Finding Bugs in Deep Learning Programs

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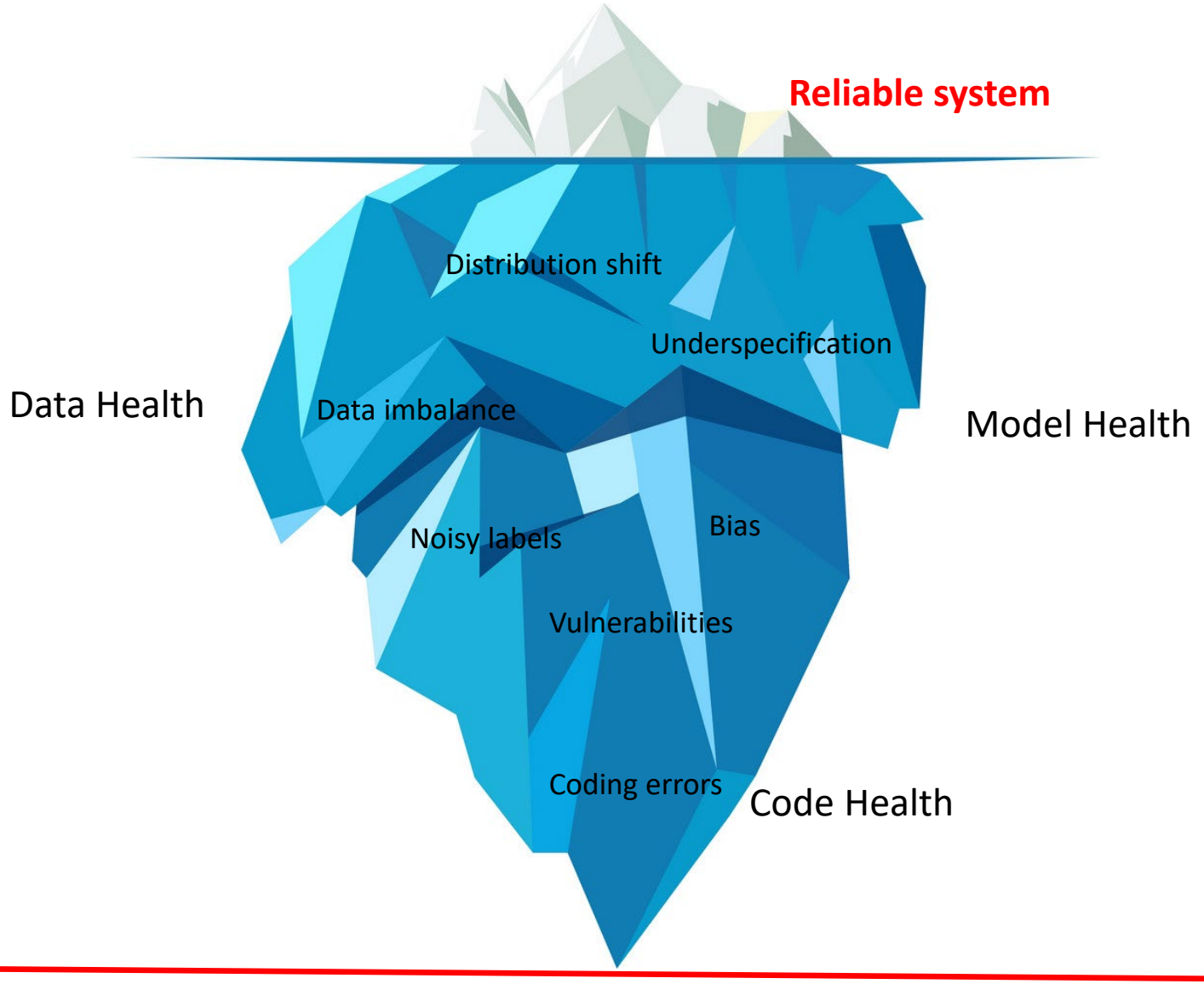
Mila

