Special Meeting

Review 2024, Future Plan in 2025

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15th Jan 2025

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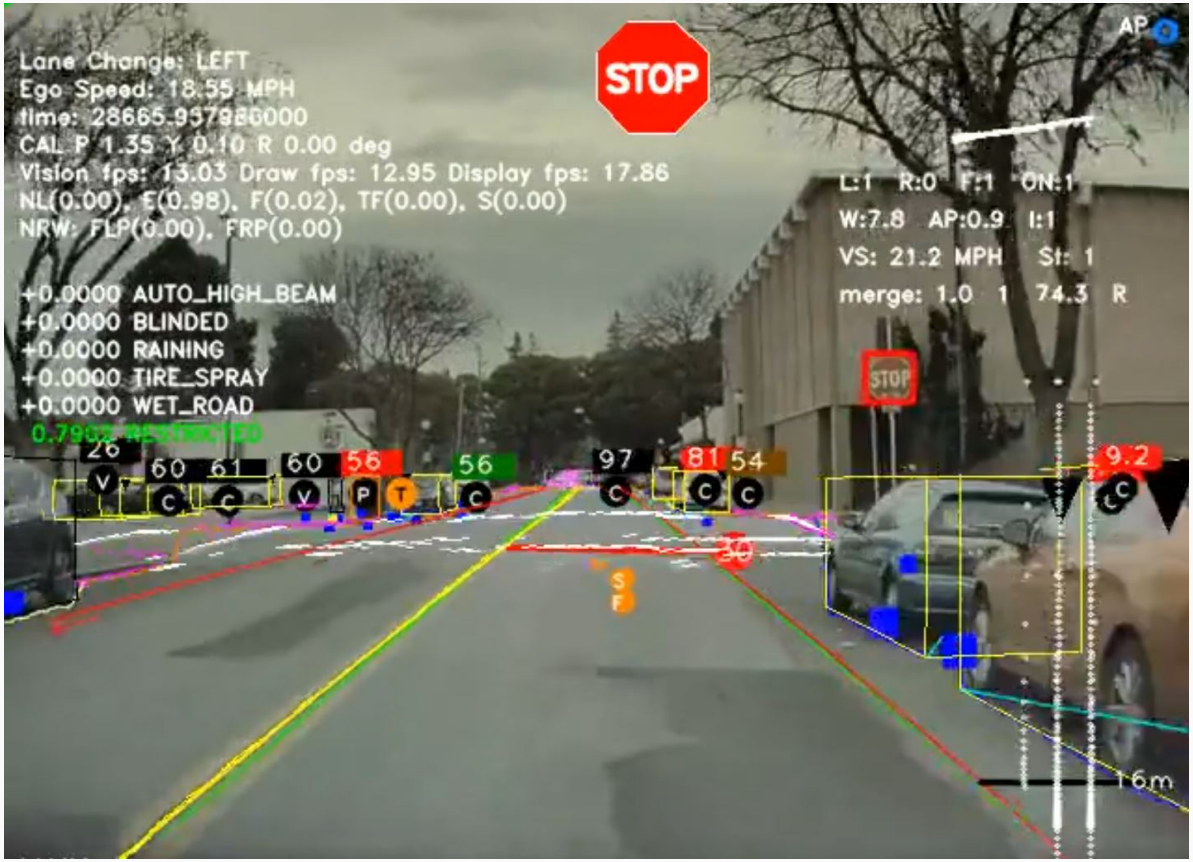
Outlines

- Research Background - Neural Network Verification
- Backward and Forward Analysis Framework
- Future Plan in 2025

