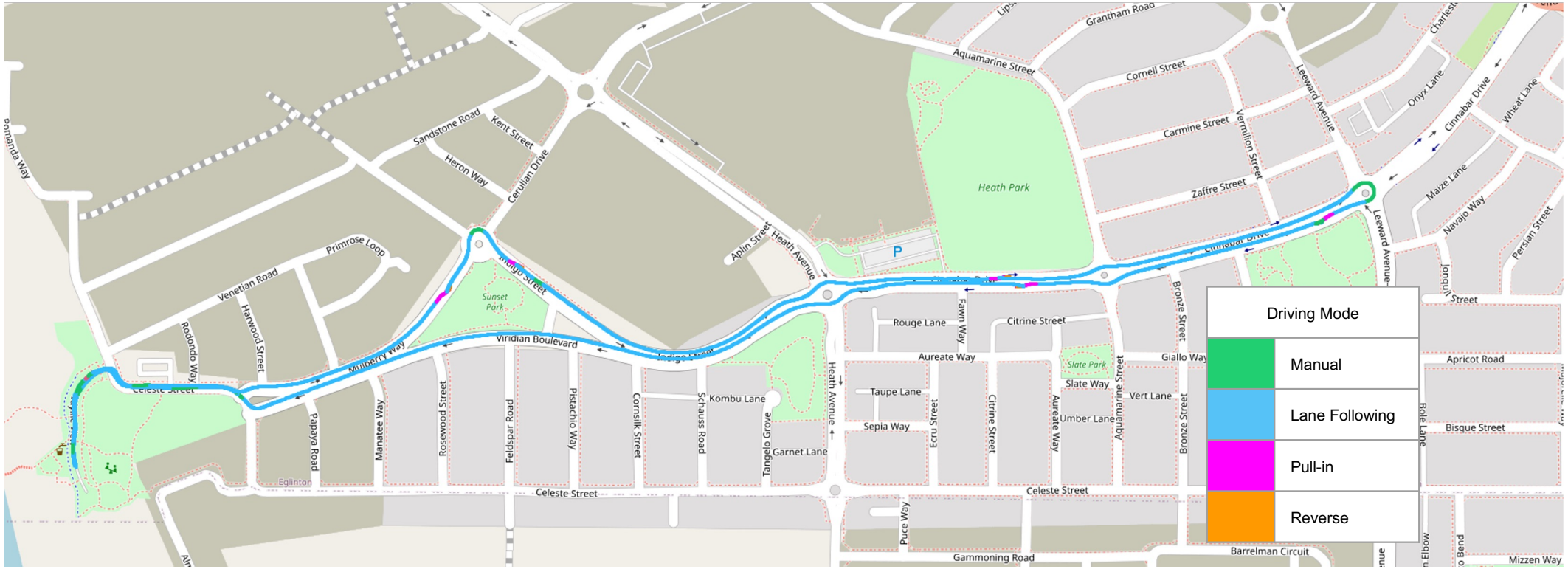


Model Running

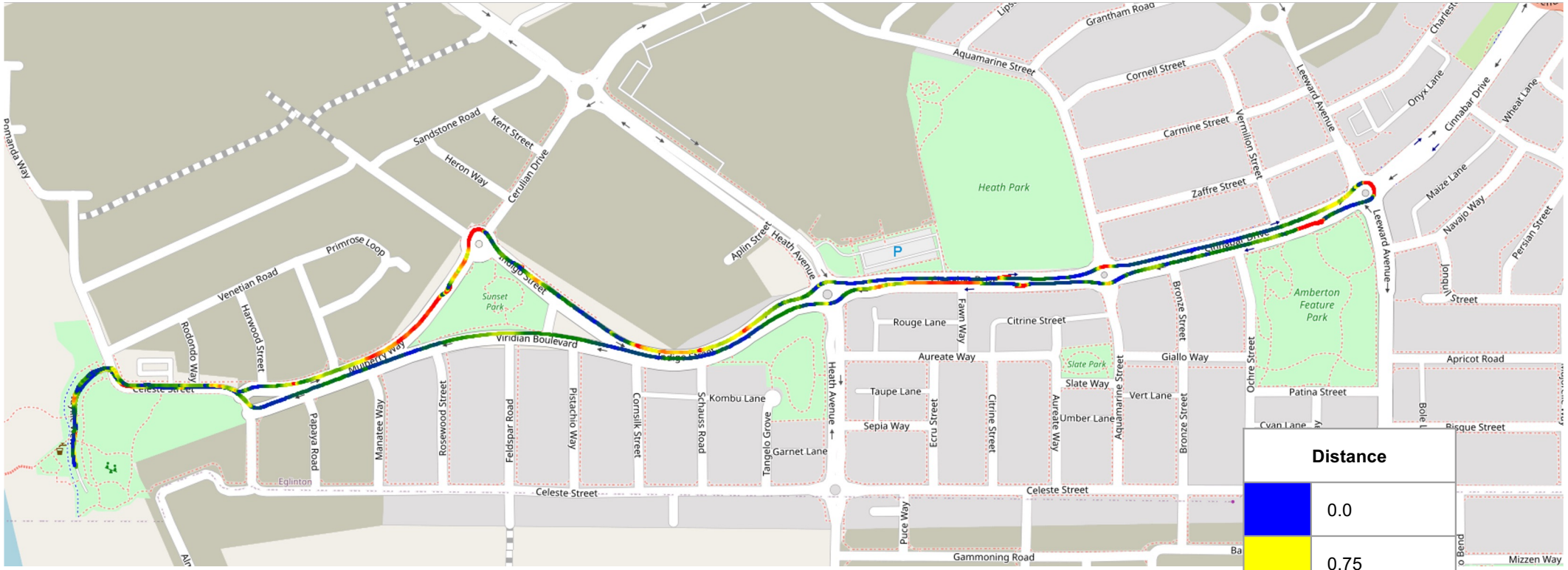
Interventions



Autonomous vs manual mode