SEMLA
Trustworthy Engineering of AI Software

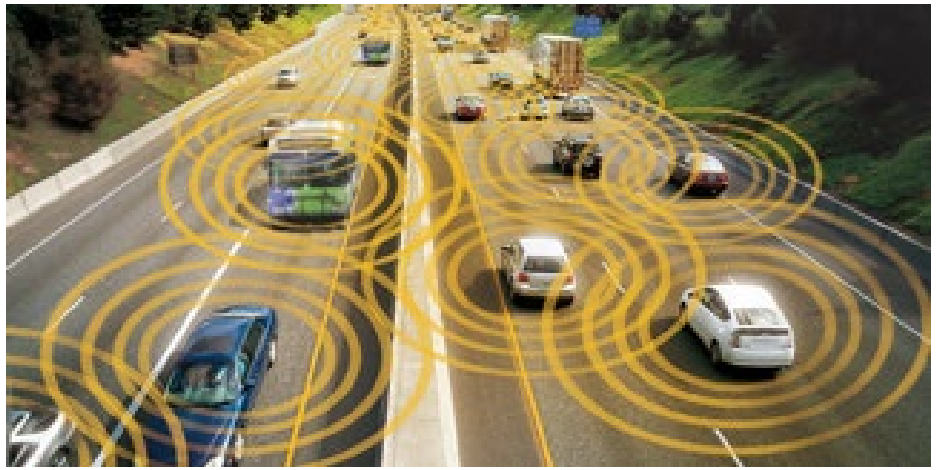
S.W.A.T
SoftWare Analytics and Technologies Lab