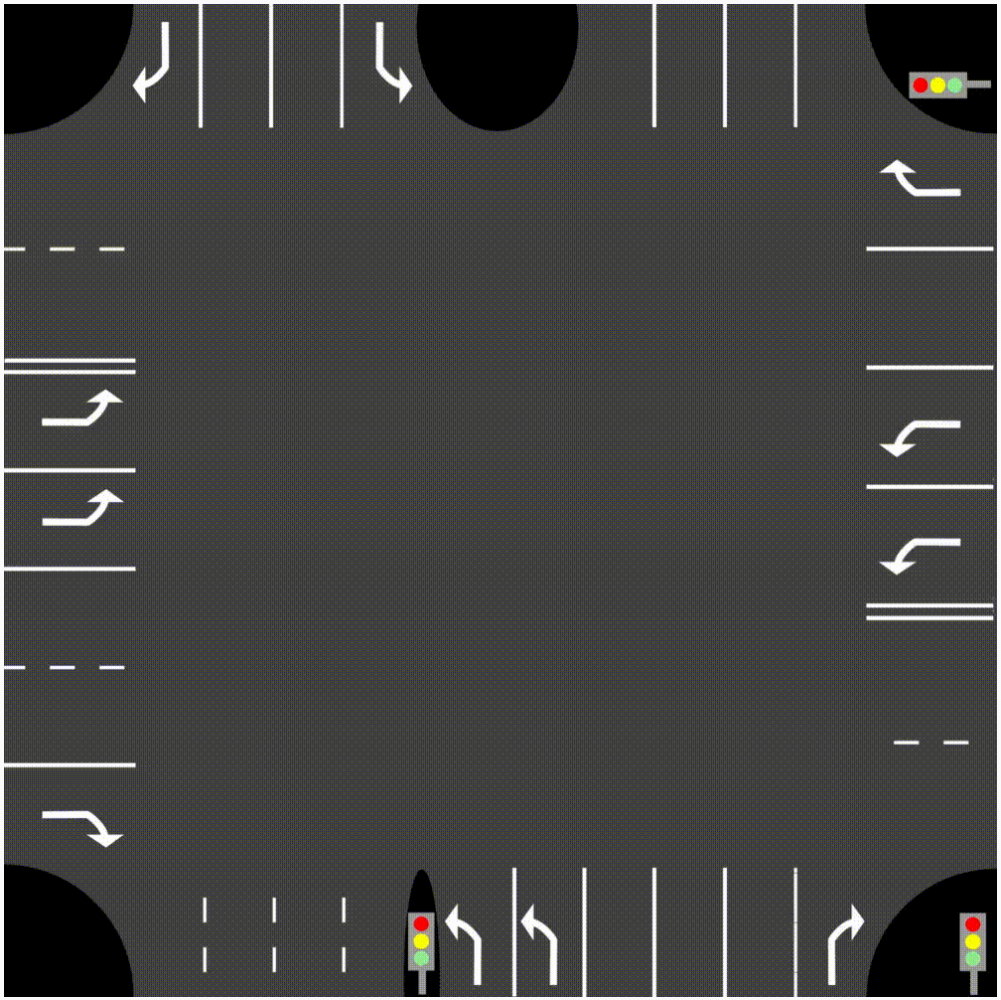
Research Background

What can neural networks do?



Is there any problem?

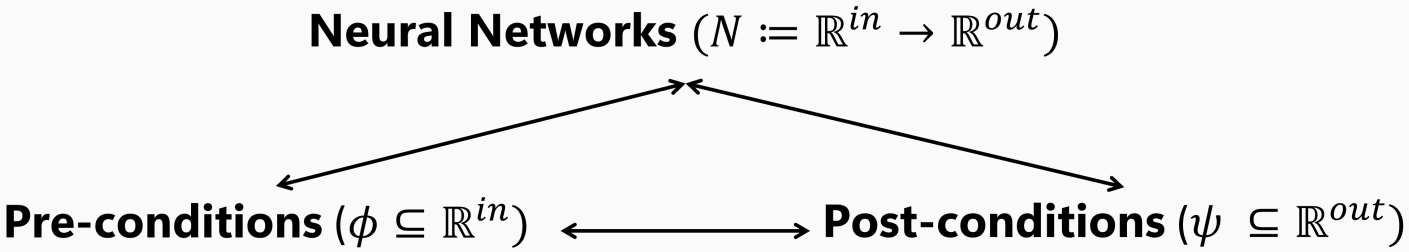
Gardena, California, USA (December 29, 2019)

