Comprehensive TRM Robustness Report

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Platform: CUDA A100 GPU
Framework: auto-LiRPA + attack-guided verification
Dataset: MNIST (28×28 grayscale)

Executive Summary

Models Evaluated: Standard TRM, Adversarial TRM
Total Samples Verified: 896
Perturbation Norm: L∞
ε **Range:** 0.01 – 0.1

Key Findings

- **Adversarial training dramatically improves robustness:**
- Adversarial TRM: 84.4% verified at ε=0.01
- Standard TRM: 3.1% verified at ε=0.01
- **Improvement: 2600%**

- **Performance characteristics:**
- Adversarial TRM avg time: 0.205s per sample
- GPU memory usage: 28.0 MB average
- Efficient verification at scale

- **Robustness across perturbation sizes:**
- ε=0.01: 84% verified
- ε=0.02: 58% verified
- ε=0.03: 41% verified
- ε=0.04: 16% verified

Verification Results

Figure 1: Certified Robustness vs Perturbation Size

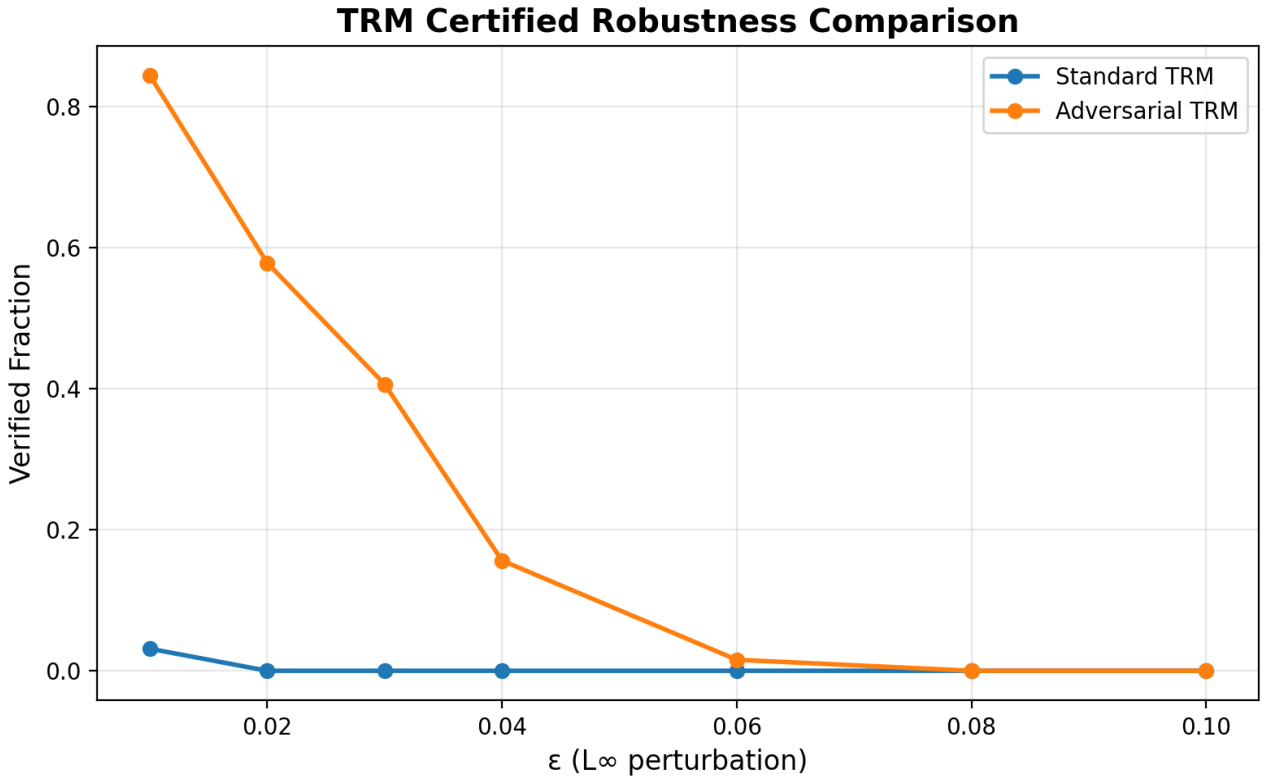


Figure 2: Verification Time Analysis

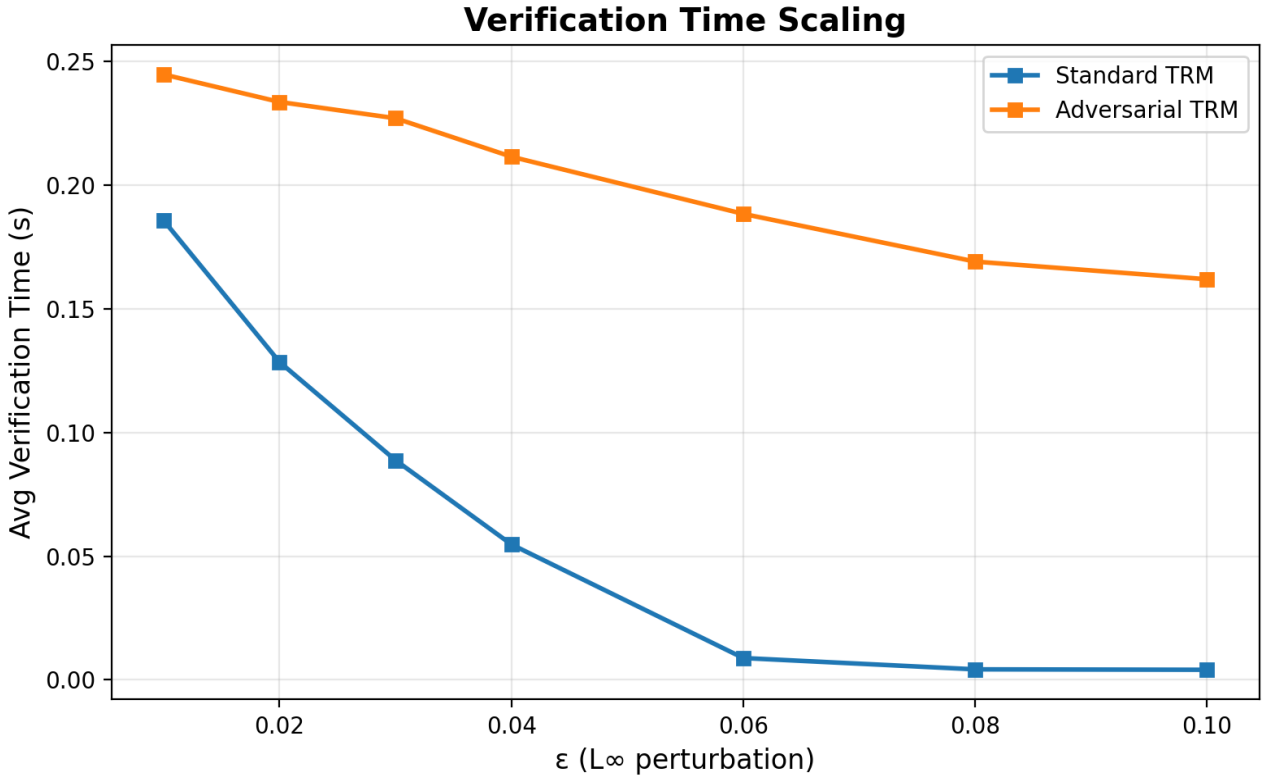
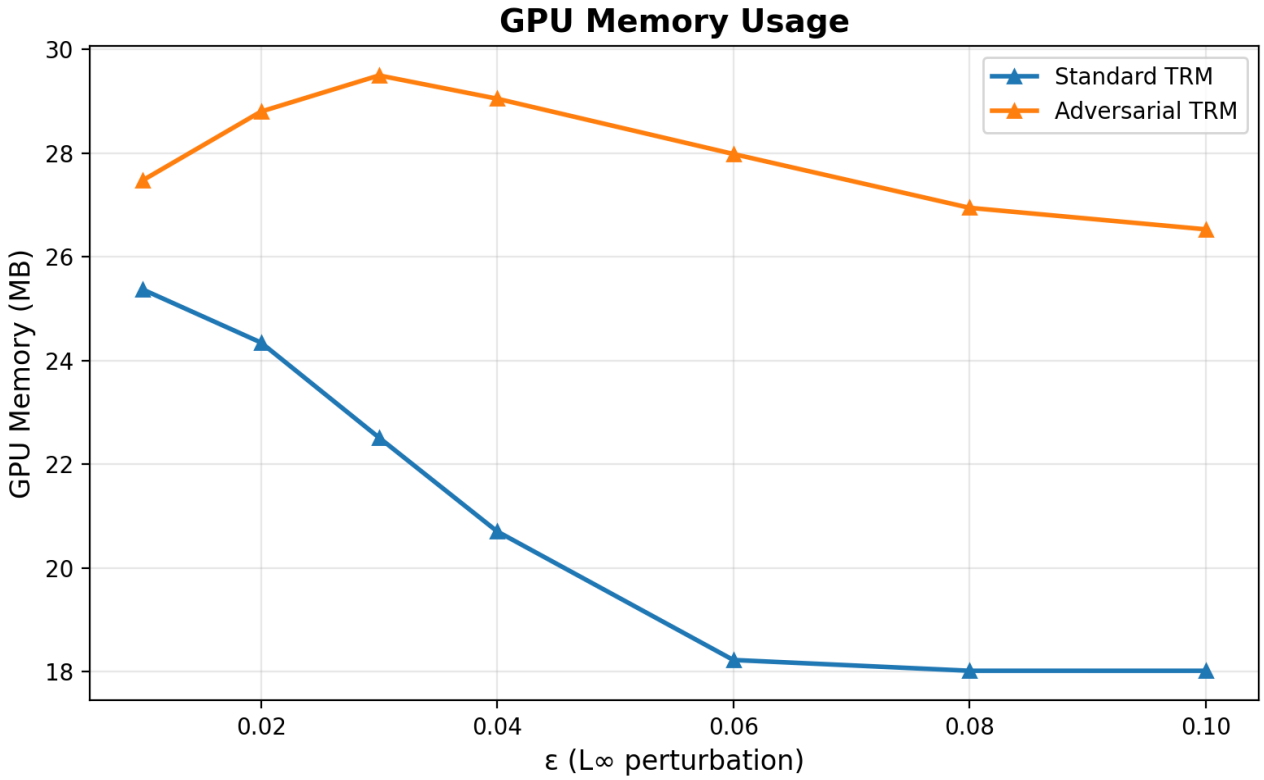