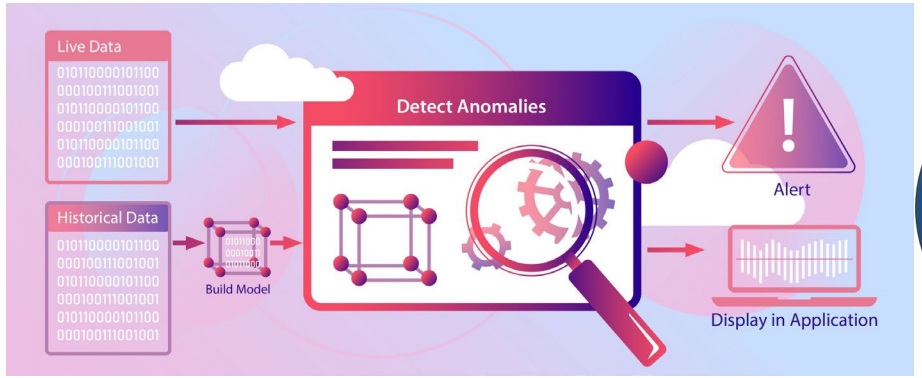
Quality Assurance of ML-enabled systems

System evolution & continuous delivery

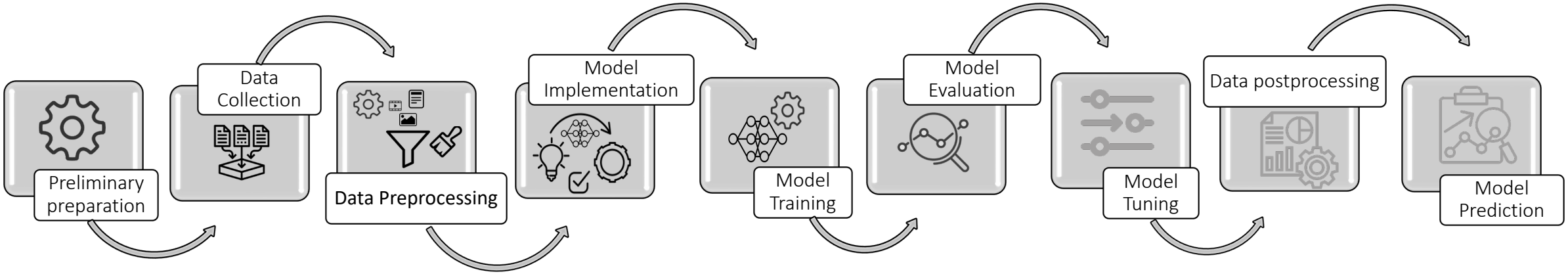


Deep Learning is being rapidly adopted in industry





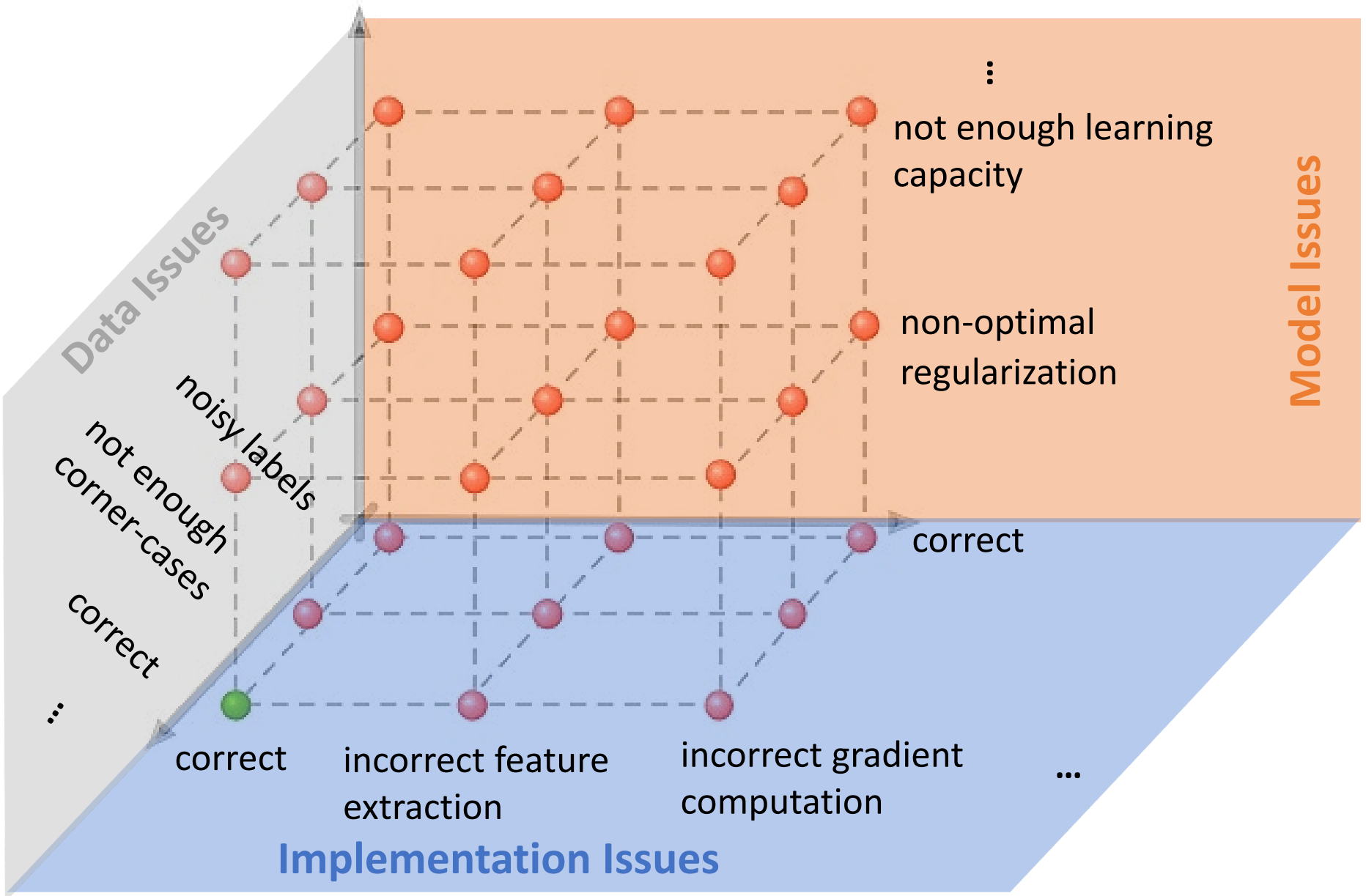
DL development phases produce a lot of code!



