Performance of DeepReach on High-Dimensional Reachability Problems

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1. Introduction

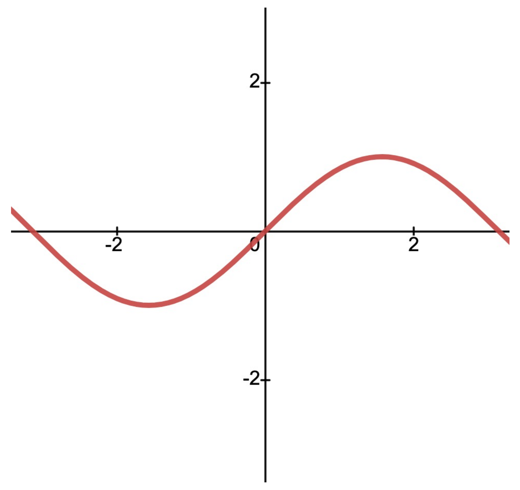
Goal: We aim to provide safety guarantees for **safety-critical** autonomous and robotics systems, such as autonomous cars, drones, legged-robots, etc.

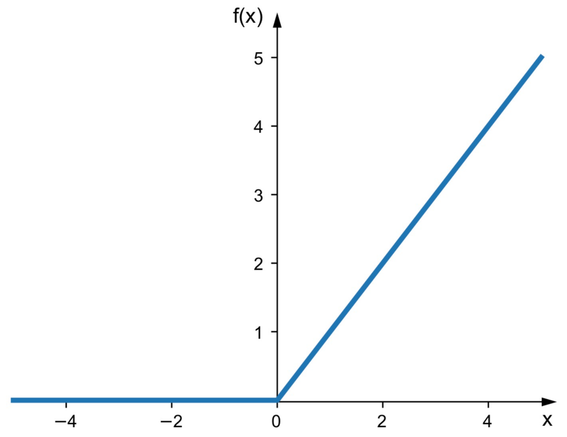
Theoretical Framework: We use **Hamilton-Jacobi Reachability Analysis** to formulate the problem mathematically. This formal verification method provides theoretical safety guarantees for dynamical systems and is widely applicable to a variety of tasks and challenges.

Project: **DeepReach** is a deep learning-based approach to approximately solve high-dimensional reachability problems. We explore how different choices of activation function in DeepReach affect its performance and seek ways for improvement.

2. Methods

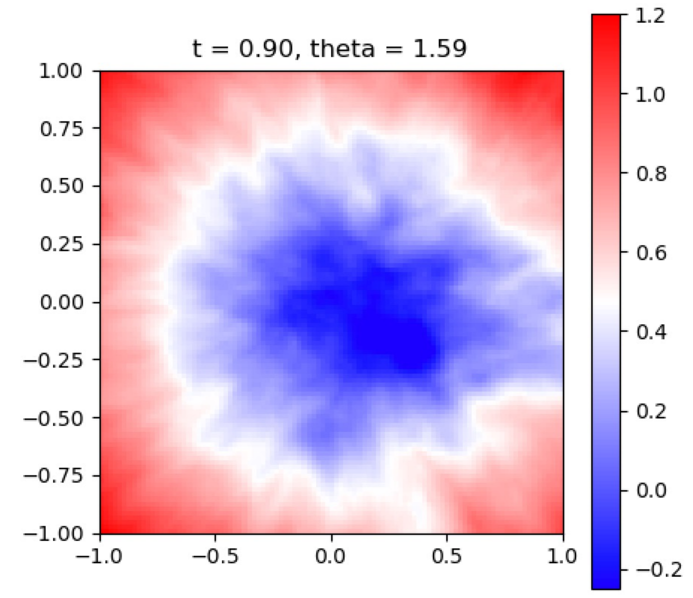
- Use combinations of Sine and ReLU
- Run experiments on 3D and 9D systems
- Compute violation rates of our results to quantify the performance of DeepReach