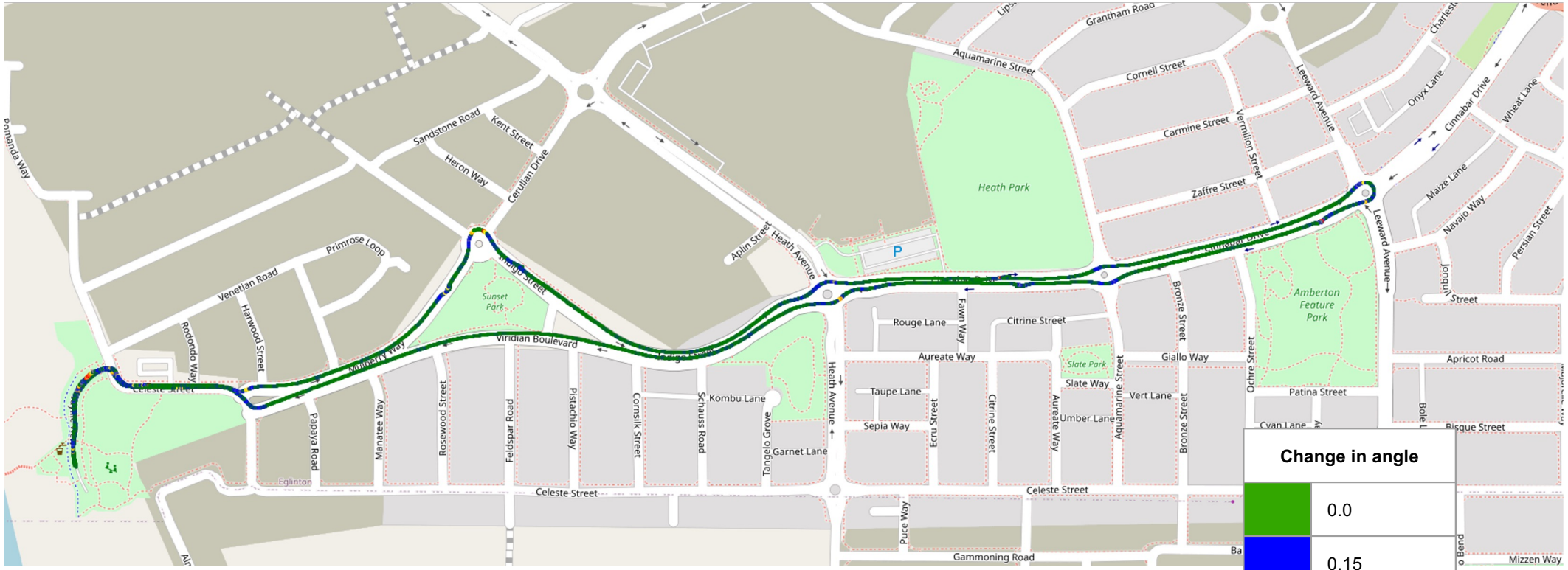


Deviation from optimal path

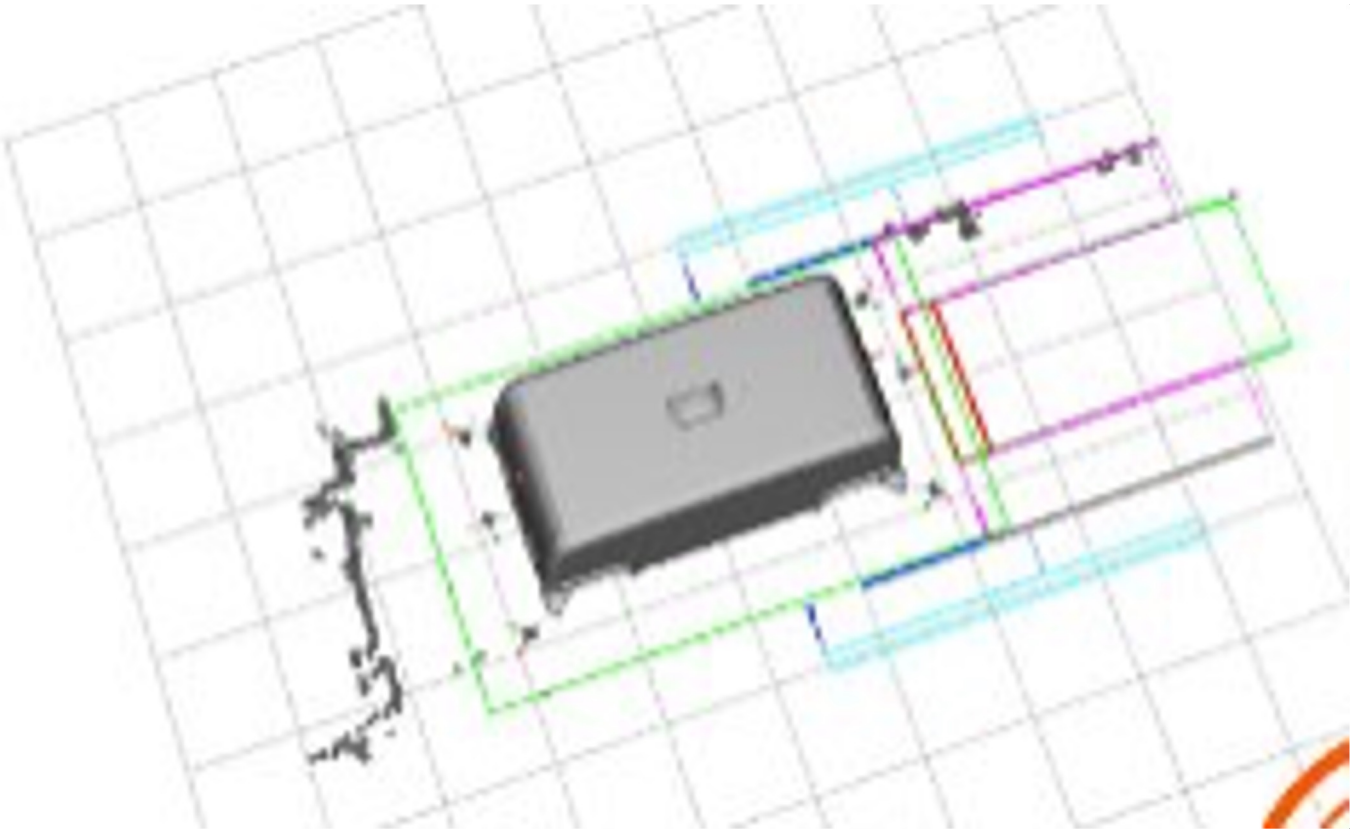


Speed variation

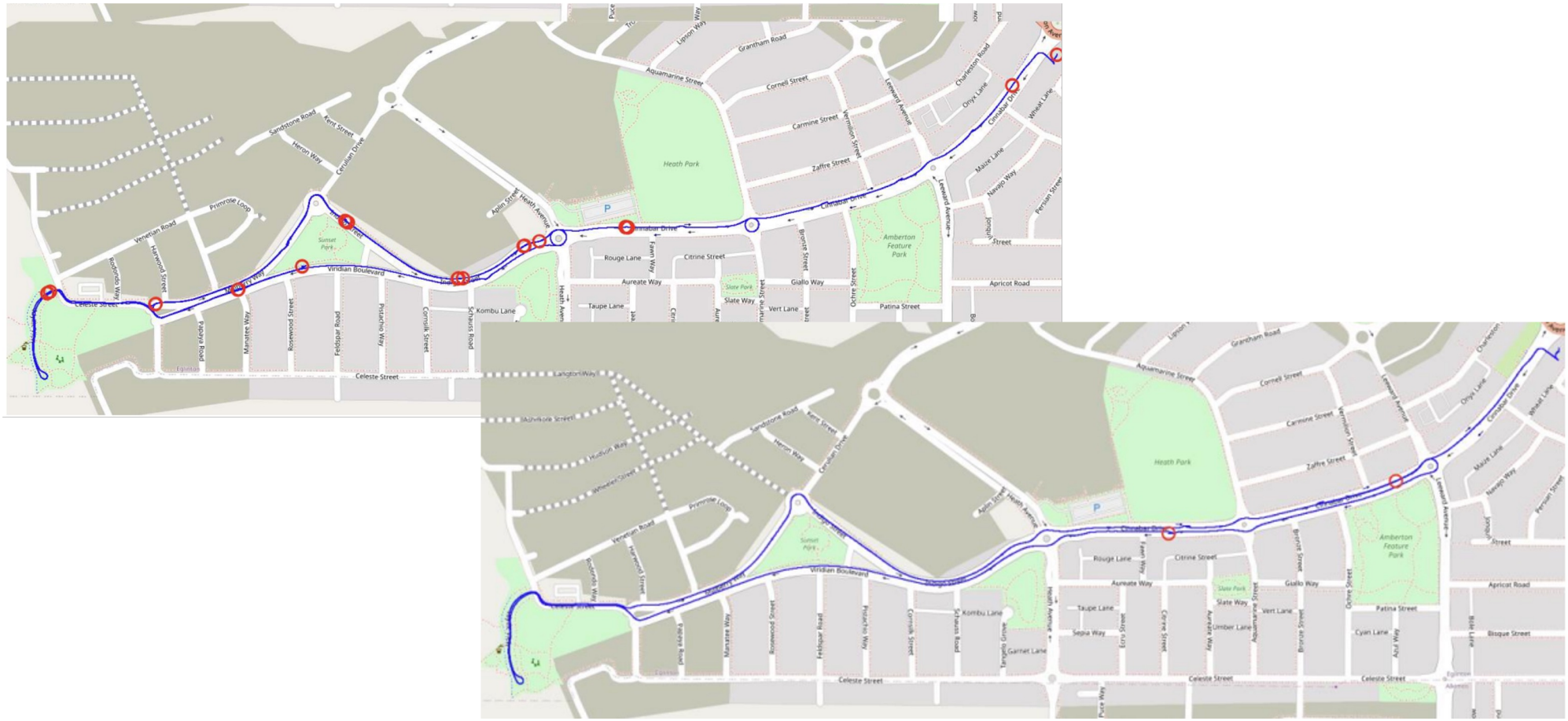