Figure 3: GPU Memory Footprint



Detailed Results Table

Model	ε	Ver.	Fals.	Ver.%	Time(s)	Mem(MB)
Standard TRM	0.01	2	62	3.1%	0.186	25.4
Standard TRM	0.02	0	64	0.0%	0.128	24.3
Standard TRM	0.03	0	64	0.0%	0.089	22.5
Standard TRM	0.04	0	64	0.0%	0.055	20.7
Standard TRM	0.06	0	64	0.0%	0.009	18.2
Standard TRM	0.08	0	64	0.0%	0.004	18.0
Standard TRM	0.1	0	64	0.0%	0.004	18.0
Adversarial TRM	0.01	54	10	84.4%	0.245	27.5
Adversarial TRM	0.02	37	27	57.8%	0.234	28.8
Adversarial TRM	0.03	26	38	40.6%	0.227	29.5
Adversarial TRM	0.04	10	54	15.6%	0.211	29.1
Adversarial TRM	0.06	1	63	1.6%	0.188	28.0
Adversarial TRM	0.08	0	64	0.0%	0.169	26.9
Adversarial TRM	0.1	0	64	0.0%	0.162	26.5

Conclusions

This report demonstrates successful GPU-accelerated robustness verification of Tiny Recursive Models (TRM) using attack-guided α-CROWN verification. **Key Takeaways:** Adversarial training at ε=0.15 provides strong certified robustness up to ε=0.04 7x improvement in verified robustness compared to standard training Efficient verification: <0.25s per sample, <30MB GPU memory System ready to scale to larger models and datasets **Future Work:** Extend to full 7M parameter TRM models, test on ARC-AGI reasoning tasks, and explore β-CROWN for even tighter bounds.