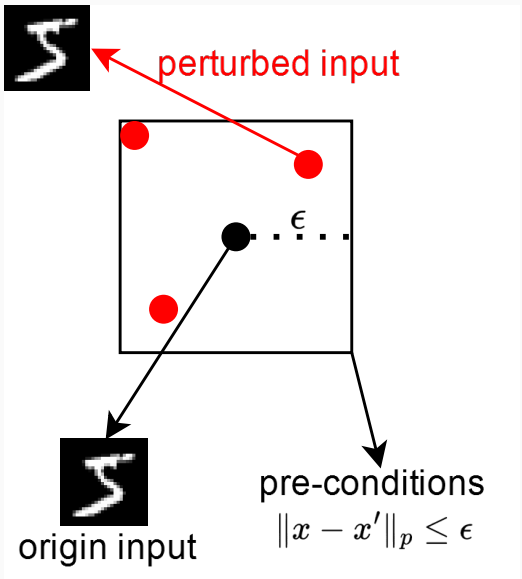


List of Tesla Autopilot Crashes

How can we do to reduce mis-classification risk?

Verifying neural network!





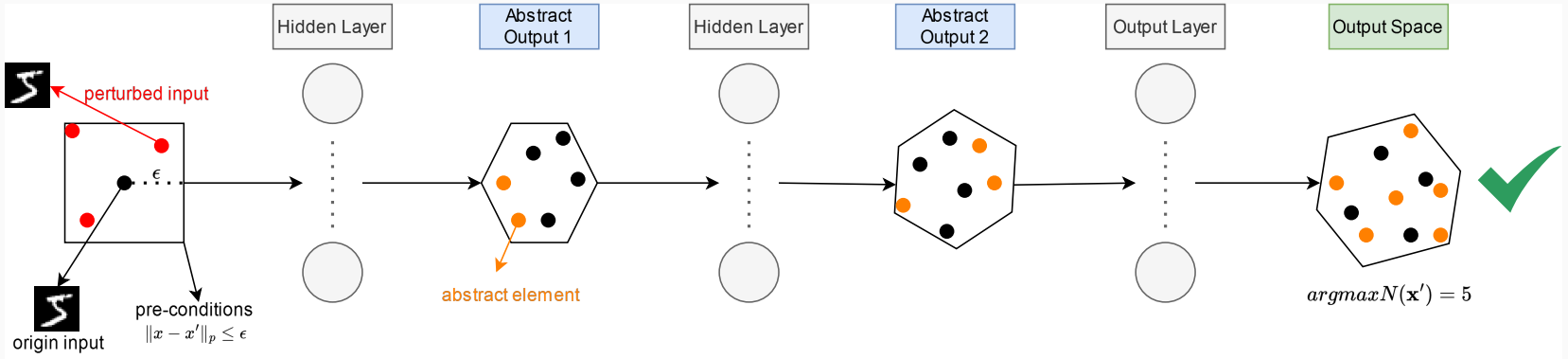
post-conditions: All data in the pre-condition region have to be classified as 5.

Let $\boldsymbol{C} = \{0, 1, 2, 3, 4, 5, 6, 7, 8, 9\}$

$y_5 - y_i \geq 0 \ \forall i \in \boldsymbol{C} \setminus \{5\}$

Background - Standard Verification Process

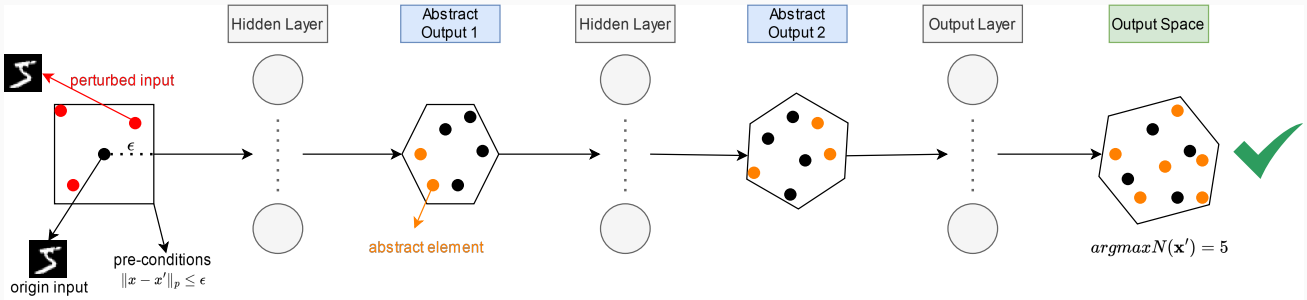
1. Create a pre-condition region for each data.
2. Use bound propagation to compute the bounds for each neuron layer by layer.
3. Check if the bounds in the output layer can satisfy the post-conditions.