Journey “Smoothness” Variation



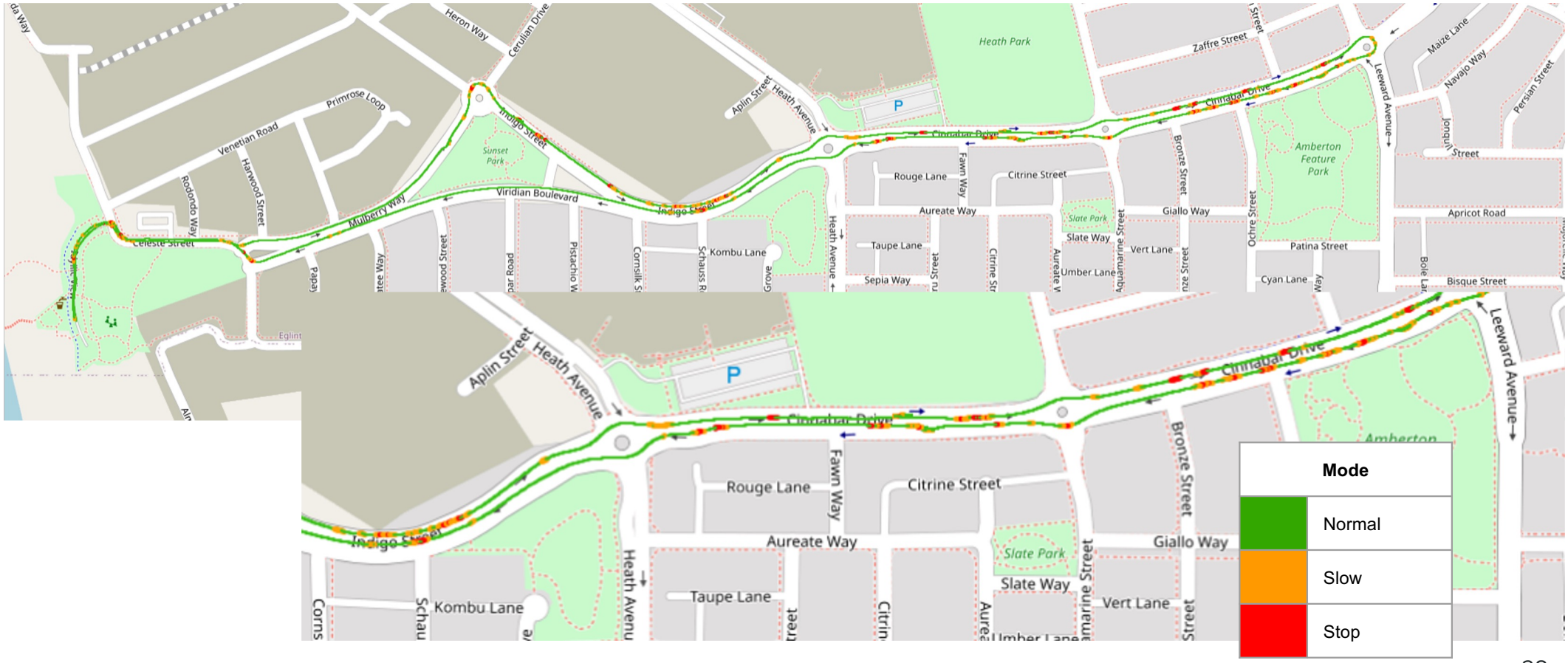
Safety checks when using NNs



‘Disengagements’ Before and After slow node



