Perception in Snow Covered Environments

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Project Summary

- Develop **perception model** which can enable an autonomous vehicle to **“see” in snowy environments**

- Fusion of **RGB camera + LiDAR** data

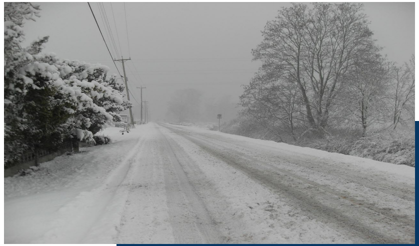
- **Drivable path detection**

- **Object detection and tracking**

Motivation

- **Snow is a challenging weather condition** for autonomous vehicles
  - Traditional visual cues such as lane markers are not visible and cannot be used
- **Sensor accuracy decreases** in snow:
  - Camera has decreased visibility, glare, and contrast
  - LiDAR has signal scattering, attenuation, and absorption
  - Radar can detect objects but not classify them correctly

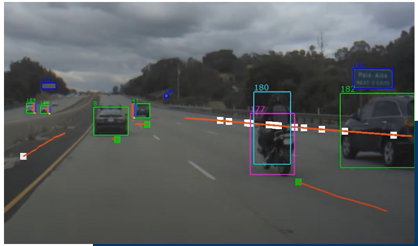
Goals



Provide ego vehicle with roadway boundaries

Identify objects in the vicinity of the ego vehicle

Robust to broad range of snow conditions and environments



Sensor fusion with LiDAR and RGB camera

Use Cases

Safety

Decrease the number of accidents due to snow, thereby preventing death or bodily injury

Inclement weather is the 5th most common cause of accidents in the U.S.

Feasibility

Increase the geographical range of autonomous vehicles

~70% of the lower 48 states in the U.S. receive snow each year

Industry

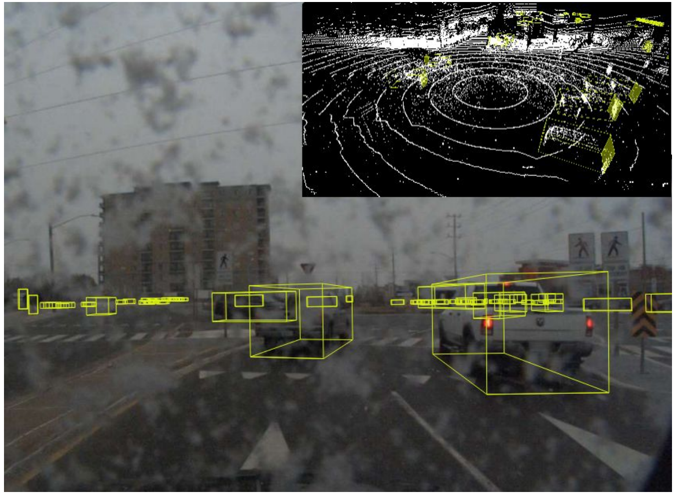
Make clearing snow from roadways more efficient and cost-effective

States are struggling to find enough people willing to become snowplow operators

Datasets

- DENSE
  - Labels: Drivable path
  - LIDAR: HDL64-S3
  - 13k frames
  - 64 channels -> 32 channels

- Canadian Adverse Driving Conditions
  - Labels: Detected objects
  - LIDAR: VLP-32C
  - 7k frames
  - 32 channels