Han et al., What do Programmers Discuss about Deep Learning Frameworks

DL programs can be faulty!

Multi-dimensional space of DL bugs



Deep Learning Model Verification Using Graph Transformations

AMIN NIKANJAM*, K. N. Toosi University of Technology, Iran and SWAT Lab., Polytechnique Montreal, Canada
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TOSEM'21

NeuraLint : A linter for DL programs

- ✓ Capture defects early, so saves rework cost.
- ✓ Less expensive, because it doesn't require execution.
- ✓ Find defects in seconds.
- ✓ …

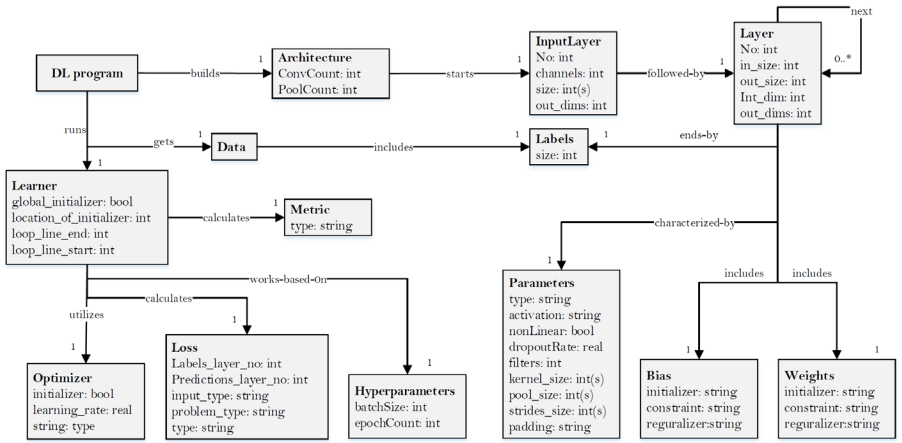
Try it out!

NeuraLint is fast and effective!

- ✓ It achieves an accuracy of 91.7 % .
- ✓ It correctly reported 18 additional bugs that were not found by developers.
- ✓ The average execution time of NeuraLint for the studied TensorFlow and Keras based programs are 2.892 and 3.197 seconds respectively.

