Run-time Monitoring of 3D Object Detection in Automated Driving Systems Using Early Layer Neural Activation Patterns

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Contact

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Outline

- Introduction
- Methodology
- Results
- Conclusion

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Introduction: Motivation

https://www.abc15.com/news/region-southeast-valley/chandler/waymo-car-involved-in-chandler-arizona-crash

https://abc7.com/tesla-gardena-crash-driver/11873142/#:~:text=GARDENA%2C%20Calif.%20%28KABC%29%20--%20The%20driver%20of%20a,vehicular%20manslaughter%2C%20a%20Los%20Angeles%20County%20judge%20said.

- Object detection is essential for understanding the environment in automated driving systems (ADS).
- Failure in object detection may cause significant harm to road users.
- Deep neural network-based mechanisms are prone to errors.

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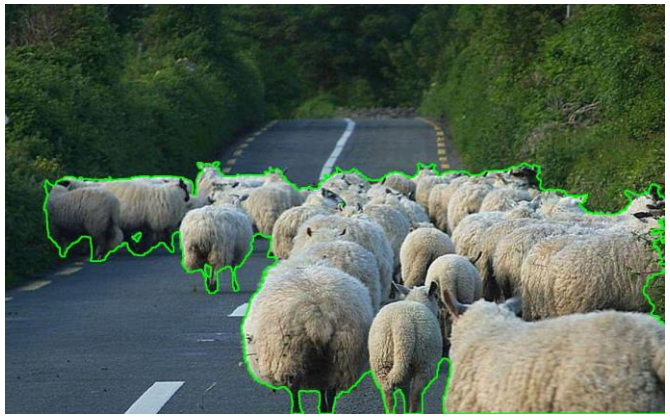
Problem Definition: Object Detection Errors

In Distribution

Missing or misclassifying known objects.

Out-of-Distribution

Not being able to detect unknown objects.



Adversarial

Missing or misclassifying known objects due to external perturbation.

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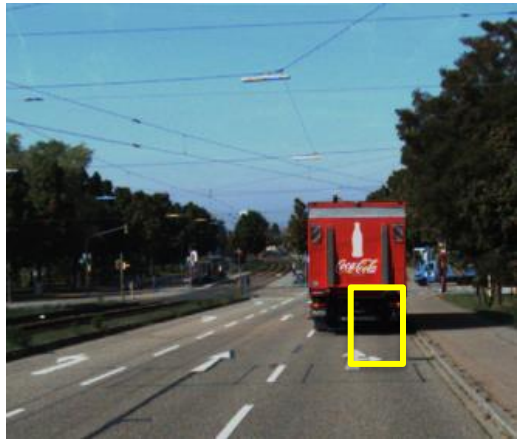
Object Detection Errors

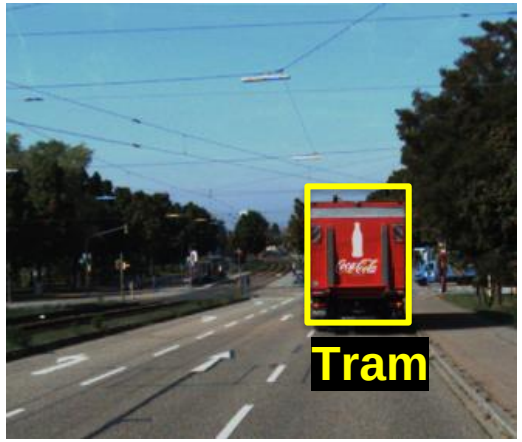
Missing an object



Poor localisation

Not being able to detect at all

Misclassifying an object



Incorrect label

Prediction

Run-Time Monitoring : State of the Art & Challenges

- Primary work on out-of-distribution errors, and uncertainty awareness.
- Gap for in-distribution

- Primary work on 2D object detection.
- Gap for 3D data and 3D object detection.

- Primary work on last layer activation patterns from object detectors for monitoring.
- Gap exploring different layers for monitoring.