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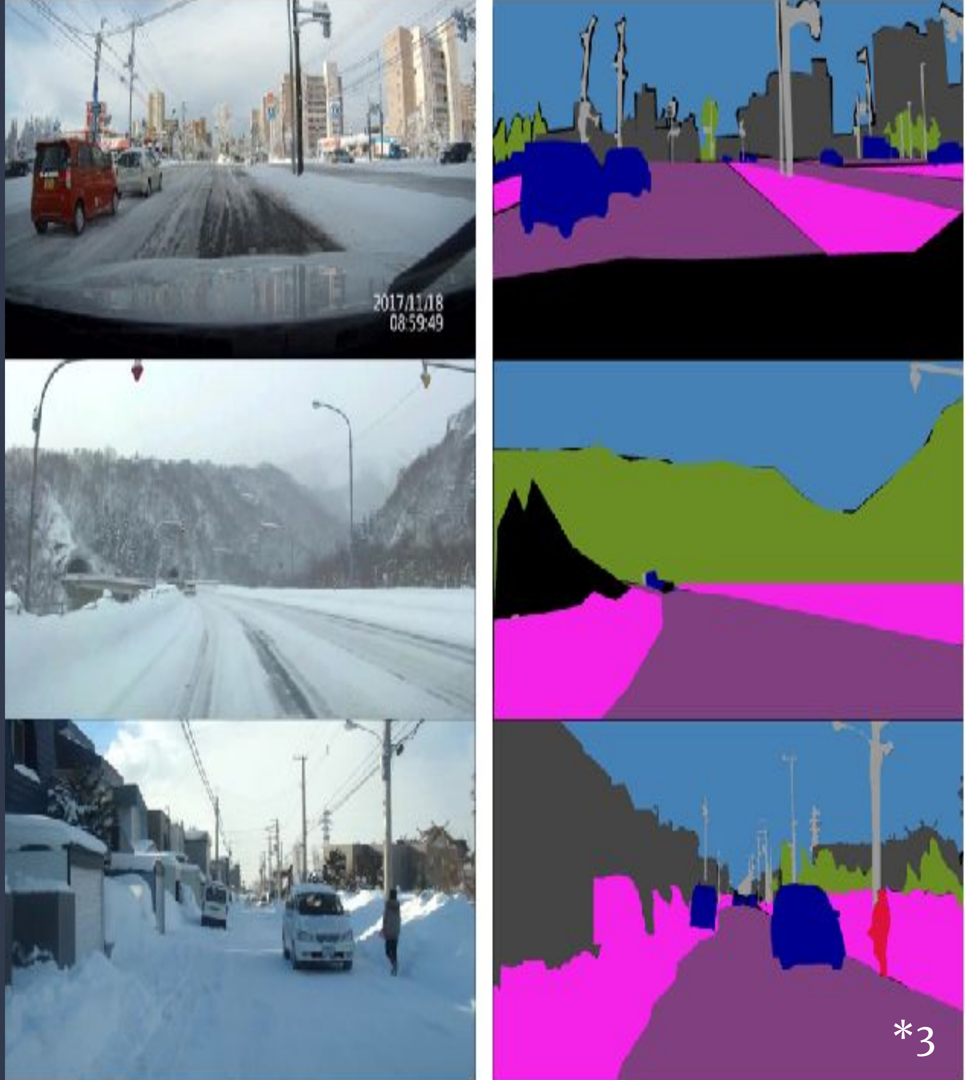
Methodology

- **Goal 1: Drivable Path Detection**
  - Dataset: DENSE
  - Models:
    - RGB
    - LIDAR
    - RGB + LIDAR - CNN based fusion
    - RGB + LIDAR - Multi-headed cross-attention based fusion
  - Metric: Pixel Accuracy, Mean IOU
  - Non-functional requirement:
    - Efficiency