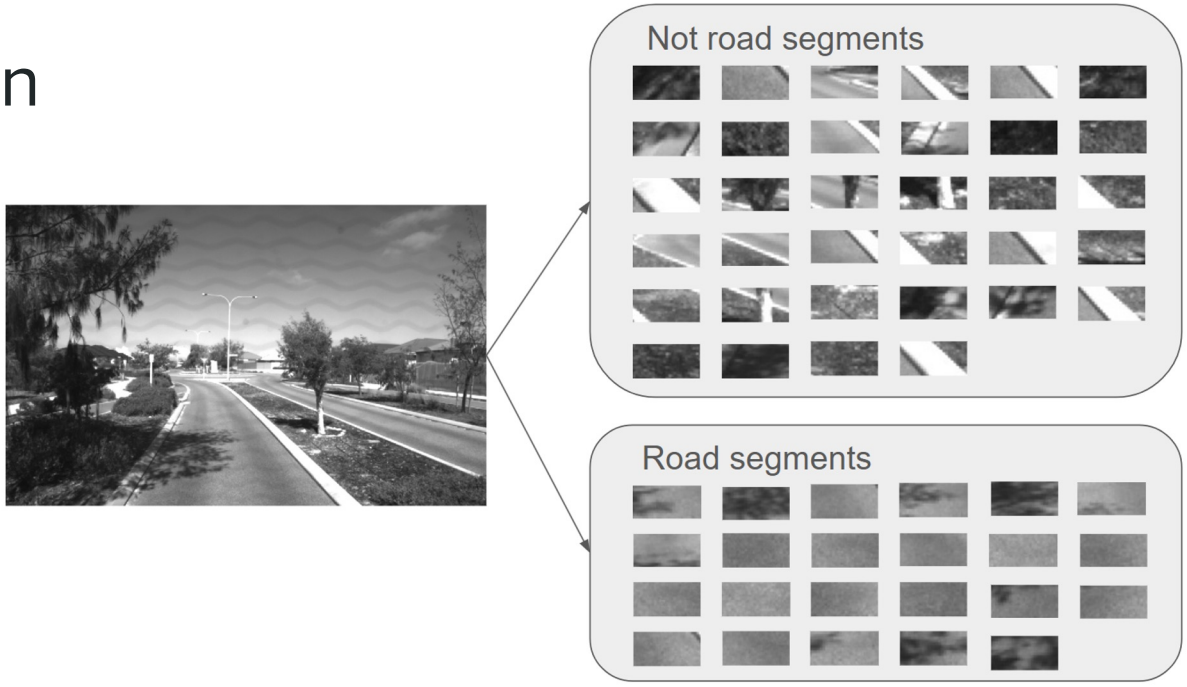
Slow/Stop node impacts

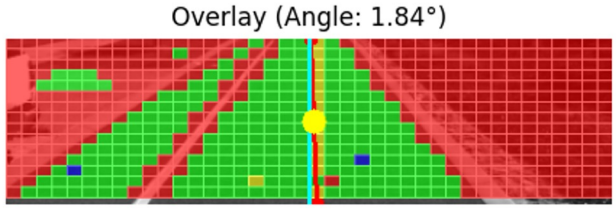


Driving results - preliminary