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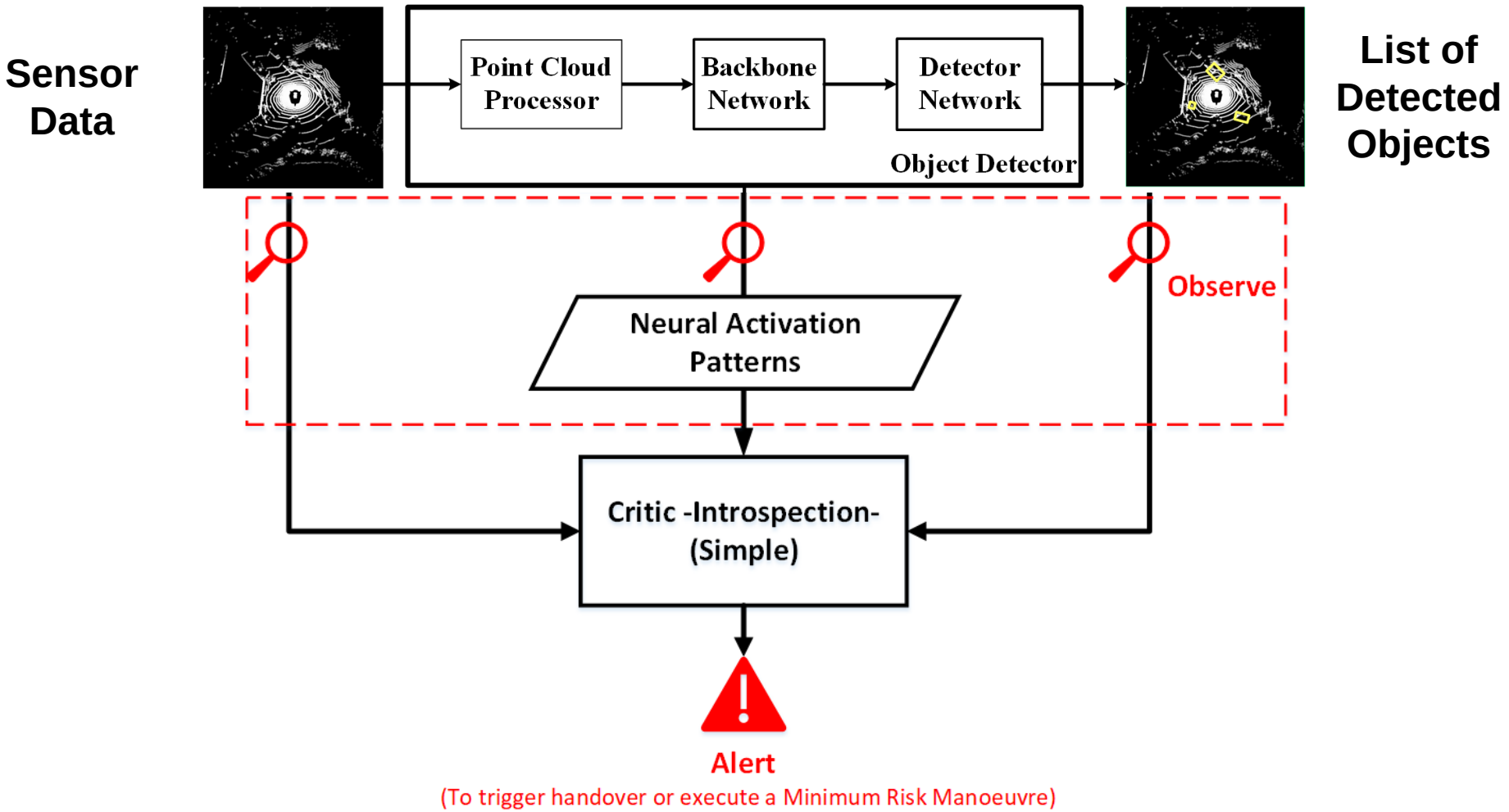
Actor-Critic Architecture