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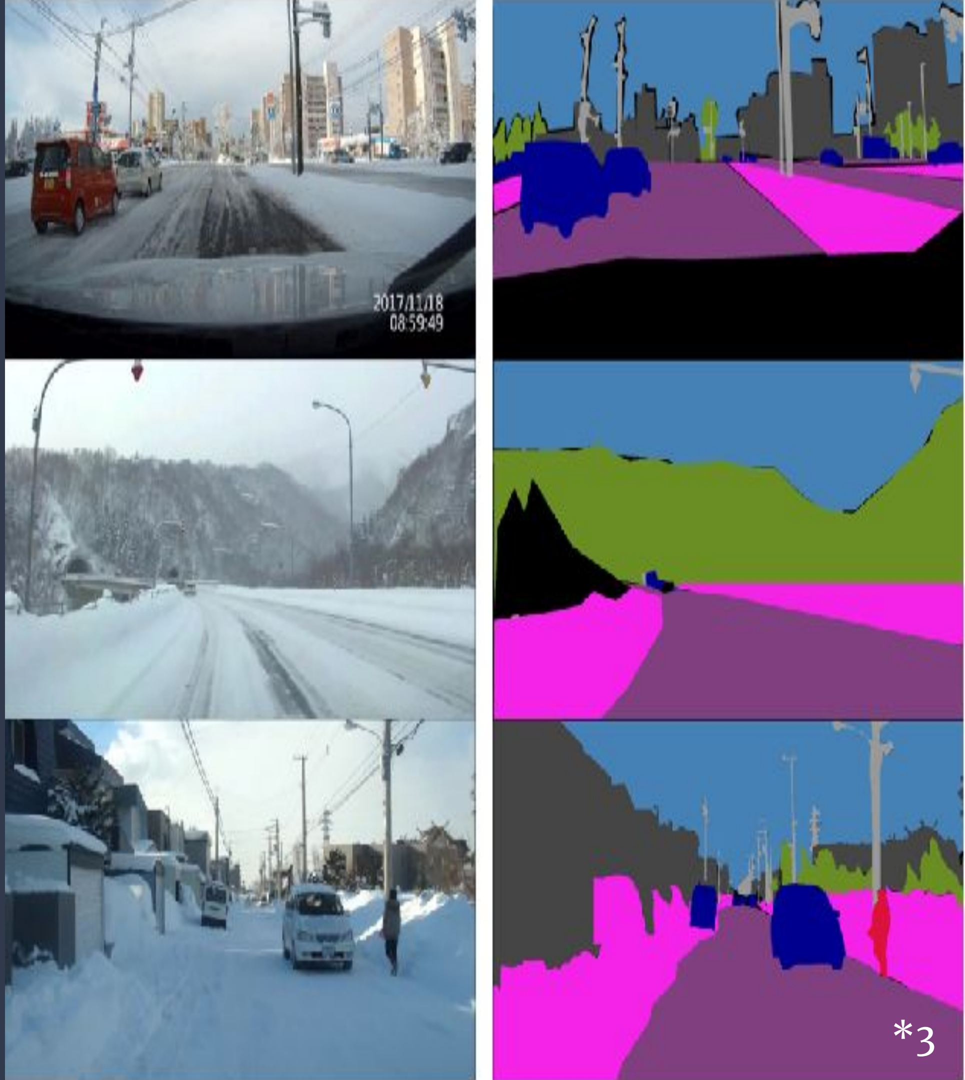
Methodology

- **Goal 1: Drivable Path Detection**
  - Compare with baseline (code not available)
  - Verify results on CADC dataset + label it.
  - Can the RGB camera and LIDAR make use of the different cues?
    - Road boundaries and surfaces
    - Curbs
    - Tire tracks
    - Vegetation
    - Poles
    - Depth difference



