

# Complete Verification via Multi-Neuron Relaxation Guided Branch-and-Bound



Claudio Ferrari



Mark Müller



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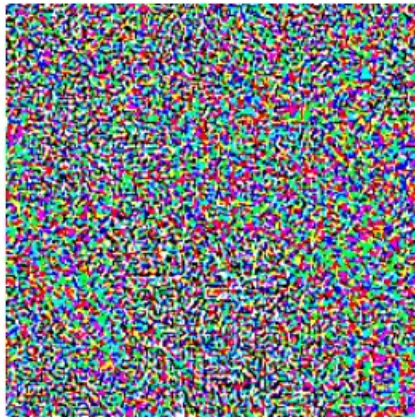
Martin Vechev

# Adversarial Examples



“panda”  
57.7% confidence

+ .007 ×



=

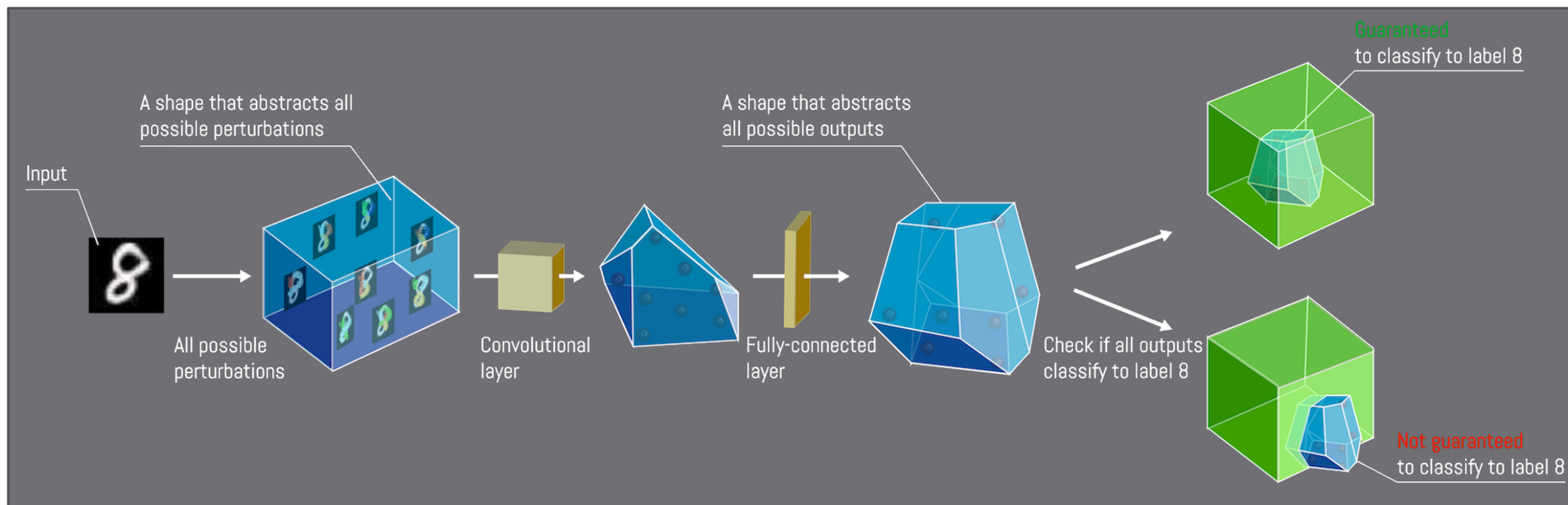


“gibbon”  
99.3 % confidence

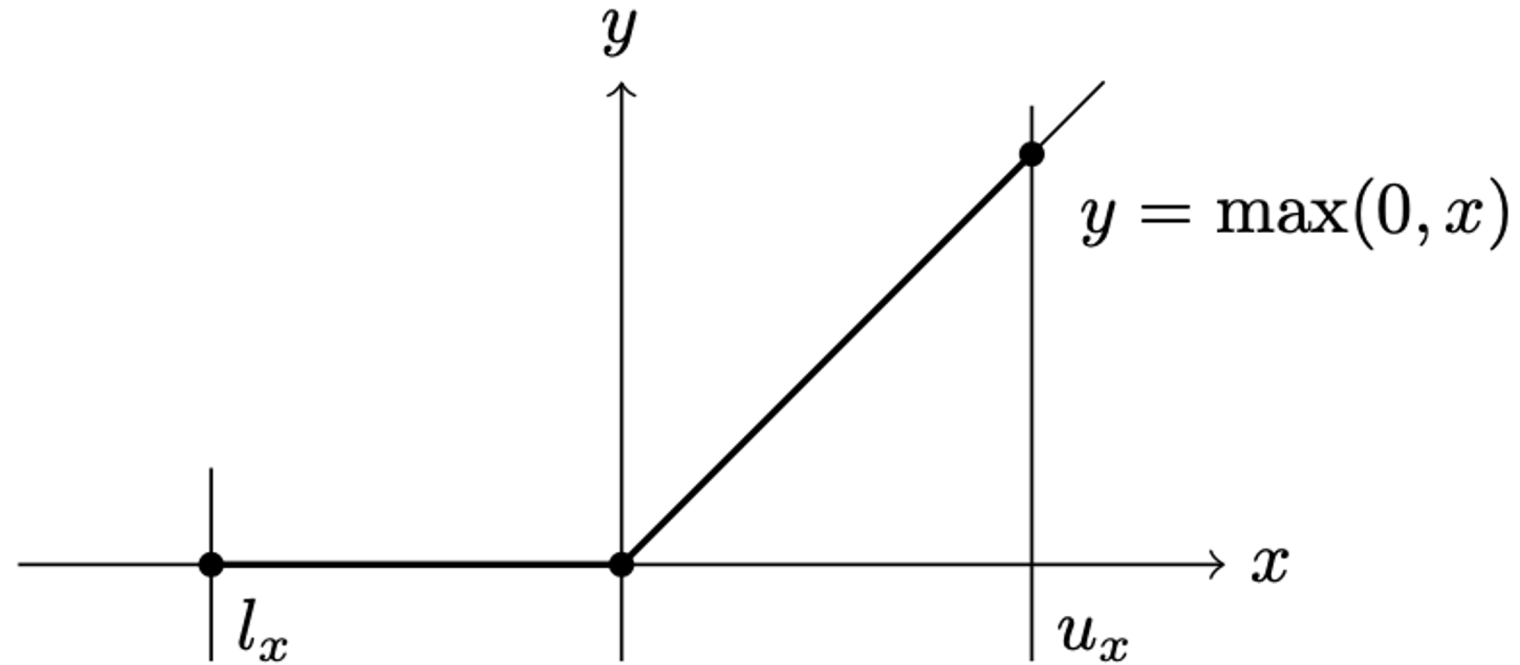
# Neural Network Verification

Robustness property:

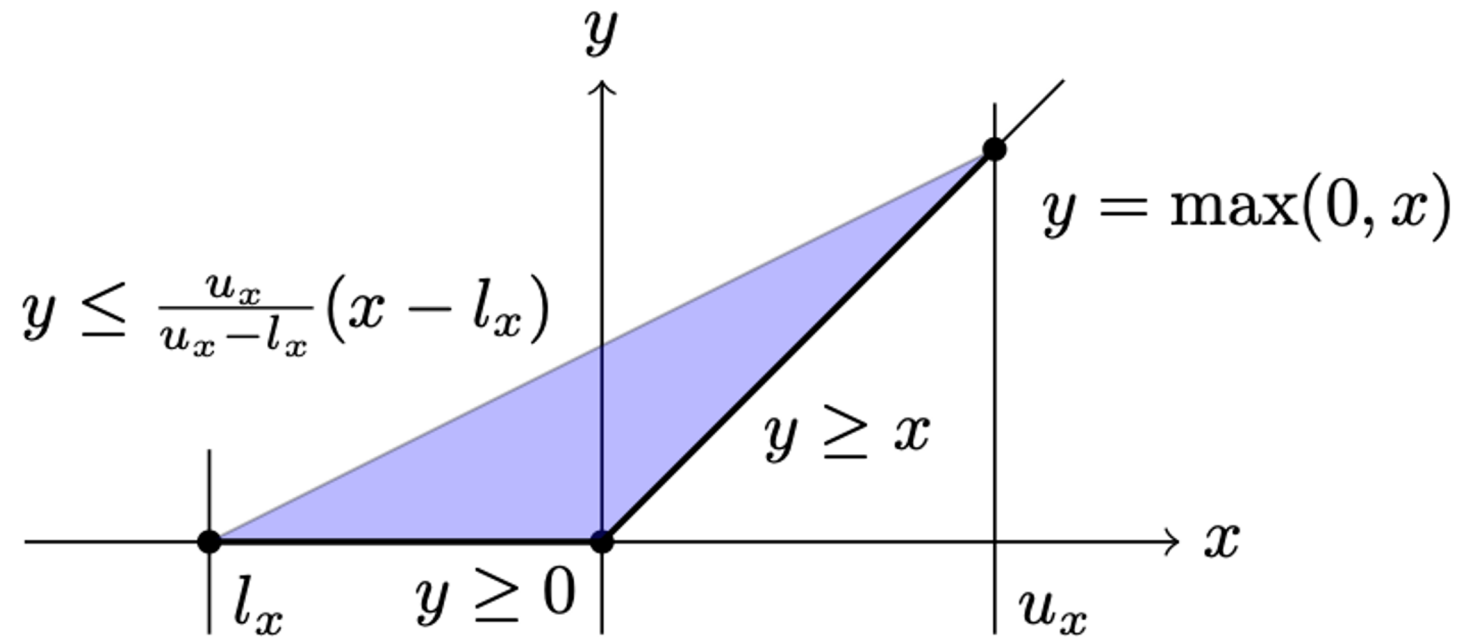
$$\operatorname{argmax}_i f(x)_i = \operatorname{argmax}_i f(x')_i \forall x' \in B_\epsilon^\infty(x)$$