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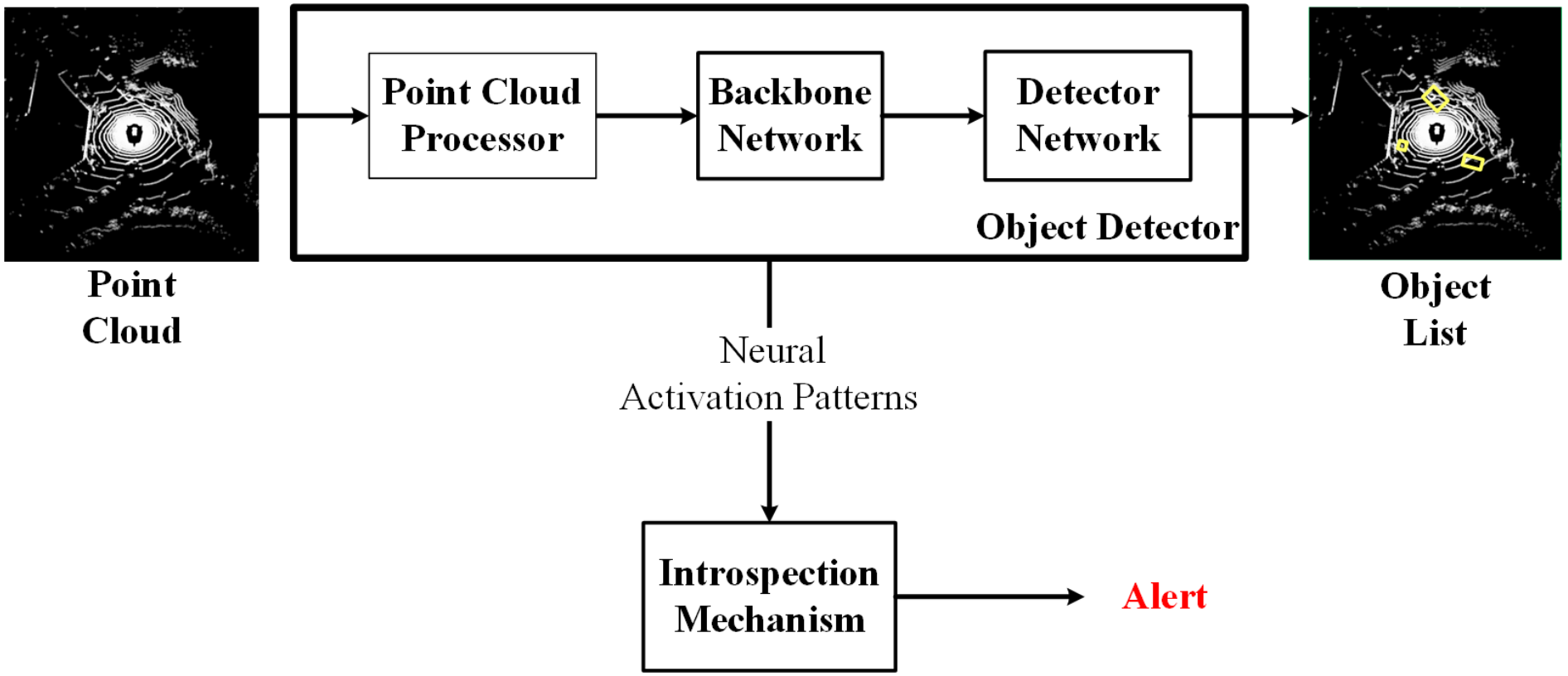
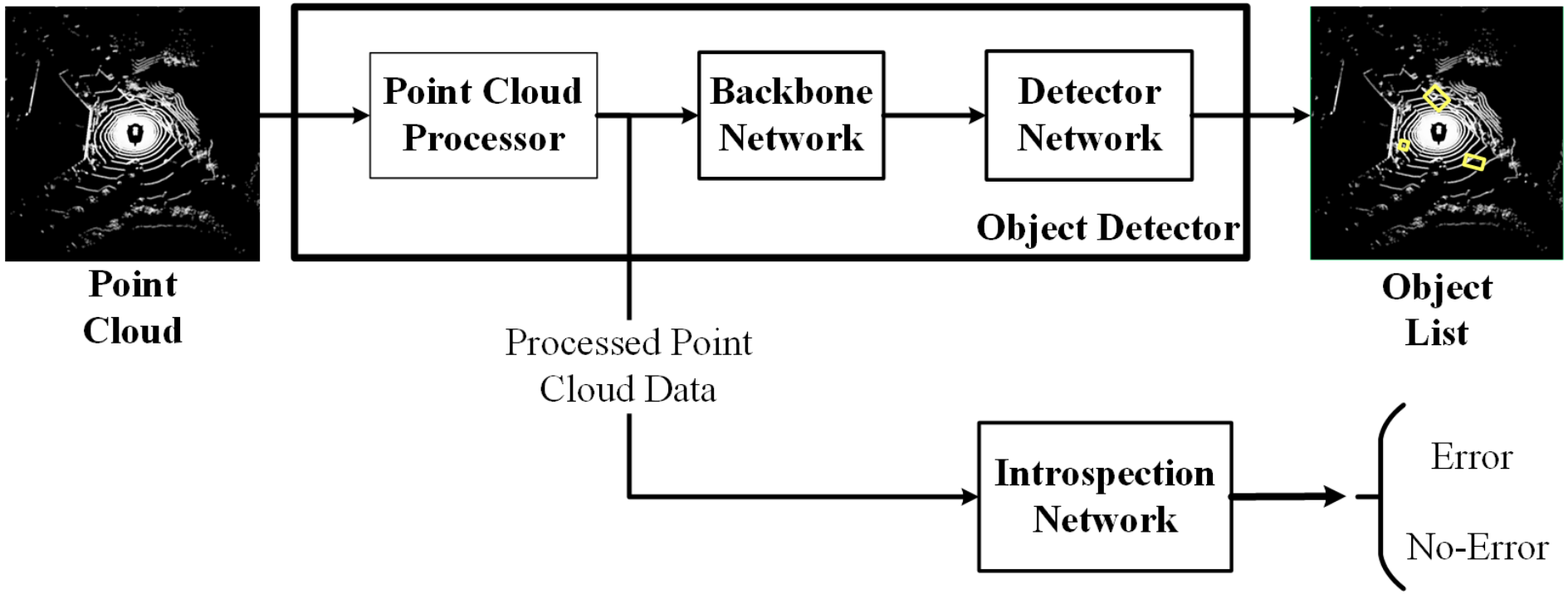
Method: Actor-Critic Architecture