NeuraLint has two pillars…

A meta-model of DL programs



Taxonomy of common DL faults

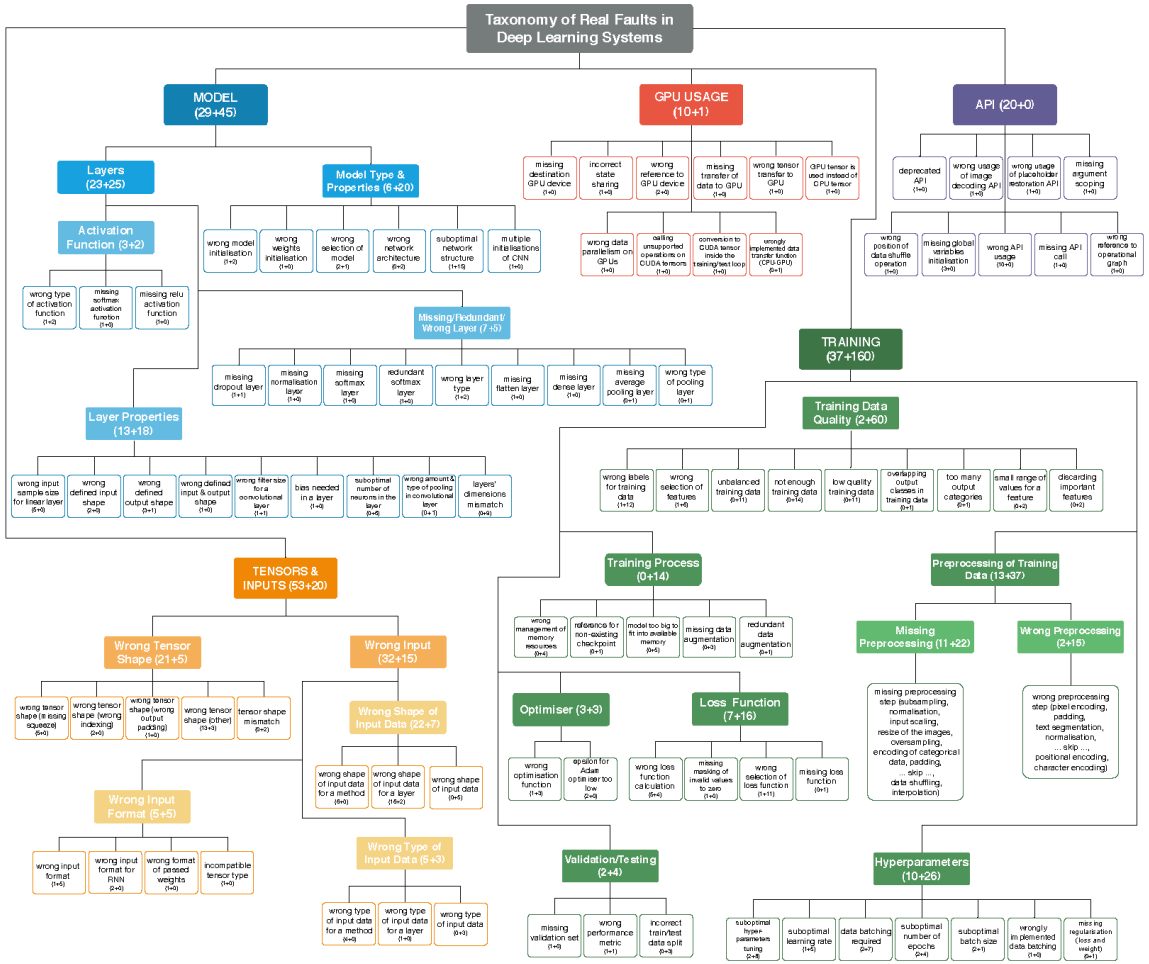
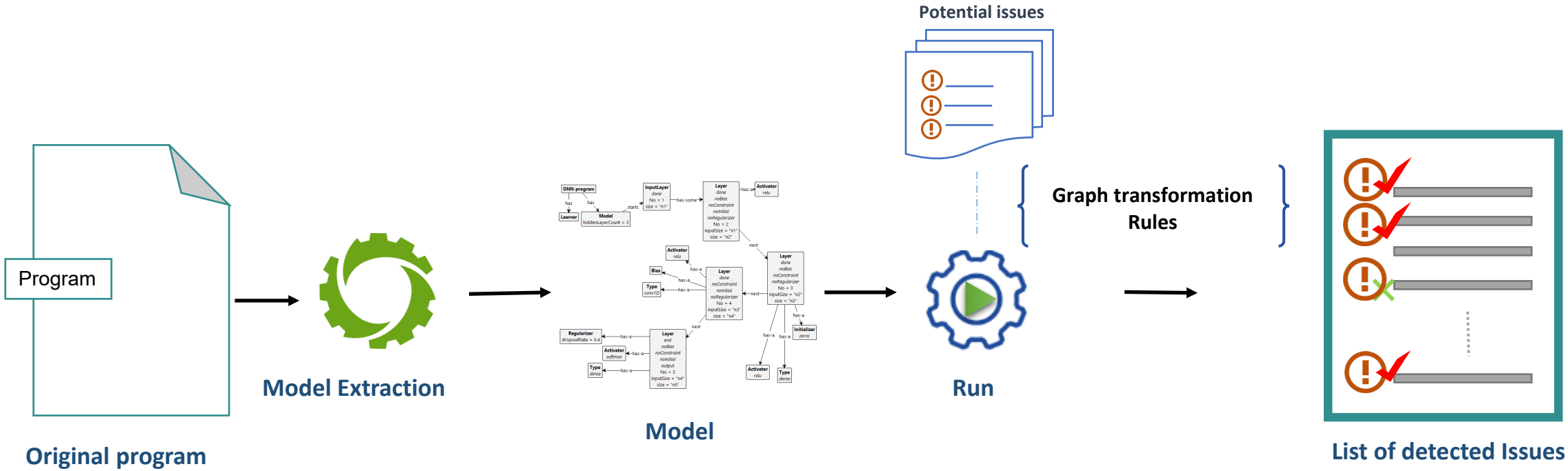