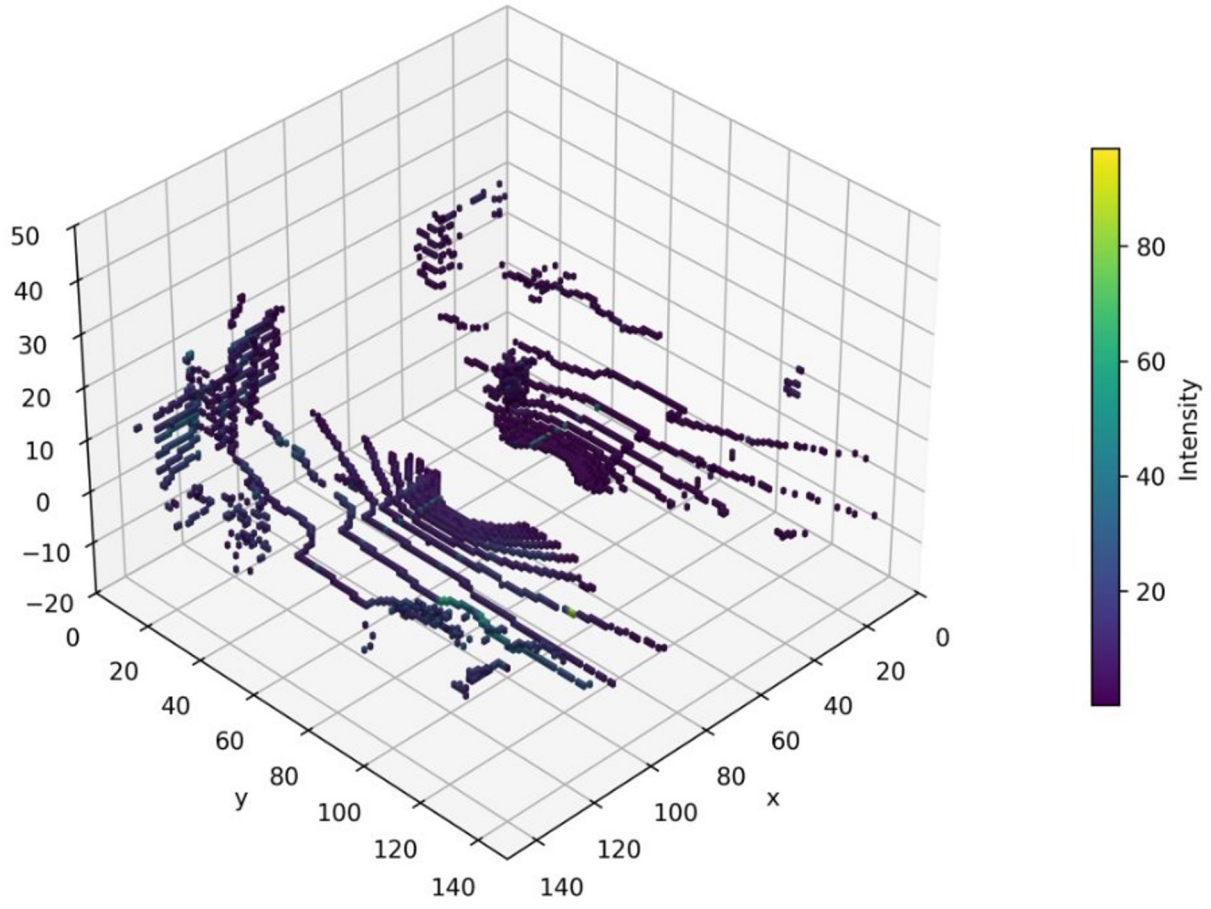
Model	Disengagements	Interventions	Auto (sec)	Manual (sec)	Slow/Stop (sec)	Autonomy %
EfficientNet	9	19	1162.6	262.95	130	81.55
ViT	3	22	1252.6	341.8	145.5	78.56
Swin	1	9	1037.7	184.15	126.6	84.92
ViM	5	10	1040.55	138.55	115.65	88.25
VMamba	1	13	1178.55	139.5	112.5	89.42