Method: Early Layer Activations



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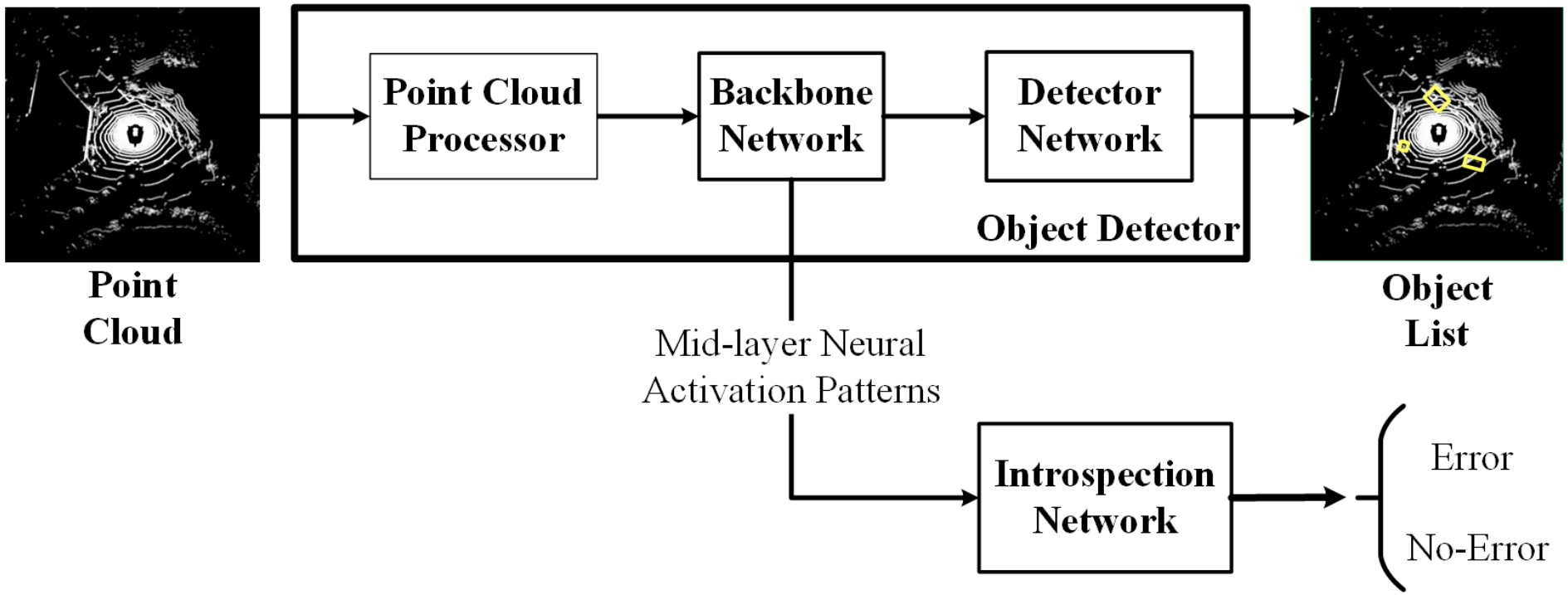
Method: Mid-Layer Activations