Background - Challenges in state-of-the-art

However, the modern neural network is becoming deeper.

- VGG-16 (16 layers).
- GoogLeNet (22 layers).
- ResNet (18-152 layers).
- ...



The challenge in neural network verification is that the bound will be weaker in the later layers.

Proposed Method - Backward and Forward Analysis Framework

Could we stop the bound propagation in the intermediate layers?

- **Backward analysis**
  Use the given post-conditions and substitution procedure to generate more post-conditions in each layer.

- **Forward analysis**
  Check if the bound can satisfy the post-condition in the layer. Use the bound propagation method to compute the bound for each neuron.

Example - Standard Verification Process

Post-condition: $x_{30} \geq x_{31}$

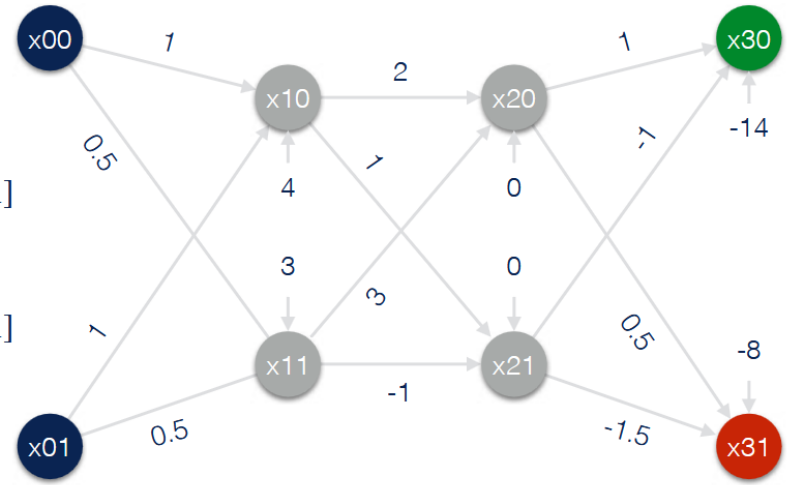
Interval Abstraction

with Symbolic Constant Propagation [Li19]

$$x_{10} \mapsto \begin{cases} x_{00} + x_{01} + 4 \\ [4, 6] \end{cases} \qquad x_{20} \mapsto \begin{cases} 2 \cdot (x_{00} + x_{01} + 4) + 3 \cdot (0.5 \cdot x_{00} + 0.5 \cdot x_{01} + 3) \\ [17, 24] \end{cases}$$

$$x_{00} \mapsto \begin{cases} x_{00} \\ [0, 1] \end{cases}$$

$$x_{01} \mapsto \begin{cases} x_{01} \\ [0, 1] \end{cases}$$



$$x_{30} \mapsto \begin{cases} 3 \cdot x_{00} + 3 \cdot x_{01} + 2 \\ [2, 8] \end{cases}$$

