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Accelerate Functional Coverage Closure Using Machine-Learning-Based Test Selection

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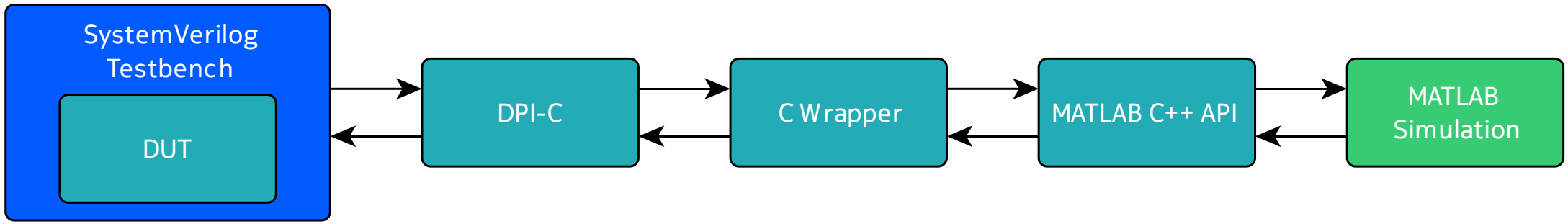
NOKIA MathWorks accellera SYSTEMS INITIATIVE

Premise

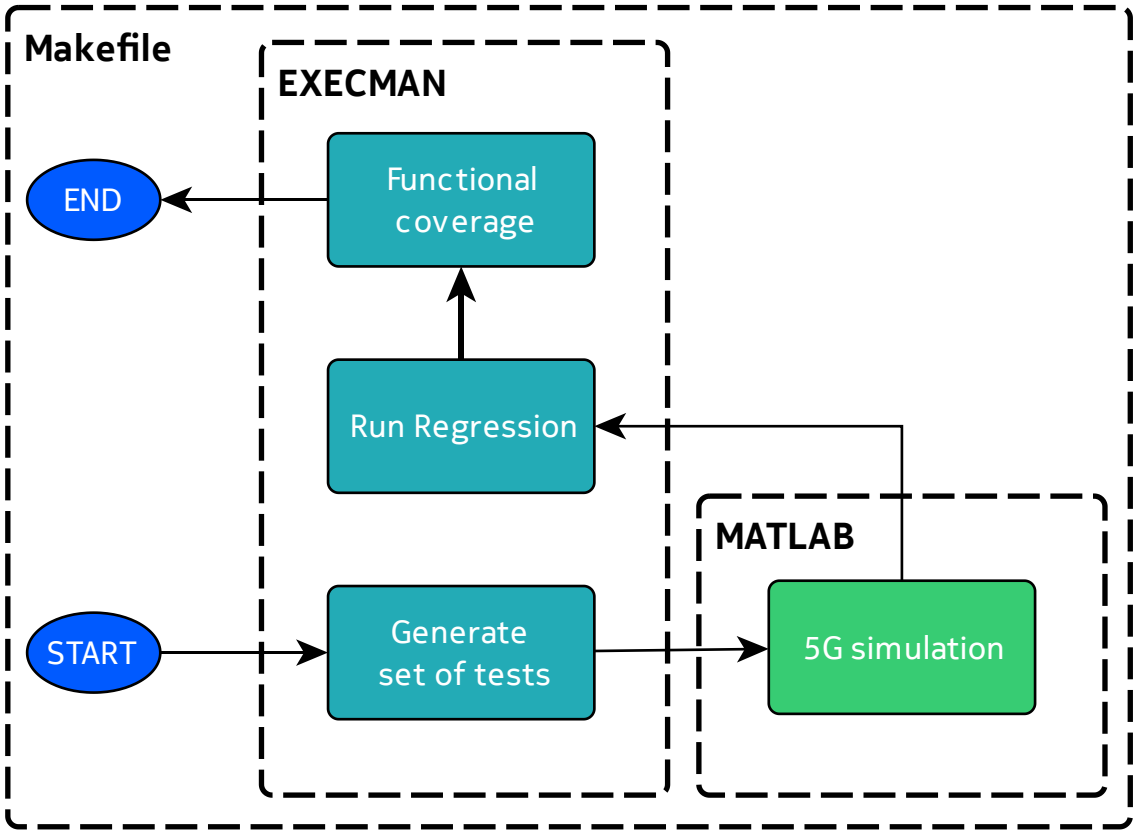
- Constrained random verification.
- Some coverage points are being hit extremely frequently.
- **Solution:** reliably producing stressful tests with most stimuli veriety.
- Use of autoencoders to reduce the numer of simulations.