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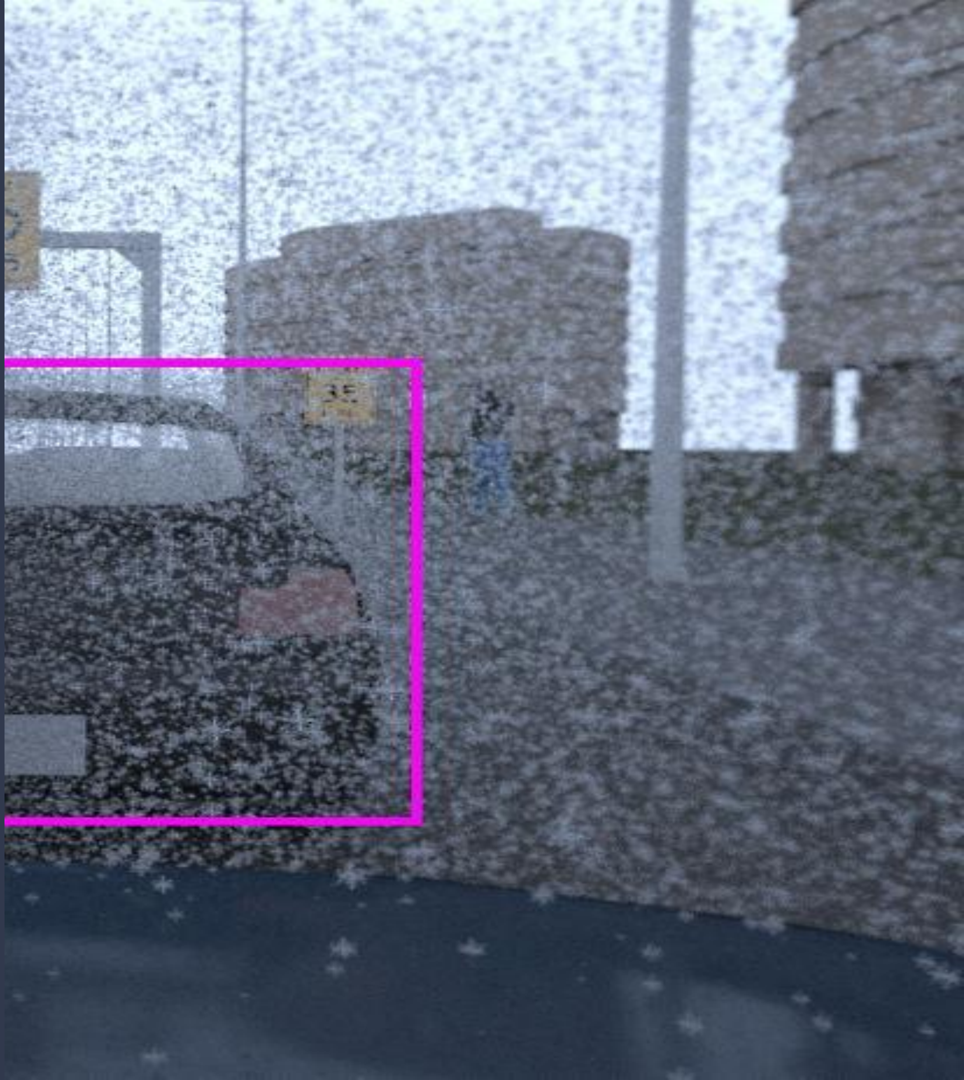