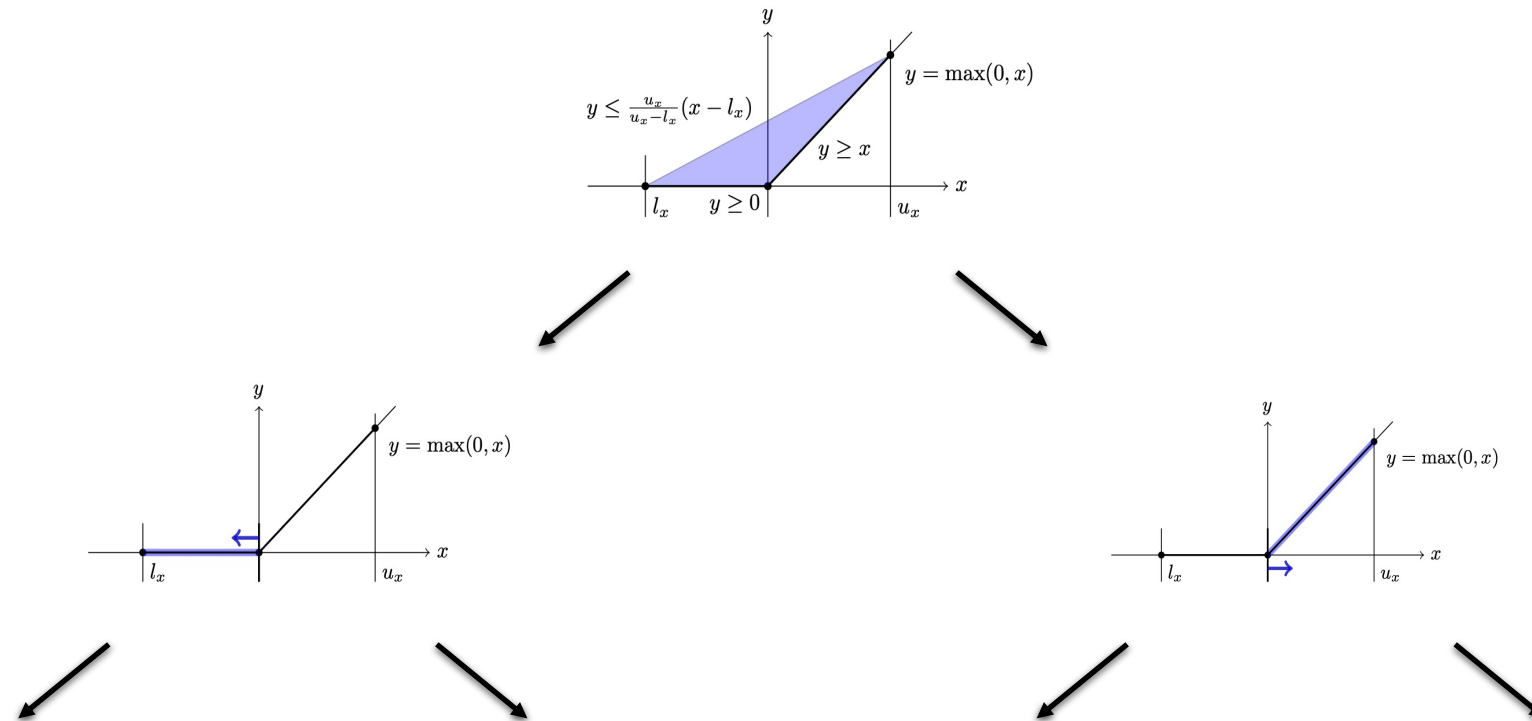
# Key Challenge: Convex Approximation of ReLU Layer