Figure 1: Final Taxonomy

Gunel Jahangirova, Nargiz Humbatova, Gabriele Bavota, Vincenzo Riccio, Andrea Stocco, and Paolo Tonella. 2019. Taxonomy of Real Faults in Deep Learning Systems. arXiv preprint arXiv:1910.11015

NeuraLint: Execution Flow



Testing Neural Networks Training Programs

HOUSSEM BEN BRAIEK, SWAT Lab., Polytechnique Montreal, Canada
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TOSEM'22

TheDeepChecker : Dynamic testing of DL programs

- ✓ Capture defects during the training process.
- ✓ Less expensive than testing the resulting model.
- ✓ Some overhead on the training process.

…

TheDeepChecker outperforms AWS SMD

- ✓ DL coding bugs and misconfigurations are detected with (precision, recall), respectively, equal to (90%, 96.4%) and (77%, 83.3%).
- ✓ Finds 30% more defects than AWS SageMaker.

Try it out!

TheDeepChecker verification rules…

Parameters-related Issues	Untrained Parameters
	Poor Weight Initialization
	Parameters' Values Divergence
	Parameters Unstable Learning
Activation-related Issues	Activations out of Range
	Neuron Saturation
	Dead ReLU
Optimization-related Issues	Unable to fit a small sample
	Zero Loss
	Diverging Loss
	Slow or Non decreasing Loss
	Loss Fluctuations
	Unstable Gradient: Exploding
	Unstable Gradient: Vanishing

TheDeepChecker verification rules…

Parameters-related Issues

Untrained Parameters

Poor Weight Initialization

Parameters' Values Divergence

Parameters Unstable Learning

Issue

Given a layer i and N iterations

$$W_i^0 = W_i^1 \ , b_i^0 = b_i^1$$
$$W_i^1 = W_i^2 \ , b_i^1 = b_i^2$$
$$\dots$$
$$W_i^{N-1} = W_i^N \ , b_i^{N-1} = b_i^N$$

