

Neuromorphic Vision for Reliable Robot Navigation in Challenging Conditions

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Research Question

How can neuromorphic vision improve the reliability of mobile robot navigation and mapping in visually challenging environments?

Methodology

Environment:

- Gazebo Sim 8 tunnel (200m, 10 tiles, 20 obstacles)
- 9 conditions: 3 lighting × 3 fog levels

Robot:

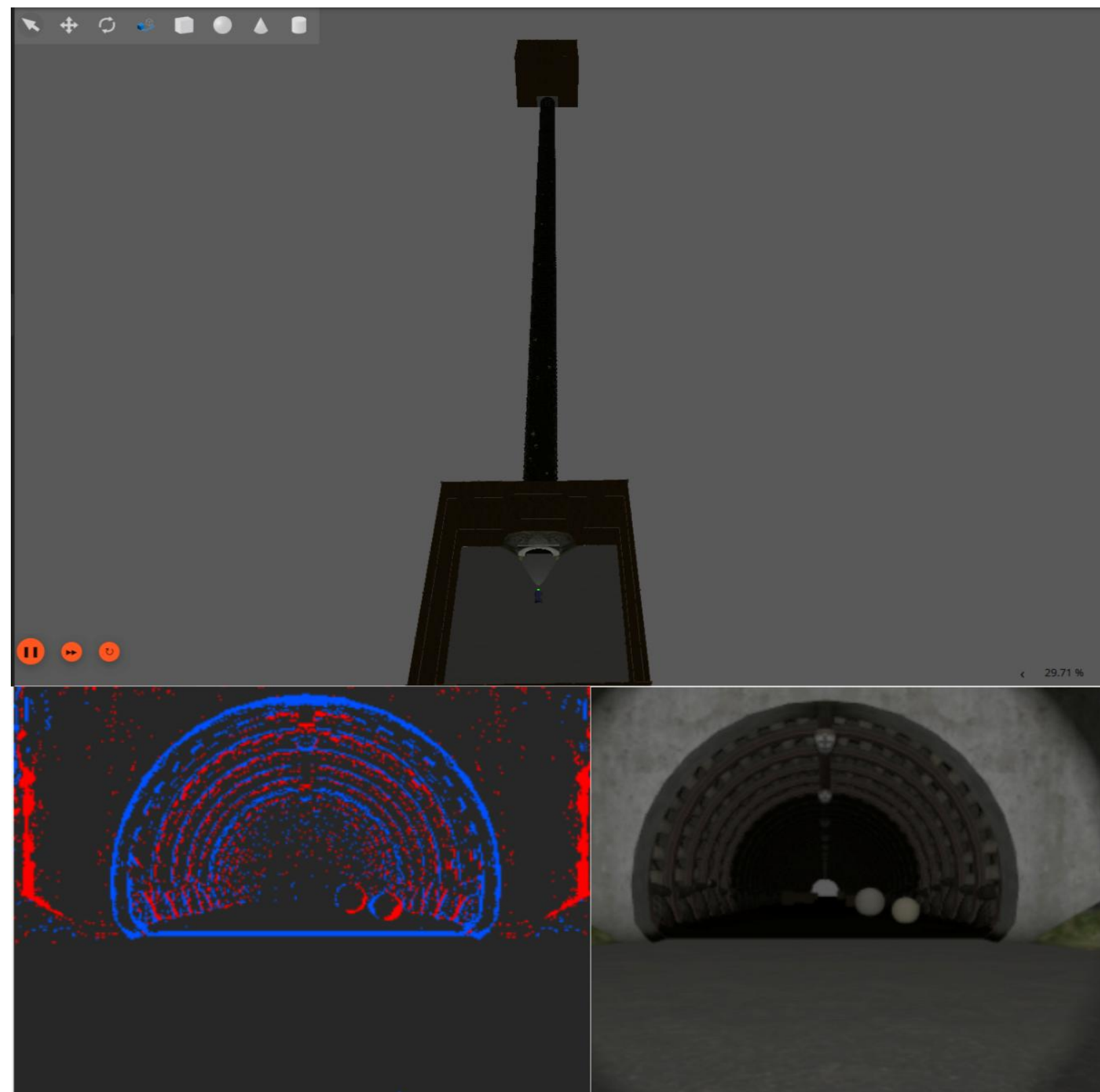
- 4-wheeled differential drive, RGB camera (320×240), depth camera, headlight

Perception Modes:

- RGB-only (3ch), Event-only (3ch), RGB+Event Fusion (6ch)
- Event data via v2e log-intensity differencing (threshold = 0.25)

Training & Evaluation:

- DQN with CNN backbone (5 conv + 3 FC), 4 actions
- 50 episodes per condition, 15 evaluation trials per mode
- 3D mapping via depth back-projection, voxel scoring (0.5m³)



Background

The Problem:

- Underground tunnels and mines present low visibility, fog, dust, and near-dark conditions
- RGB cameras fail in low-light due to limited dynamic range

Event-Based Vision:

- Detects per-pixel brightness changes asynchronously
- Low-latency, high-dynamic-range output even in degraded lighting
- Few studies evaluate combined RGB + event perception for robot navigation

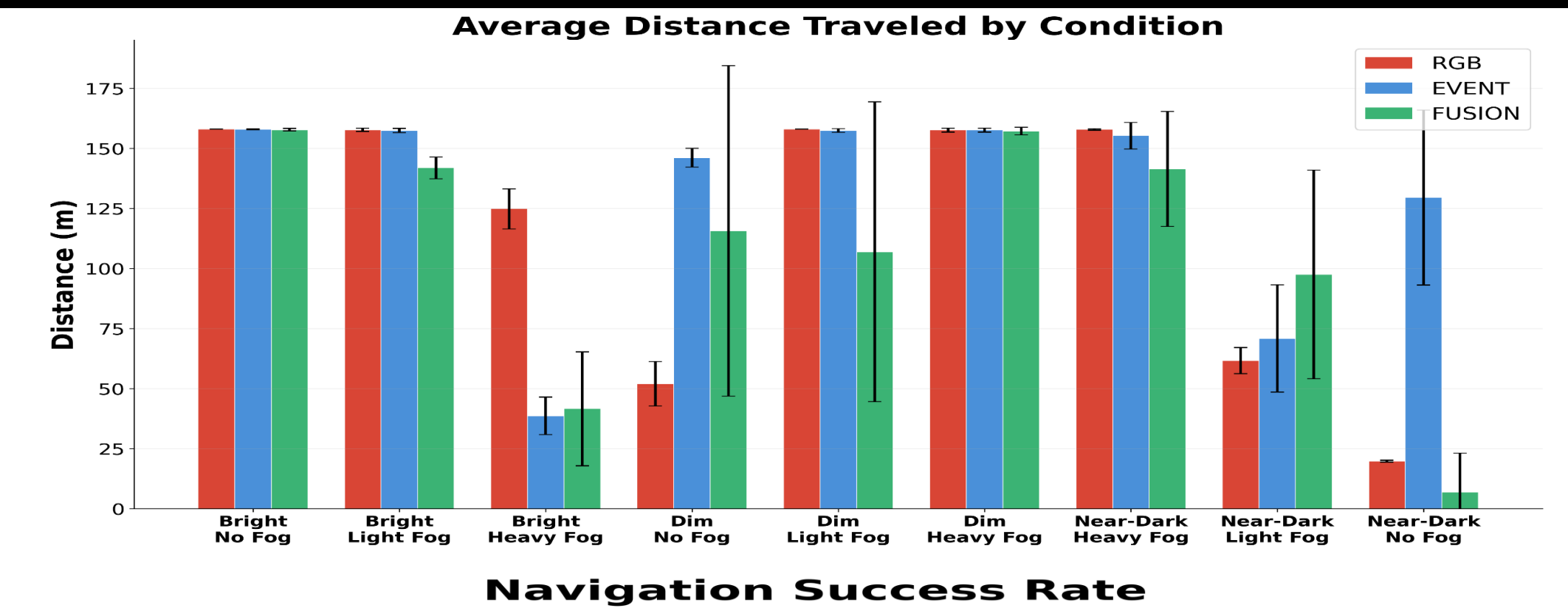
Results

Navigation:

- Event-only achieved 80% success in near-dark where RGB and Fusion both failed (0%)
- In bright heavy fog, Event dropped to 60% while RGB maintained 100%

Key Findings:

- Event-based vision is the most reliable mode in low-light conditions
- Simple channel concatenation fusion fails in near-dark as uninformative RGB channels dilute the event signal
- All modes perform equally in well-lit conditions



Condition	RGB	Event	Fusion
Bright, No Fog	100%	100%	100%
Bright, Light Fog	100%	100%	93%
Bright, Heavy Fog	100%	60%	80%
Dim, No Fog	100%	100%	100%
Dim, Light Fog	100%	100%	100%
Dim, Heavy Fog	100%	100%	100%
Near-Dark, Heavy Fog	100%	100%	100%
Near-Dark, Light Fog	100%	100%	100%
Near-Dark, No Fog	0%	80%	0%

Future Work

- Validate on physical hardware with a real event camera (e.g., DVXplorer)
- Extend to dynamic obstacles and complex tunnel geometries
- Investigate attention-based fusion architectures

Conclusion

- Event-based vision significantly outperforms RGB in low-light navigation (80% vs 0% in near-dark)
- Simple channel concatenation fusion fails when RGB input is uninformative, highlighting the need for adaptive fusion strategies
- Event-only perception is the most reliable mode in degraded lighting conditions

Acknowledgements

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References

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