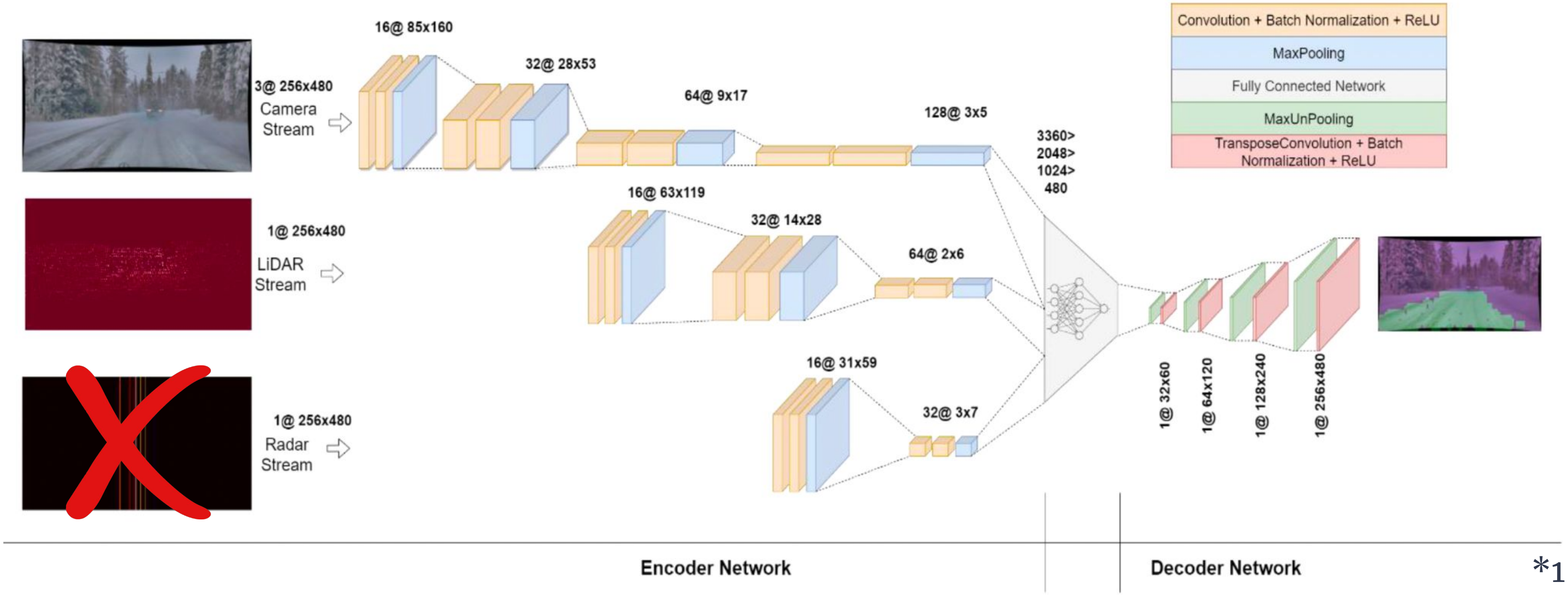
Methodology