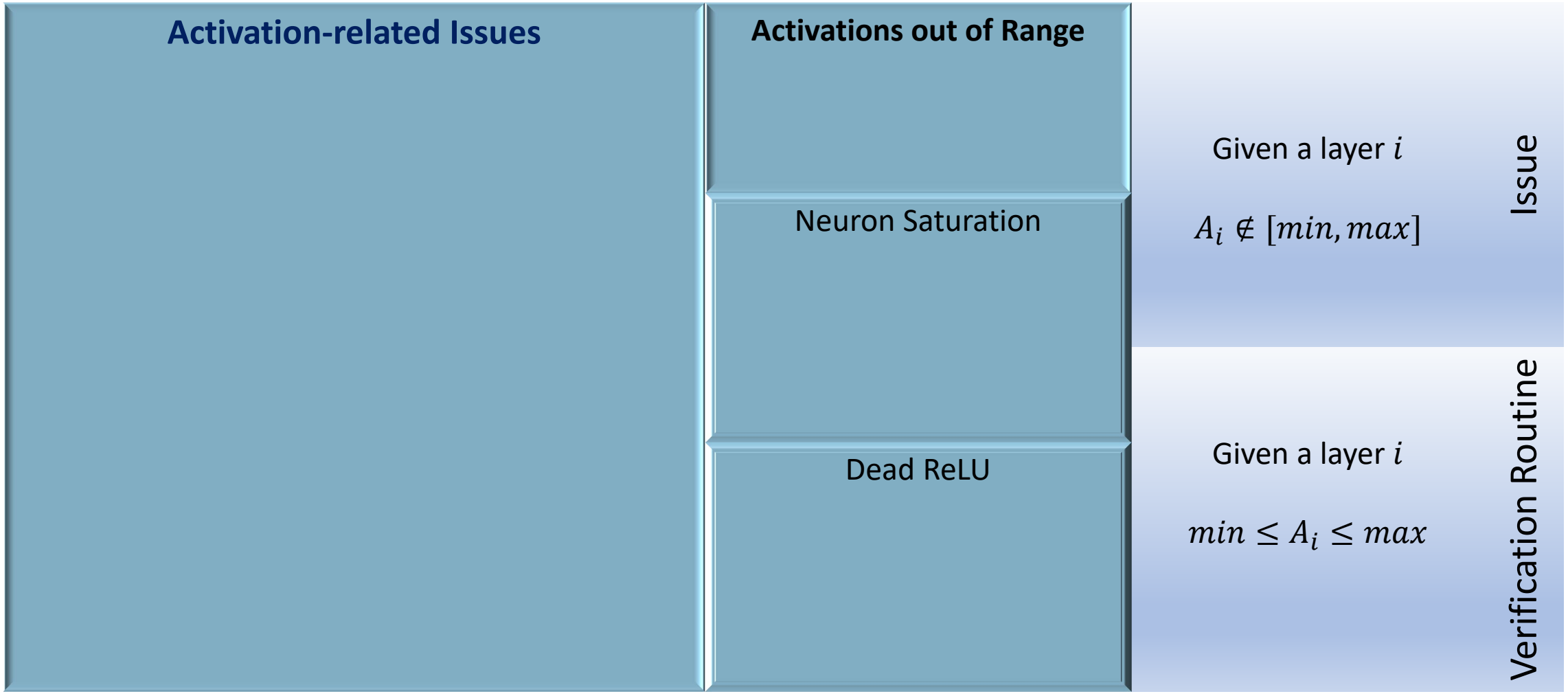
Verification Routine

Given a layer i and an iteration j

$$W_i^j \neq W_i^{j+1} b_i^j \neq b_i^{j+1}$$

$$\forall\, j \ \in [0, N-1]$$

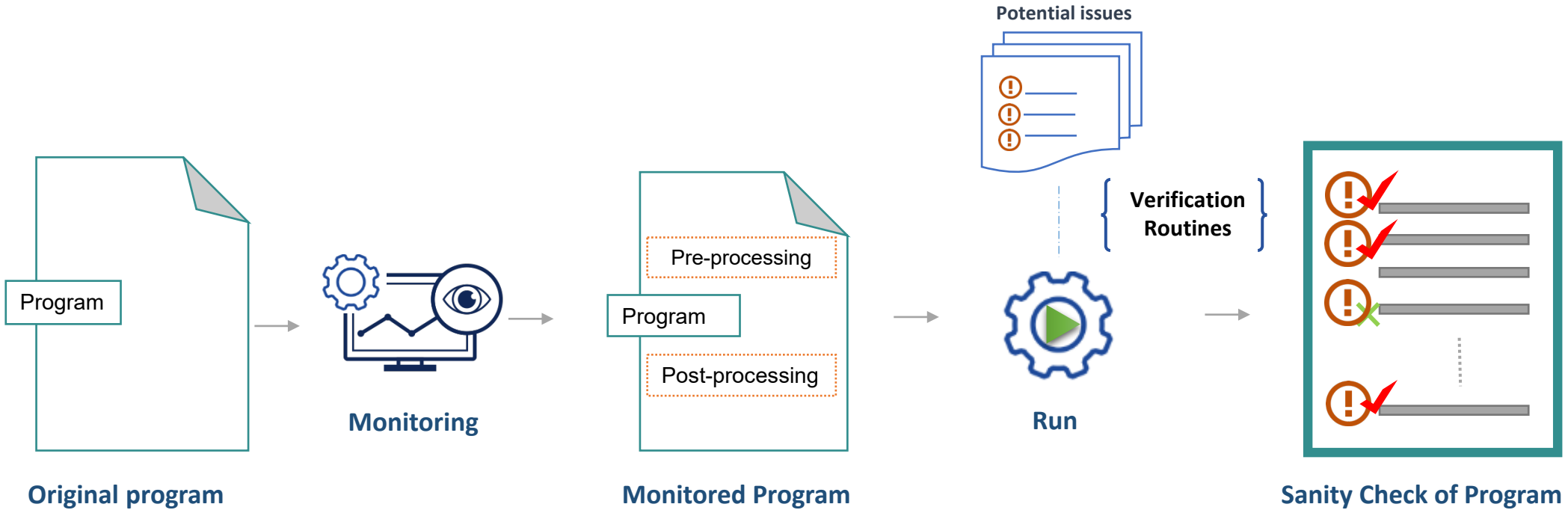
Specification of verification rules



TheDeepChecker verification rules…

Optimization-related Issues	Unable to fit a small sample		
	Zero Loss	The DNN could not properly minimize the loss.	Issue
	Diverging Loss		