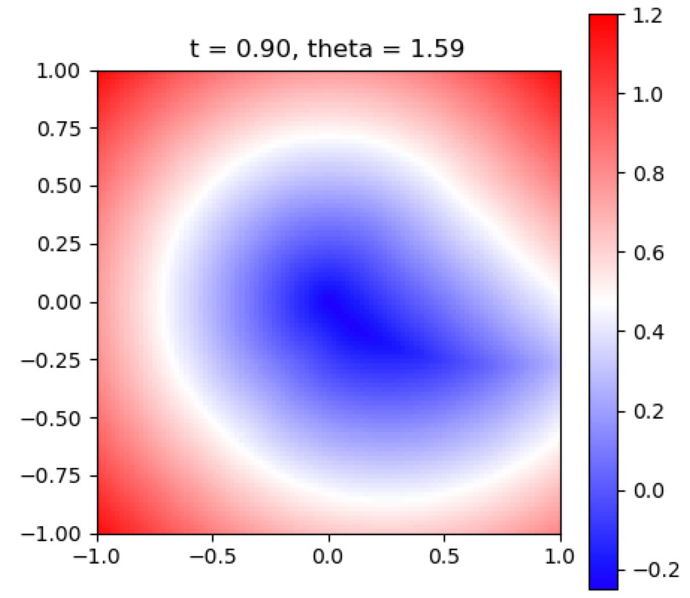


3. Results

Running example: air3D



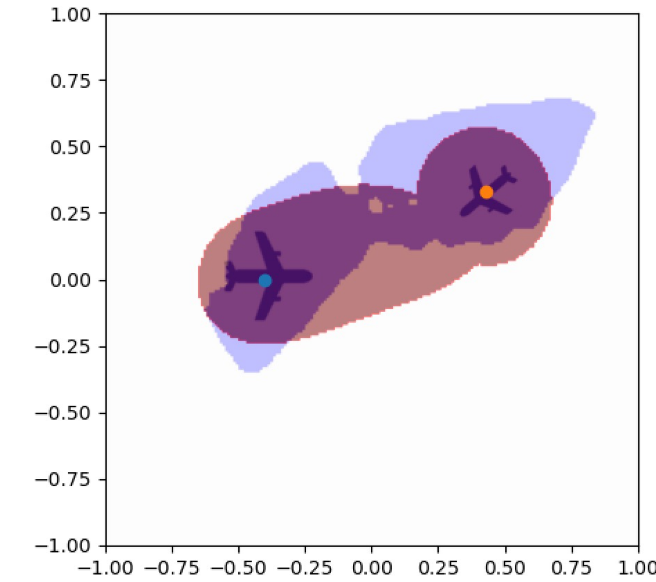
ReLU



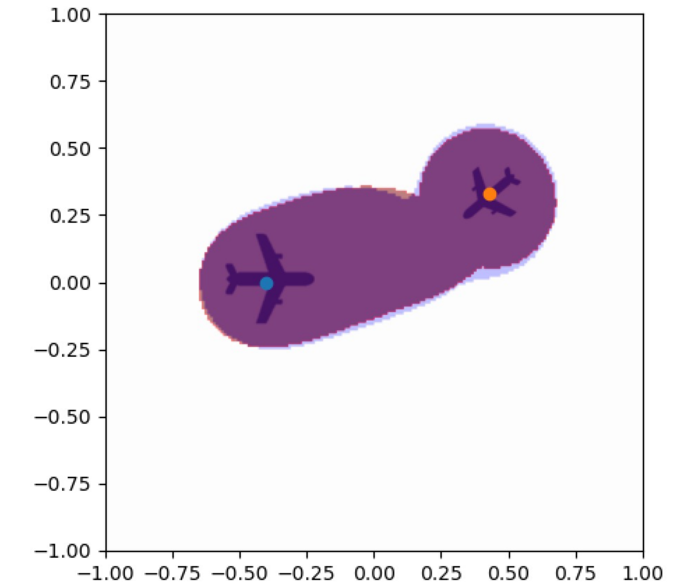
Sine

If we use Sine activation in all layers of the deep neural network, it achieves a MSE of 10^{-4}. However, ReLU fails to learn the correct **Backward Reachable Tube (BRT),** with a MSE an order of magnitude higher than Sine.

Running example: 9D three-vehicle collision



ReLU



Sine

Then we compute the violation rates when using different combinations of Sine and ReLU:

Activation	Violation Rate
ssssl	0.189
ssrsl	0.189
rsrsl	0.211
rrrsl	0.213
rrrrl	0.235

4. Conclusion

- On the 9D system, using sine activation in more layers helps learn more accurate BRTs with smaller violation rates.
- However, the results cannot be well-generalized to systems of higher dimension.
- Future work: explore other architectures and implement error correction to optimize BRTs obtained from DeepReach.

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