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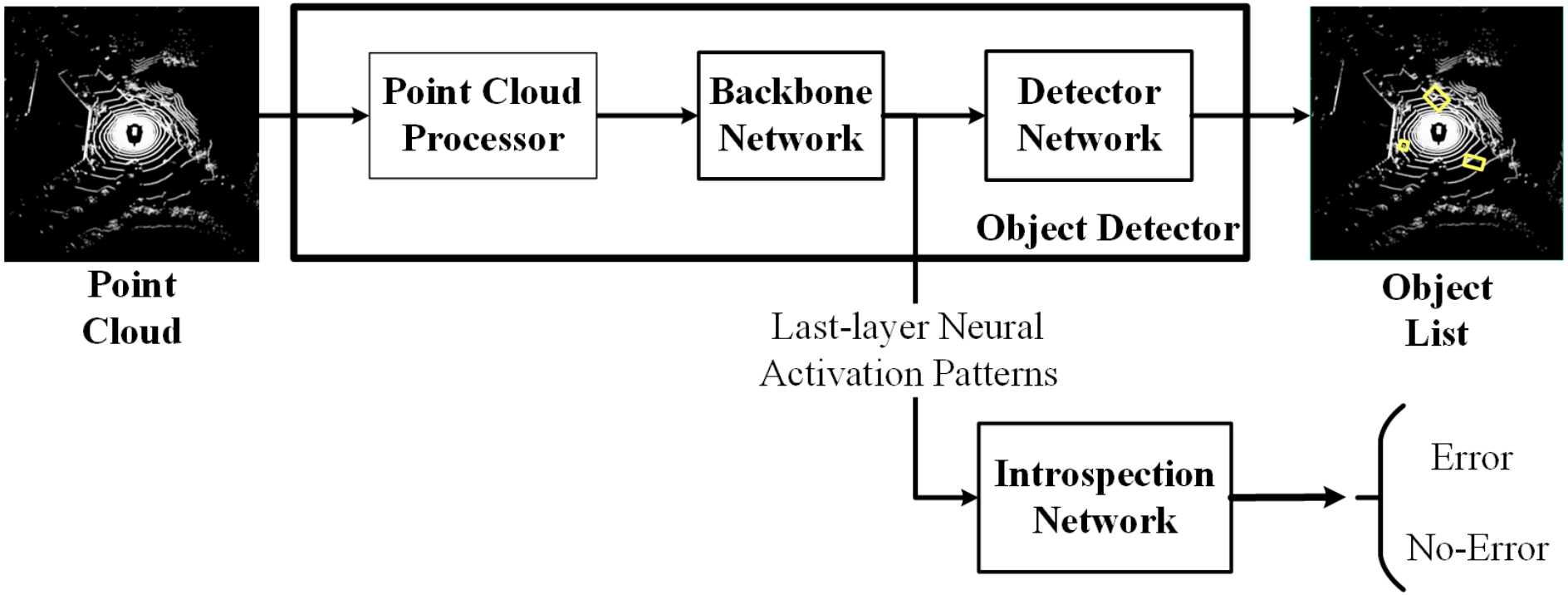
Method: Late Layer Activations