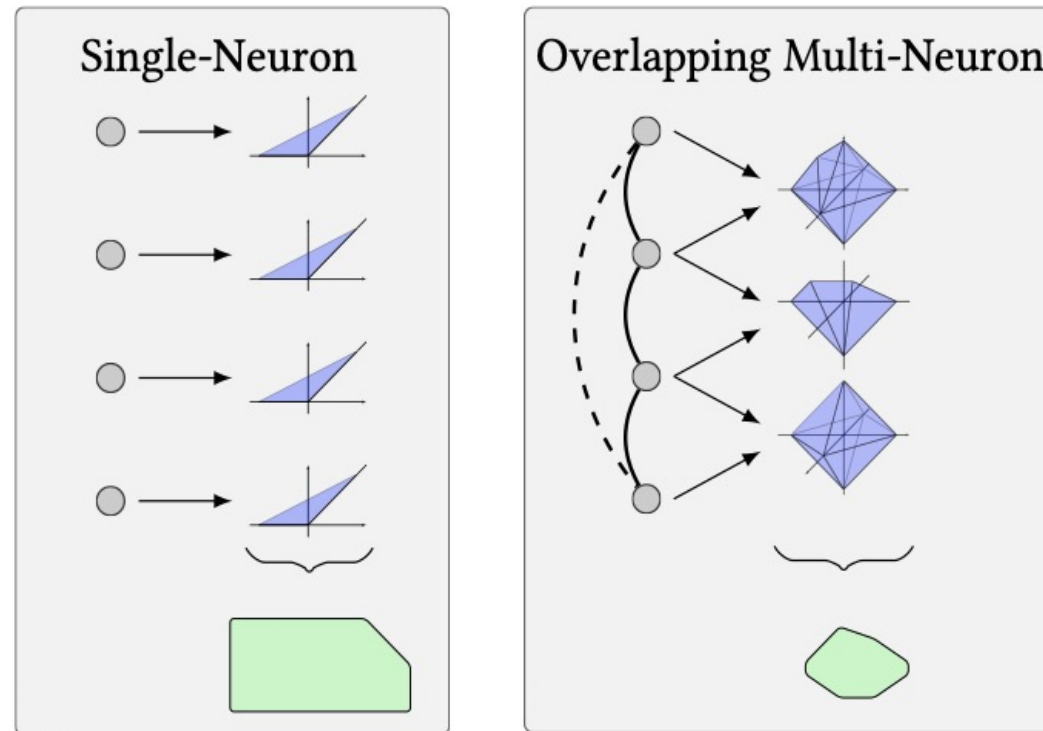
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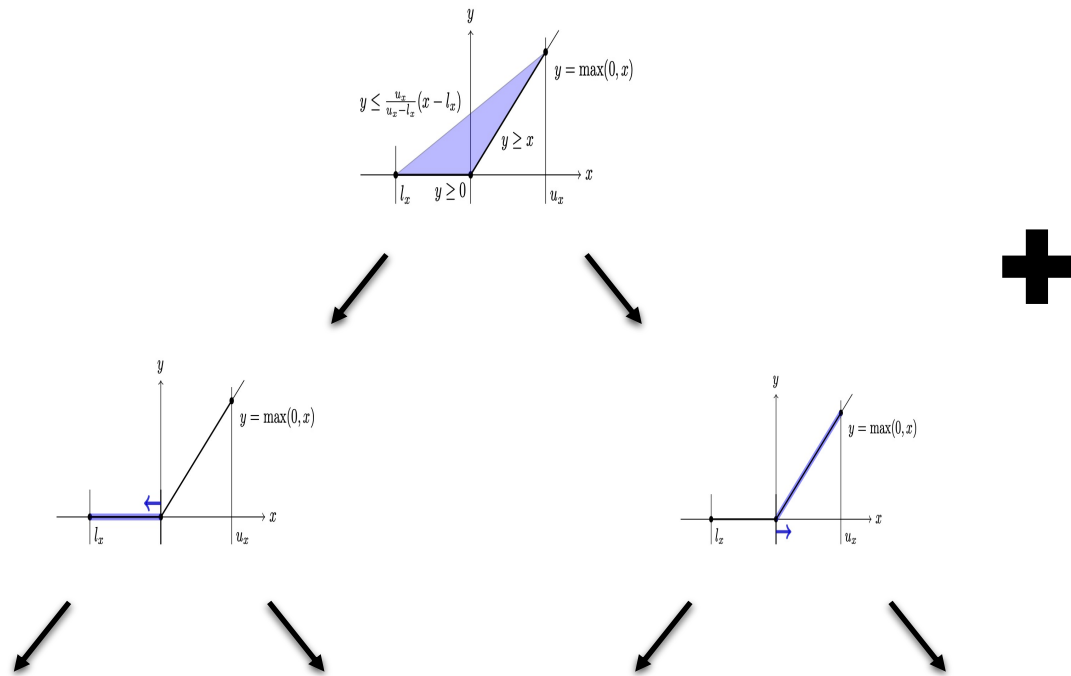