$$x_{31} \mapsto \begin{cases} x_{00} + x_{01} - 1 \\ [-1, 1] \end{cases}$$

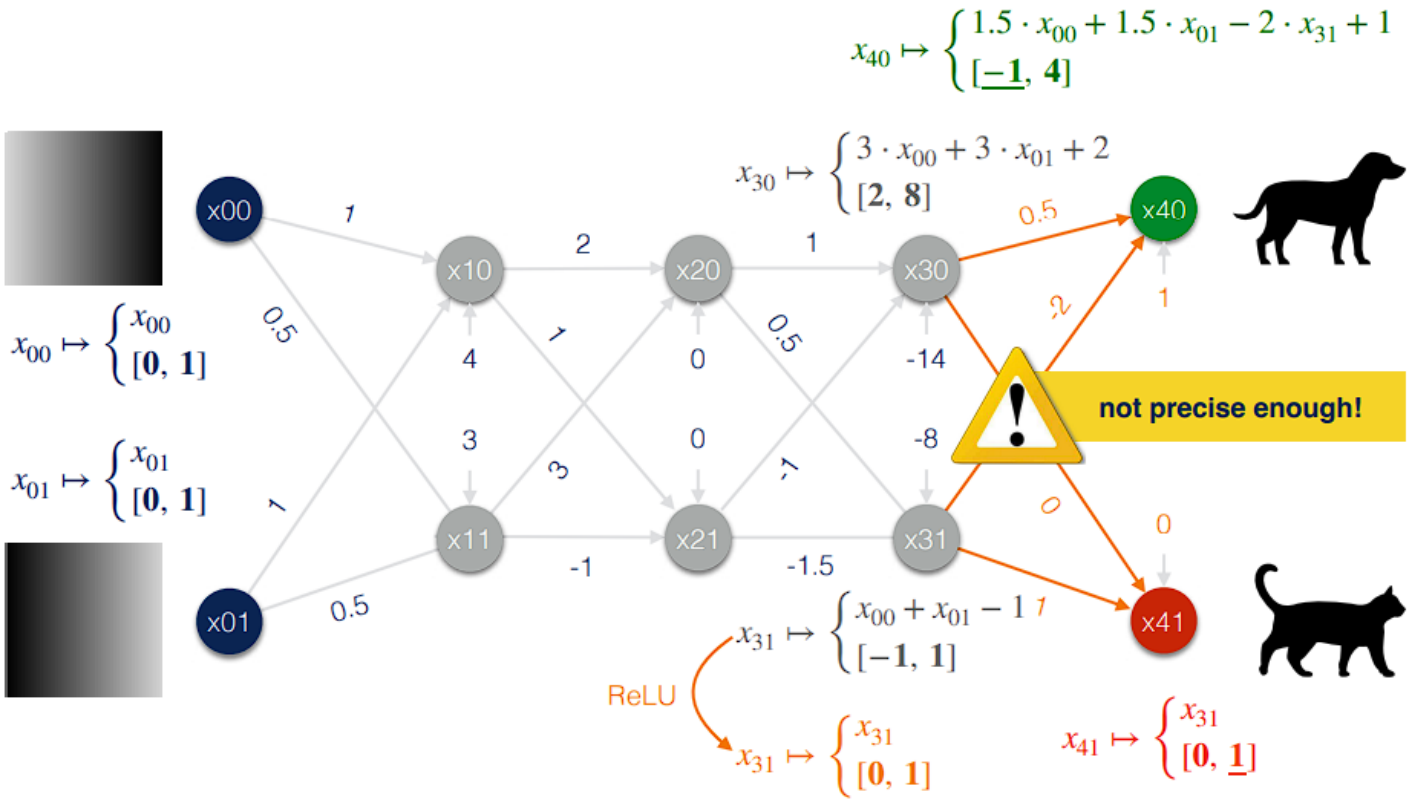
$$x_{11} \mapsto \begin{cases} 0.5 \cdot x_{00} + 0.5 \cdot x_{01} + 3 \\ [3, 4] \end{cases} \qquad x_{21} \mapsto \begin{cases} (x_{00} + x_{01} + 4) - 1 \cdot (0.5 \cdot x_{00} + 0.5 \cdot x_{01} + 3) \\ [1, 2] \end{cases}$$