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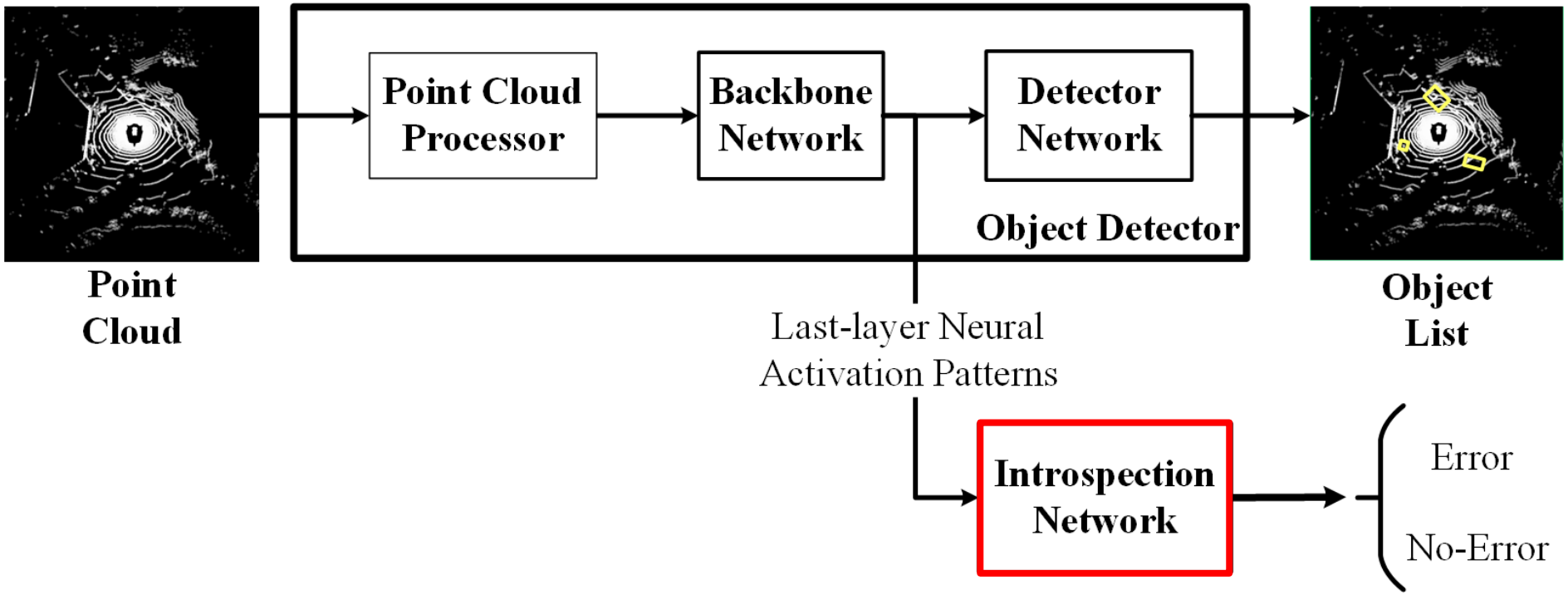
Method: Late Layer Activations



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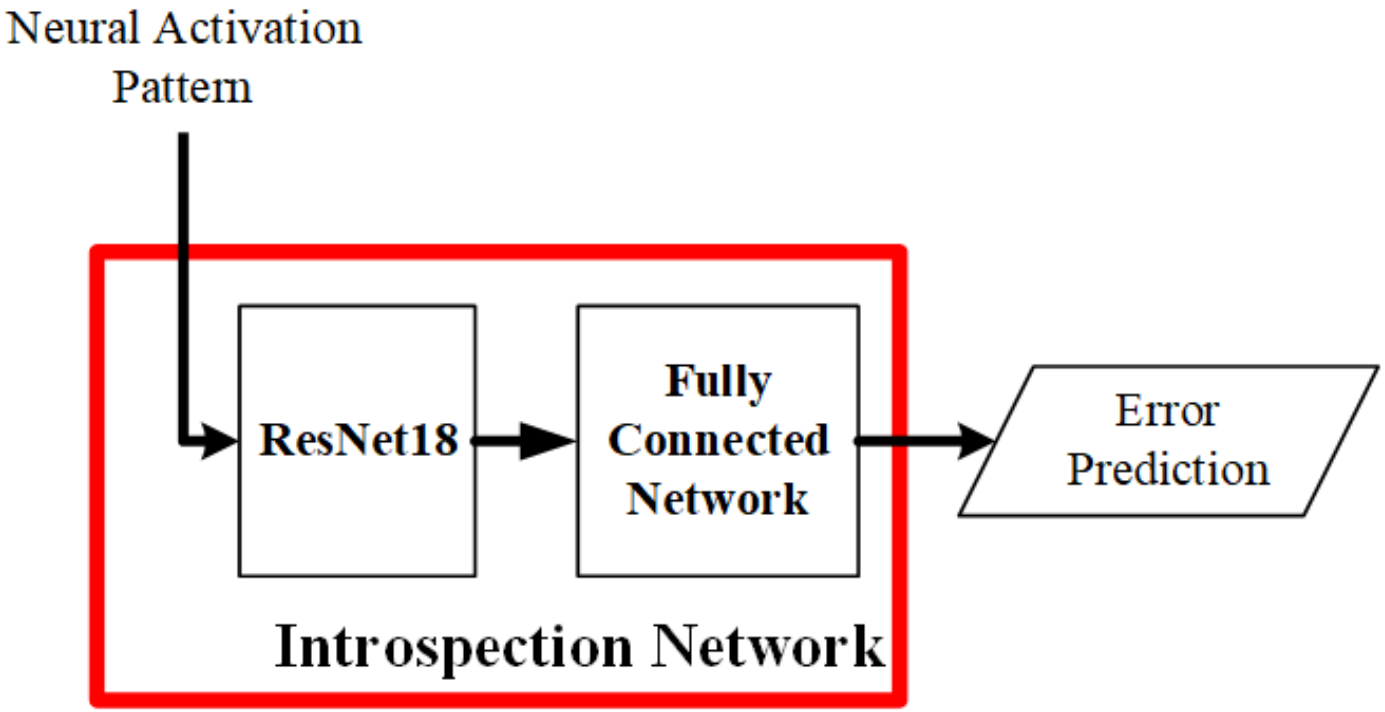
Method: Introspection Network