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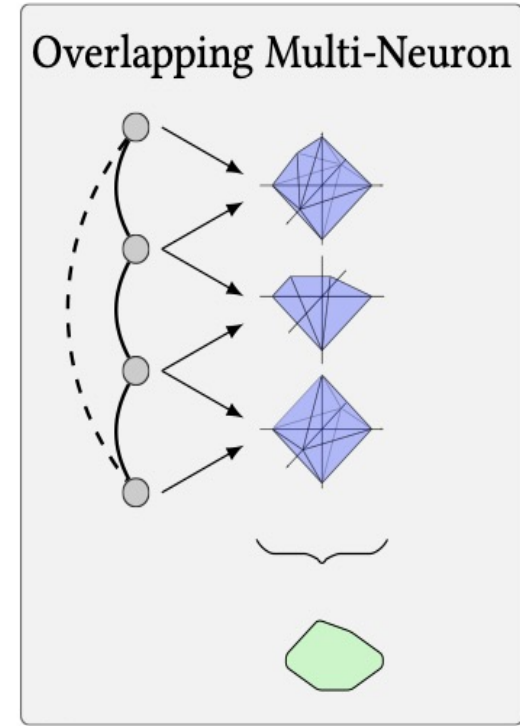
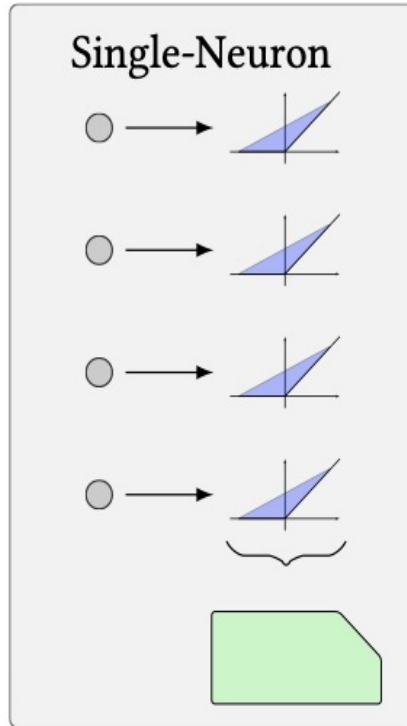
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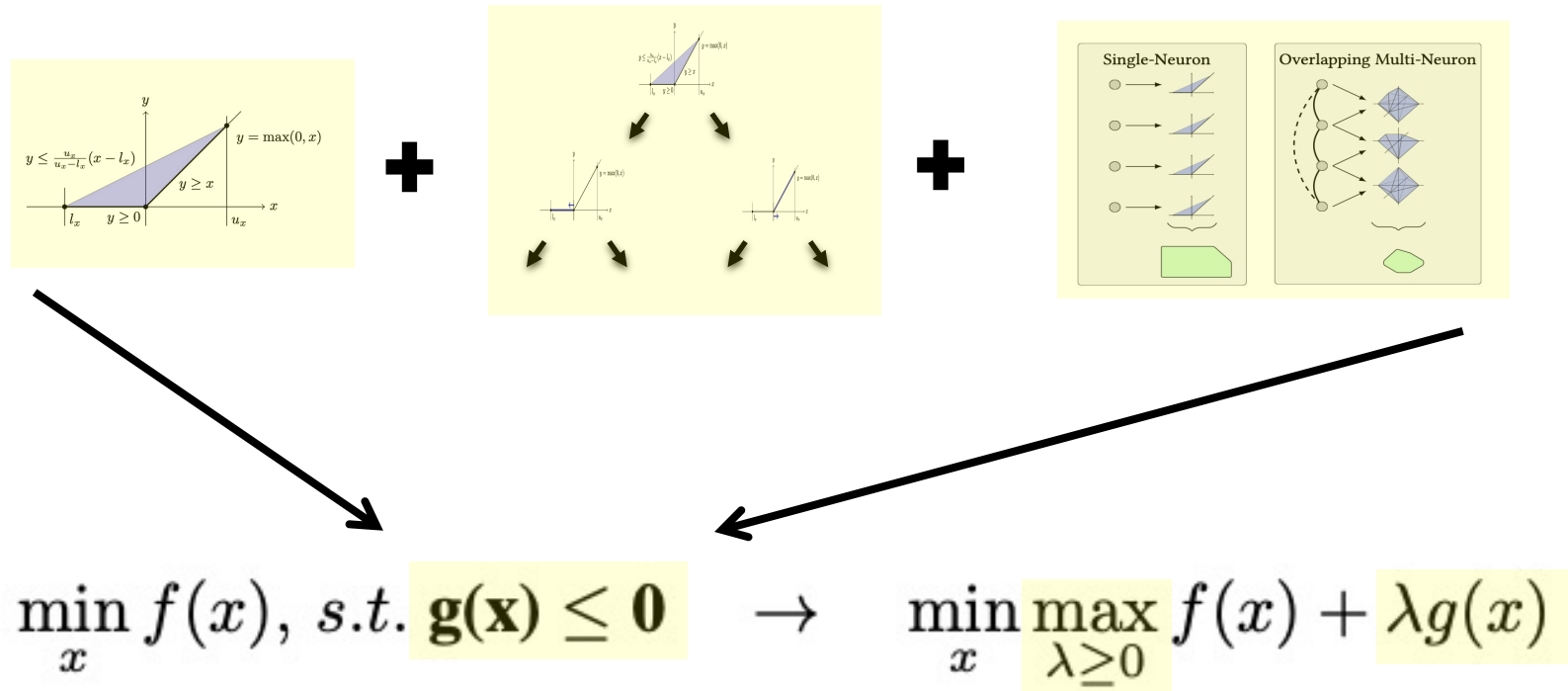