Example - Standard Verification Process

Post-condition: $x_{40} \geq x_{41}$

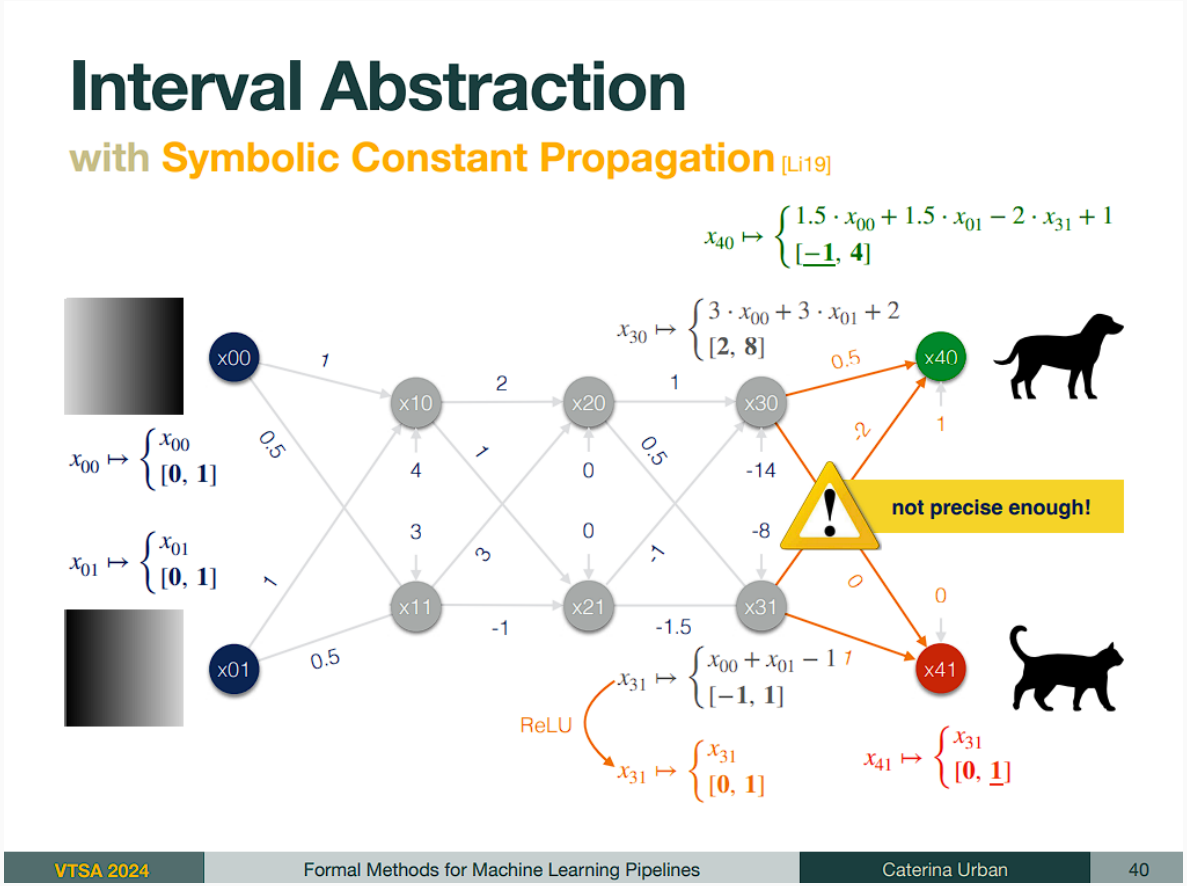
Interval Abstraction

with Symbolic Constant Propagation [Li19]