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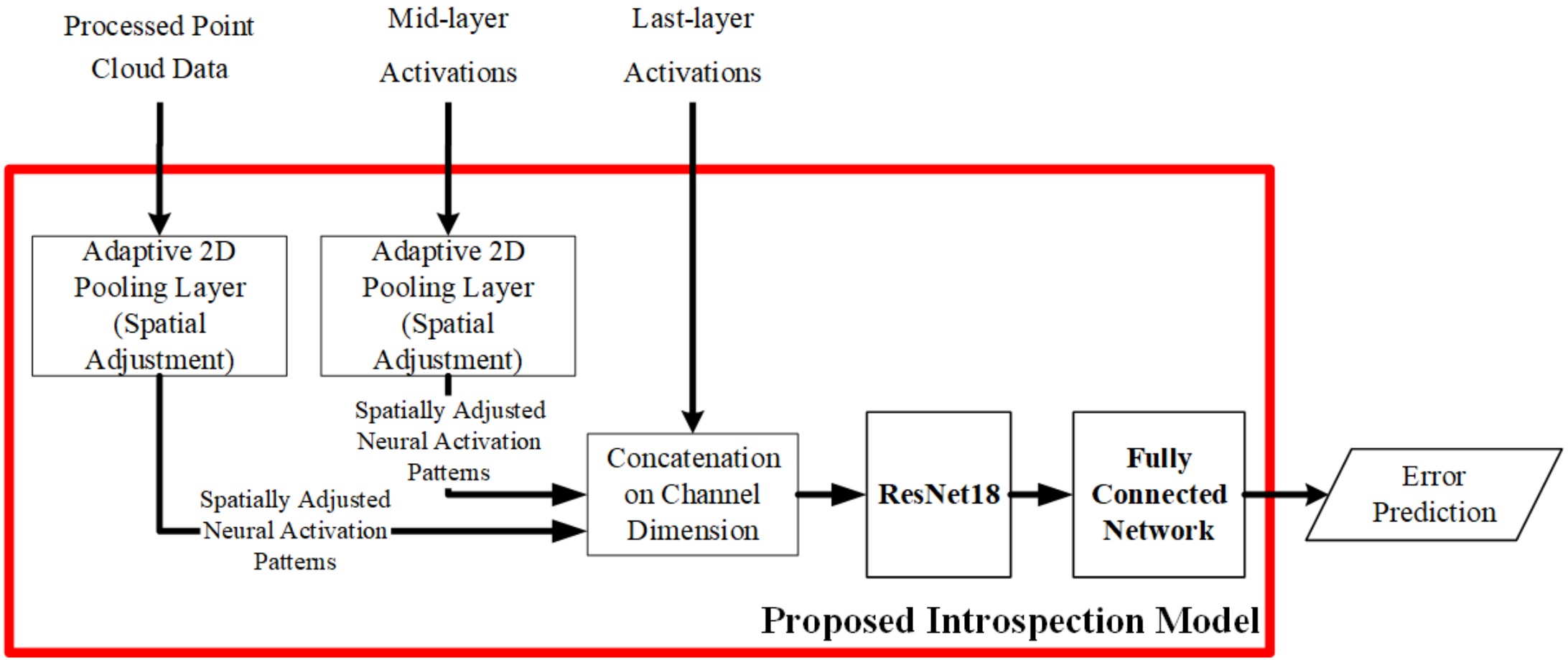
Method: Proposed Mechanism



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Performance Evaluations: Detection Performance

Dataset / Model	Input	Rec.(-)	Rec.(+)	AUROC
Kitti / PointPillars	EARLY	**0.7764**	**0.7524**	**0.8420**
	MID	<u>0.7500</u>	<u>0.7460</u>	<u>0.8368</u>
	LATE	0.6268	0.8104	0.8036
	CONCAT	0.7077	0.7858	0.8309
NuScenes / CenterPoint	EARLY	0.7945	0.8995	0.9198
	MID	**0.7945**	**0.9060**	**0.9330**
	LATE	0.7123	0.8581	0.8919
	CONCAT	<u>0.8650</u>	<u>0.8630</u>	<u>0.9288</u>