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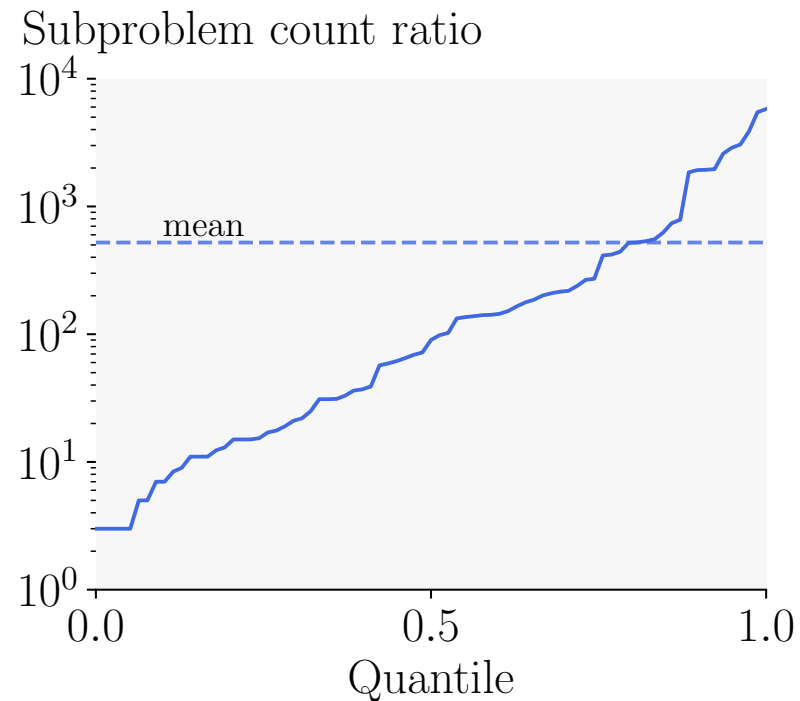
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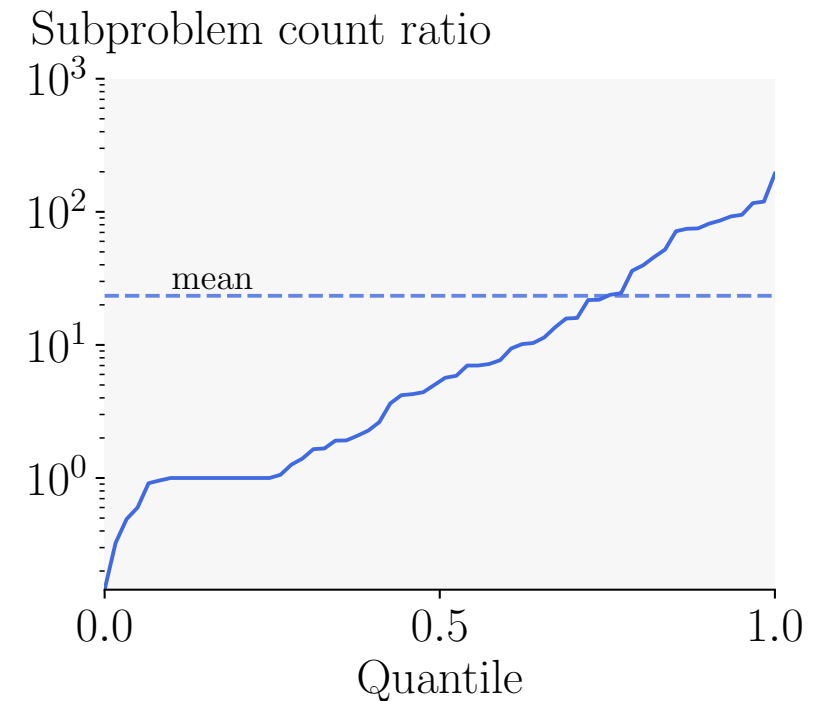
Kaidi Xu, Huan Zhang, Shiqi Wang, Yihan Wang, Suman Jana, Xue Lin, and Cho-Jui Hsieh. Fast and complete: Enabling complete neural network verification with rapid and massively parallel incomplete verifiers.

Shiqi Wang, Huan Zhang, Kaidi Xu, Xue Lin, Suman Jana, Cho-Jui Hsieh, and J Zico Kolter. Beta-crown: Efficient bound propagation with per-neuron split constraints for neural network robustness verification.

# Results





$$\frac{\# \text{ subproblems without MNC (baseline)}}{\# \text{ subproblems with MNC (ours)}}$$



$$\frac{\# \text{ subproblems BaBSR (baseline)}}{\# \text{ subproblems ACS (ours)}}$$

# Results

Model	Acc.	Upper Bound	Branching Method	MNCs	MN-BAB			
					Ver	Time		
ResNet6-A	84	75	BABSR	no	42	247.1	 + 12%	
			BABSR	yes	47	212.8		 + 9%
			ACS	yes	51	186.4		

Verified Accuracy and average runtime on the first 100 samples of the test set for  $\epsilon = 1/255$

# Conclusion

MN-BaB:

Combines **Multi-Neuron Constraints** with the **Branch-and-Bound** approach in a **fully GPU-based** solver

Paper:

<https://www.sri.inf.ethz.ch/publications/ferrari2022complete>

