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Project type: laboratory project

Topic: On the Challenges of Sound Verification of Neural Networks

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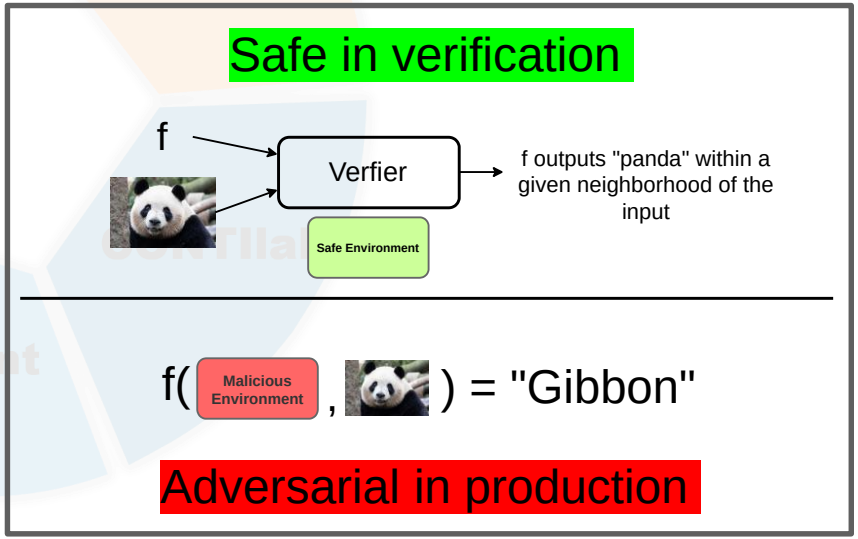
- Quantizing models to lower precision yields significant performance gains; however, many studies have shown that quantized models often suffer from considerable **accuracy degradation**.
- The main cause of this phenomenon is the effect of numerical representation on the accumulation of numerical errors, which highlights the importance of **clearly defining different environments** (e.g., training, evaluation, etc.).
- In this work, we highlighted the importance of precisely defining environments in the context of **verification**.
- Main idea: **The verifier operates under the assumption of an environment that differs from the one used in production.**
- This is a serious problem that can be exploited by an attacker.

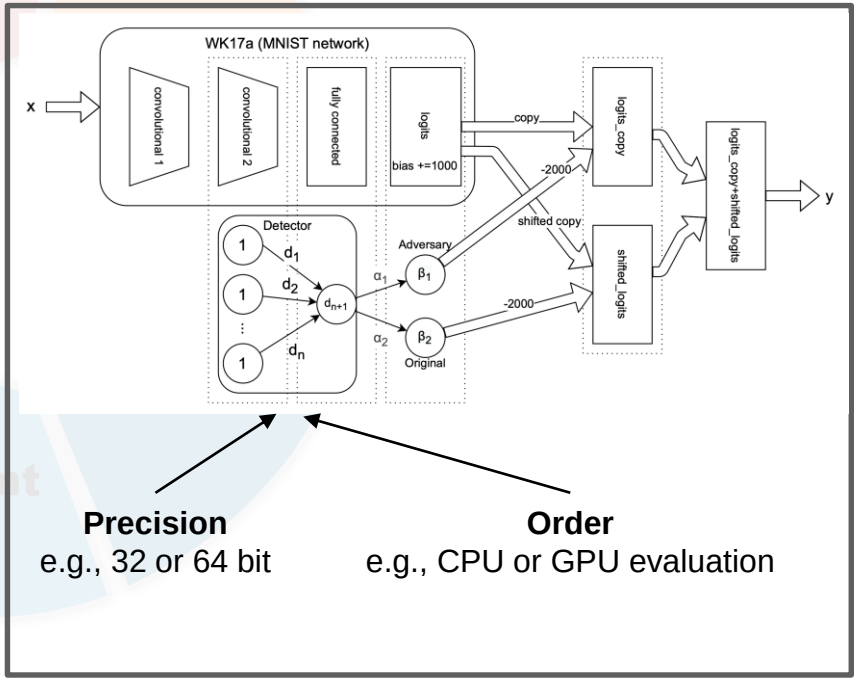


Backdoors

- We defined backdoors that detect the underlying implementation (e.g., numerical representation or the order of summation) and **trigger malicious behavior only under specific environments**. (Typically **differs from the one used during verification**.)
- Main idea: Bound propagation algorithms used in verification are sensitive to numerical precision and operation order.