Example - BaFAF - Backward Analysis

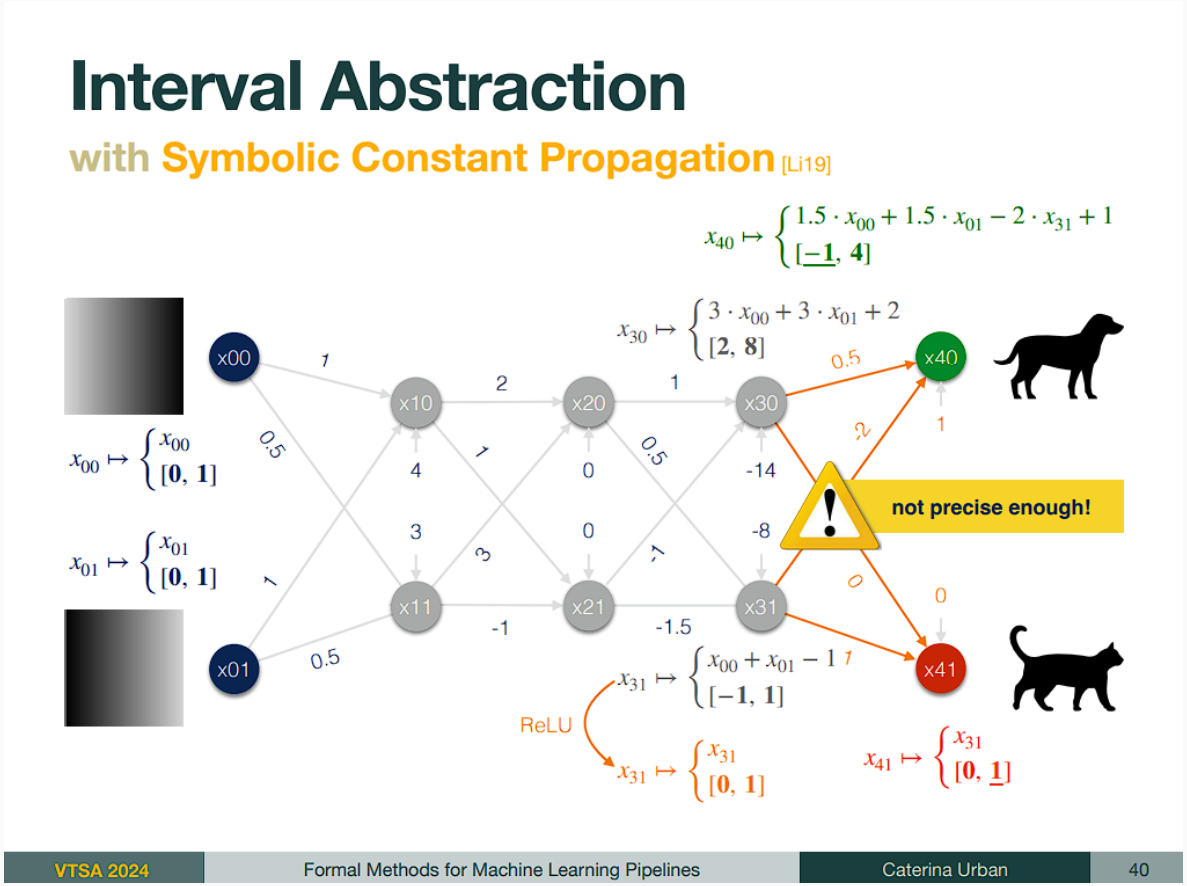
Use substitution procedure to replace the variable in the post-condition.



$x_{40} - x_{41} \geq 0,\ 0.5x_{30} - 3x_{31} + 1 \geq 0,\ -x_{20} + 4x_{21} + 18 \geq 0,$
$2x_{10} - 7x_{11} + 18 \geq 0,\ -1.5x_{00} - 1.5x_{01} + 5 \geq 0$

Example - BaFAF - Forward Analysis

Bound checking: find the minimal value in the post-condition expression.



$x_{40} - x_{41} \geq 0,\ 0.5x_{30} - 3x_{31} + 1 \geq 0,\ -x_{20} + 4x_{21} + 18 \geq 0,$
$2x_{10} - 7x_{11} + 18 \geq 0,\ -1.5x_{00} - 1.5x_{01} + 5 \geq 0$

Overview of 2024

What happened in 2024?

Learning:

- Constraint Programming Winter School
- Verification Summer School
- Abstract Interpretation Summer School

Teaching:

- Teaching Assistance - Lattice Theory for Parallel Programming

Research:

- Finished my first CET.
- Failed several times.
- Developing a backward-and-forward analysis framework for neural network robustness verification.

Next steps

My Future Plan in 2025

My first priority is to submit the paper to CAV [1].

After that,

- Improve English writing skills.
- Implement backward-and-forward analysis framework in Turbo or my own developed tool.
- Try to publish 1+ paper(s).
- Donuts trail running

[1] International Conference on Computer-Aided Verification

Thanks for your attention!