Best result is in bold.
<u>Second best is underlined.</u>

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Performance Evaluations: Computational Requirements

Computational Requirement Comparison

Method	CPU Time (ms)	GPU Time (ms)	FLOPs (G)
EARLY	54.32 (9.54)	11.47 (1.21)	36.32
MID	9.43 (3.26)	2.01 (0.10)	3.68
LAST	**5.01 (0.47)**	**1.80 (0.06)**	**1.60**
CONCAT	<u>4.94 (0.32)</u>	<u>1.95 (0.07)</u>	<u>2.60</u>

Best result is in bold.
<u>Second best is underlined.</u>

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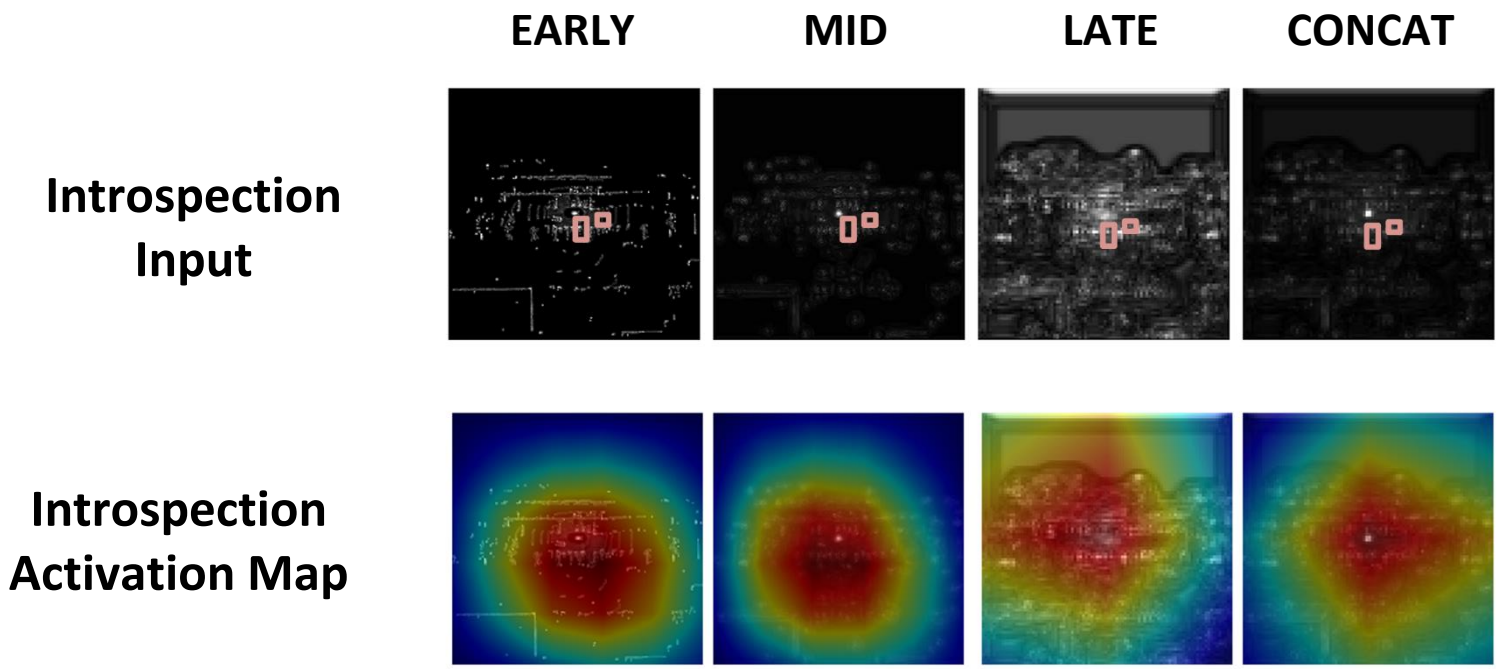
Performance Evaluations: Qualitative Results



Driving direction is from right to left in the example.

Conclusion

- **Early Layer Activations:** Improve error detection in 3D object detection, particularly for complex datasets.
- **Combining Layers:** Offers a balanced approach, enhancing both performance and computational efficiency.
- **Future Research**: Explore dataset-shift and methods for multi-layer activation utilization.

Thank You!

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Q&A

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