- **Goal 2: Object Detection and Tracking (Extra Credit)**
  - Dataset: CADC
  - Models:
    - RGB
    - LIDAR
    - RGB + LIDAR - Fusion based on results from Goal 1
  - Metric: IOU



DENSE Baseline – RGB + LIDAR + RADAR



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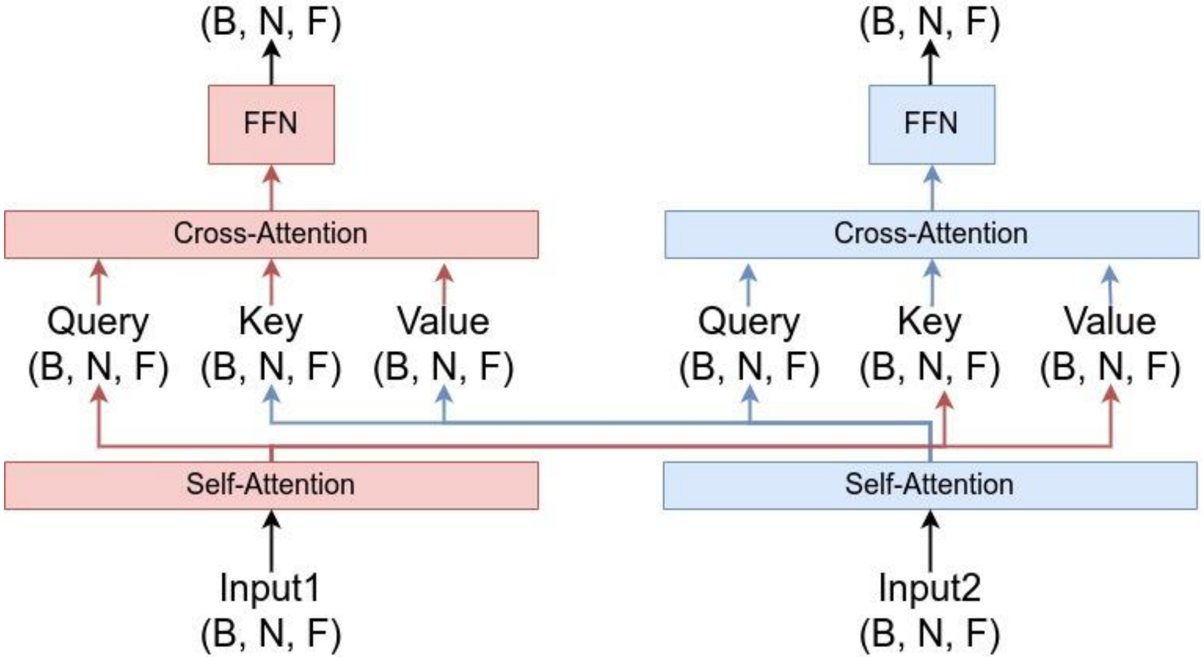
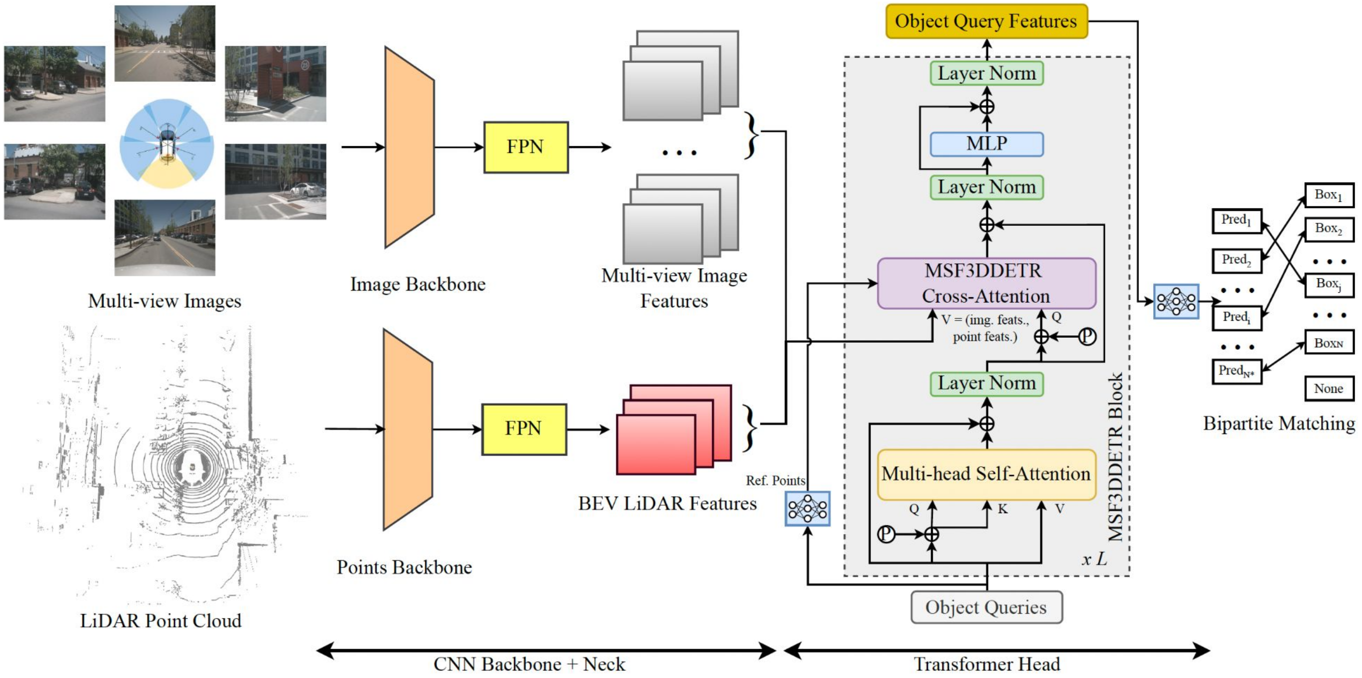
Our Approach - RGB + LIDAR + Multi-headed cross attention for Drivable Path Detection