Expression tree	$(2^{53}+1)+1$	$(1+2^{53})+1$	$(1+1)+2^{53}$
FP64 result	2^{53}	2^{53}	$2^{53}+2$
Exact value	$2^{53}+2$	$2^{53}+2$	$2^{53}+2$
Interval bounds	$[2^{53}, 2^{53}+4]$	$[2^{53}, 2^{53}+4]$	$[\mathbf{2^{53}+2}, \mathbf{2^{53}+2}]$

- Precision detector: $2^{24}+1-2^{24}$
- Order detector: $\underbrace{1+\cdots+1}_{h\times}+\omega-\omega$



Results – ICML 2025 Spotlight - Vancouver

Verifier	Ver. Env.	Bounding	Precision	Order1	Order2	Order3
MIPVerify (Tjeng et al., 2017)	64-bit, CPU	IBP	**unsound**	sound	**unsound**	**unsound**
MN-BAB (Ferrari et al., 2022)	64-bit, GPU	Polyhedra	**unsound**	sound	**unsound**	**unsound**
β-CROWN BaB (Wang et al., 2021)	32-bit, CPU	Polyhedra	**unsound**	sound	**unsound**	**unsound**
β-CROWN BaB (Wang et al., 2021)	64-bit, CPU	Polyhedra	**unsound**	sound	**unsound**	**unsound**
β-CROWN BaB (Wang et al., 2021)	64-bit, GPU	Polyhedra	**unsound**	sound	**unsound**	**unsound**
GCP-CROWN (Zhang et al., 2022)	64-bit, CPU	Polyhedra	**unsound**	sound	**unsound**	**unsound**
DeepPoly (Singh et al., 2019a)	64-bit, CPU	Polyhedra	**unsound**	sound	sound	**unsound**
RefinePoly (Singh et al., 2019a)	64-bit, CPU	Polyhedra	**unsound**	sound	sound	**unsound**
DeepZono (Singh et al., 2018)	64-bit, CPU	Zonotope	**unsound**	sound	sound	**unsound**
RefineZono (Singh et al., 2019b)	64-bit, CPU	Zonotope	**unsound**	sound	sound	**unsound**

**No Soundness in the Real World:
On the Challenges of the Verification of Deployed Neural Networks**

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Upcoming work and publication

Verifier	Ver. Env.	Bounding	Pr.	O1	O2	O3	Zombori et al. (2021)
MIPVerify (Tjeng et al. (2017))	64-bit, CPU	IBP	U	S	U	U	U
MN-BAB (Ferrari et al. (2022))	64-bit, GPU	Symbolic	U	S	U	U	U
β-CROWN BaB (Wang et al. (2021))	32-bit, CPU	Symbolic	U	S	U	U	[no 32-bit model]
β-CROWN BaB (Wang et al. (2021))	64-bit, CPU	Symbolic	U	S	U	U	S
β-CROWN BaB (Wang et al. (2021))	64-bit, GPU	Symbolic	U	S	U	U	S
GCP-CROWN (Zhang et al. (2022))	64-bit, CPU	Symbolic	U	S	U	U	S
DeepPoly (Singh et al. (2019a))	64-bit, CPU	Symbolic	U	S	S	U	S
RefinePoly (Singh et al. (2019a))	64-bit, CPU	Symbolic	U	S	S	U	U
DeepZ (Singh et al. (2018))	64-bit, CPU	Symbolic	U	S	S	U	S
RefineZono (Singh et al. (2019b))	64-bit, CPU	Symbolic	U	S	S	U	[Gurobi error]
FPSoundIBP (ours)	32-bit, CPU	IBP	S	S	S	S	S
FPSoundSymbolic (ours)	32-bit, CPU	Symbolic	S	S	S	S	S

- We developed an algorithm that is capable of handling the non-associative nature of floating-point operations.
- We implemented a neural network verifier incorporating this algorithm (FPSoundIBP and FPSoundSymbolic) and demonstrated that our approach is uniquely capable of bounding the aforementioned numerical error-based backdoors.
- This work is currently being prepared for publication.