	Slow or Non decreasing Loss		
	Loss Fluctuations	The DNN (with regularization off) should overfit a tiny sample of data. Given N iterations $loss_N = 0$	Verification Routine
	Unstable Gradient: Exploding		
	Unstable Gradient: Vanishing		

TheDeepChecker: Execution Flow



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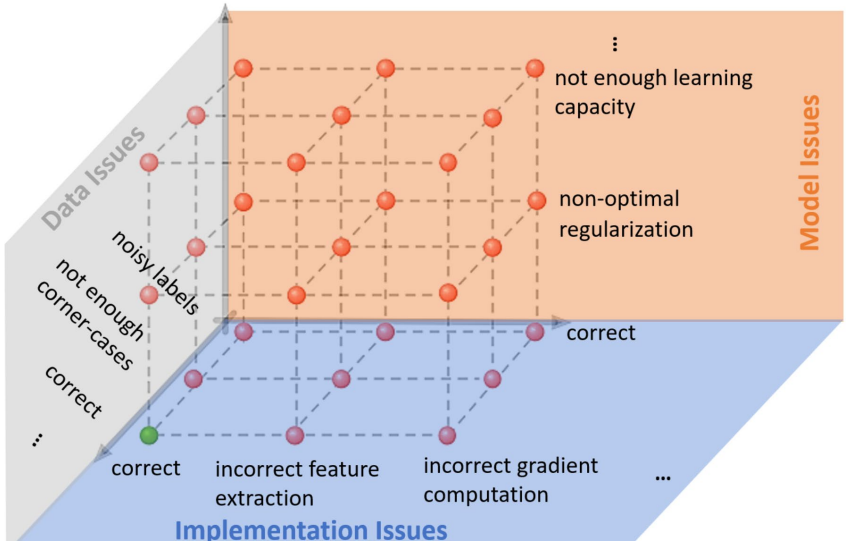

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