Cross-Encoder Layer

Proof of concept – MSF3DDETR



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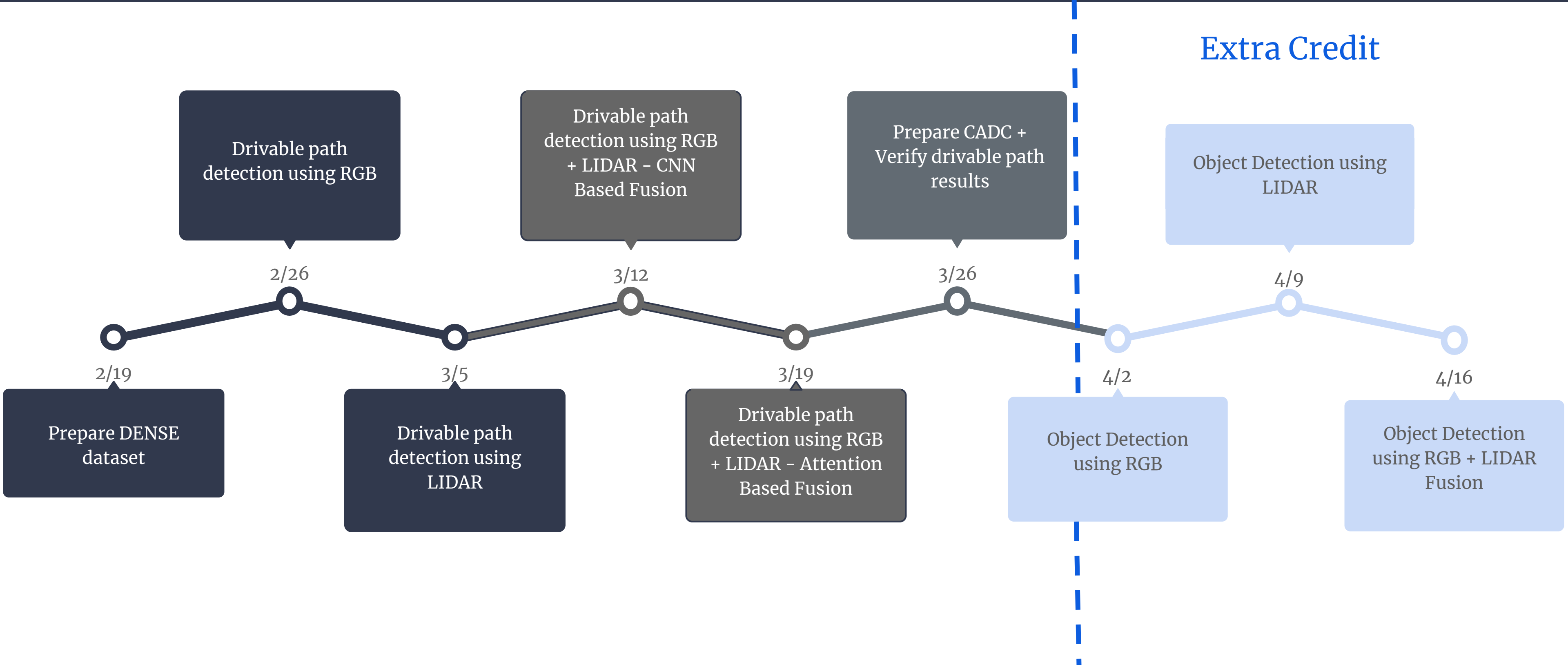
Development Milestones



Demonstration Sequences

Initial Presentation

1

Introduce project scope, motivation, datasets, and methodology

Intermediate Demonstration

2

Comparison between CNN driveable path detection with and without RGB image + LiDAR fusion

Final Demonstration

3

Multi-head cross attention drivable path detection with and without RGB image + LiDAR fusion

+ Object detection and tracking on CADC (extra credit)

Work Partitioning

01	Swathi	• Downsample DENSE dataset • Implement CNN model using DENSE RGB images • Add multi-headed cross attention to model • Implement object detection model using CADC RGB images
02	Lakshay	• Implement CNN model using LiDAR • Add multi-headed cross attention to model • Implement object detection model using CADC LiDAR • Fuse semantic segmentation + object detection on CADC dataset
03	Leah	• Implement CNN model using RGB images + LiDAR • Add multi-headed cross attention to model • Apply CNN model to CADC dataset • Fuse semantic segmentation + object detection on CADC dataset

*all team members will be participate in report writing, presentation development, and final model tuning

Conclusion

- **Determine driveable path**
- Detect and track objects
- Experiment with fusion techniques for **RGB & LIDAR**
- Generate drivable **path labels for CADC**

References

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2. Pitropov, Matthew & Garcia, Danson & Rebello, Jason & Smart, Michael & Wang, Carlos & Czarnecki, Krzysztof & Waslander, Steven. (2020). ***Canadian Adverse Driving Conditions dataset.*** The International Journal of Robotics Research. 40. 027836492097936. 10.1177/0278364920979368.
3. Yasuno, T., Sugawara, H., Fujii, J. (2022). ***Road Surface Translation Under Snow-Covered and Semantic Segmentation for Snow Hazard Index.*** In: , et al. Advances in Artificial Intelligence. JSAI 2021. Advances in Intelligent Systems and Computing, vol 1423. Springer, Cham. https://doi.org/10.1007/978-3-030-96451-1_8
4. ***DENSE Dataset***. Universitat Ulm. https://www.uni-ulm.de/in/iui-drive-u/projekte/dense-datasets/.
5. Erabati, Gopi Krishna & Araujo, Helder. (2022). ***MSF3DDETR: Multi-Sensor Fusion 3D Detection Transformer for Autonomous Driving.*** Institute of System and Robotics, University of Coimbra, Portugal. https://arxiv.org/pdf/2210.15316.pdf.

Thank you!

Q & A