Safety - low level detection

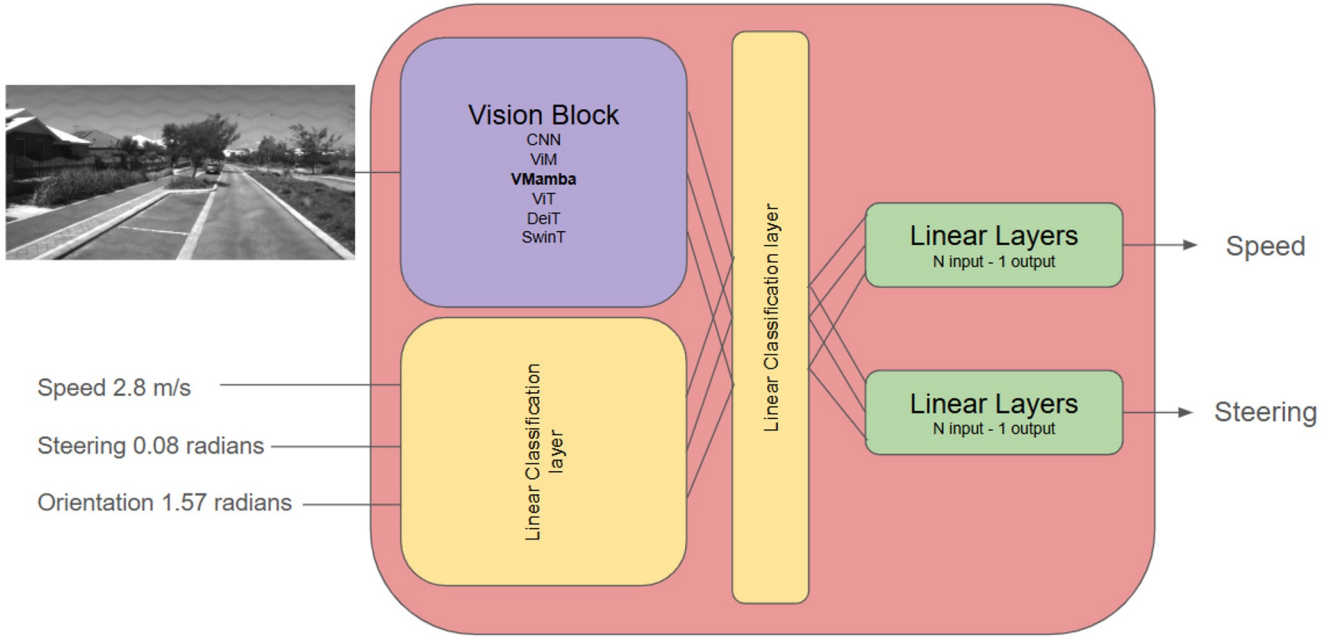


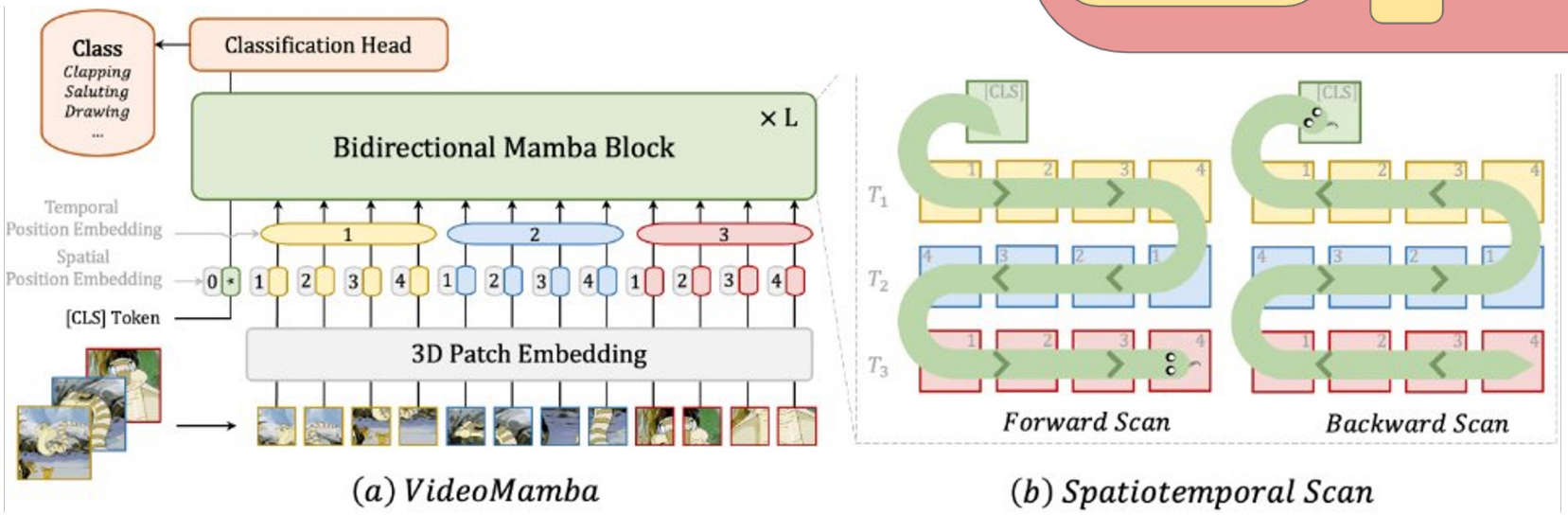


LiDAR based NN



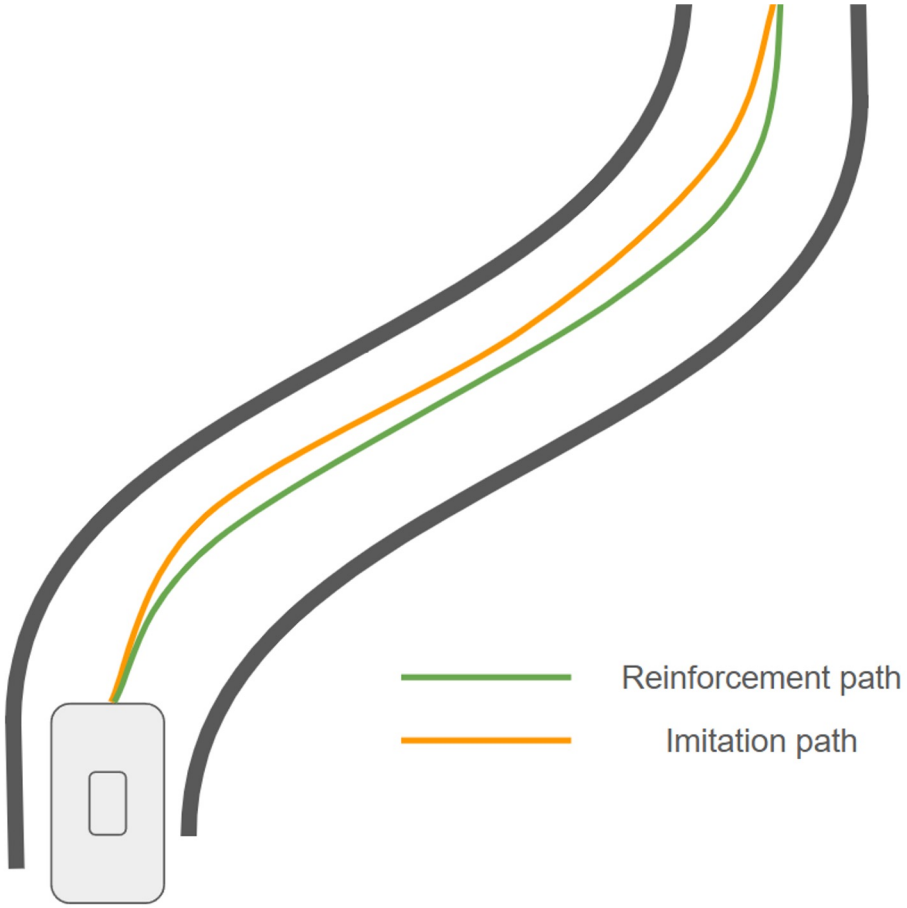
Temporal and Feedback Models





Future work

- Improving performance
  - using PPO RI
  - Introducing autoencoders and masking during training
- Be more proactive
  - Making prediction on future events
- Introduce new HMI techniques



Questions?