Co-simulation flow (1)

- Environment based on co-simulation flow
- Matlab was used as DUT input/output generator

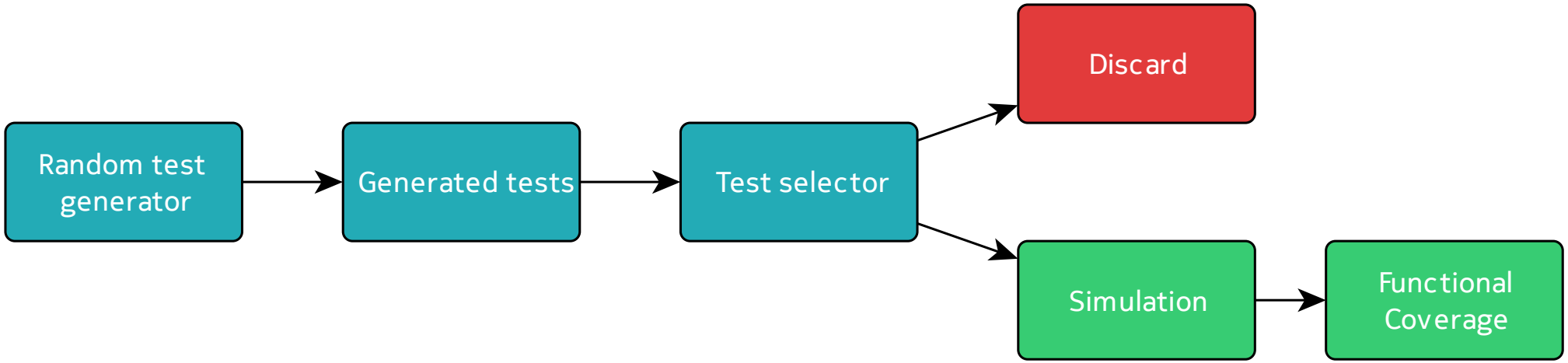


Co-simulation flow (2)



Test selector

- Dissimilar tests tend to hit dissimilar functional coverage events



Method evaluation (1)

- Multiple machine learning methods tested.
- Supervised and unsupervised.
- Supervised:
  - Support Vector Machine (SVM)
  - Decision Trees
  - Random Forest
  - Simple Neural Networks
  - Long-Short Term Memory (LSTM) networks

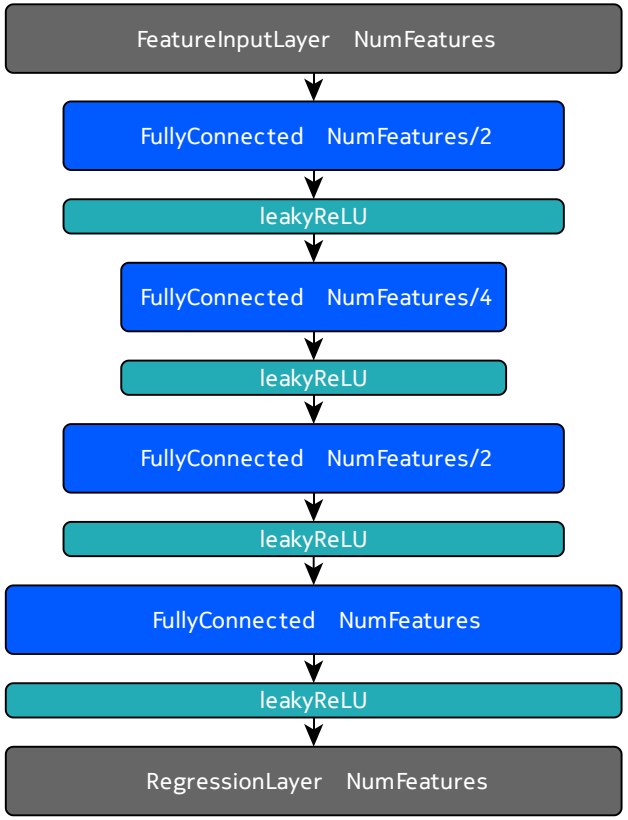
Method evaluation (2)

- Unsupervised:
  - Factorial Analysis of Mixed Data (FAMD)
  - T-distributed Stochastic Neighbour Embedding (t-SNE)
  - Uniform Manifold Approximation and Projection (UMAP)

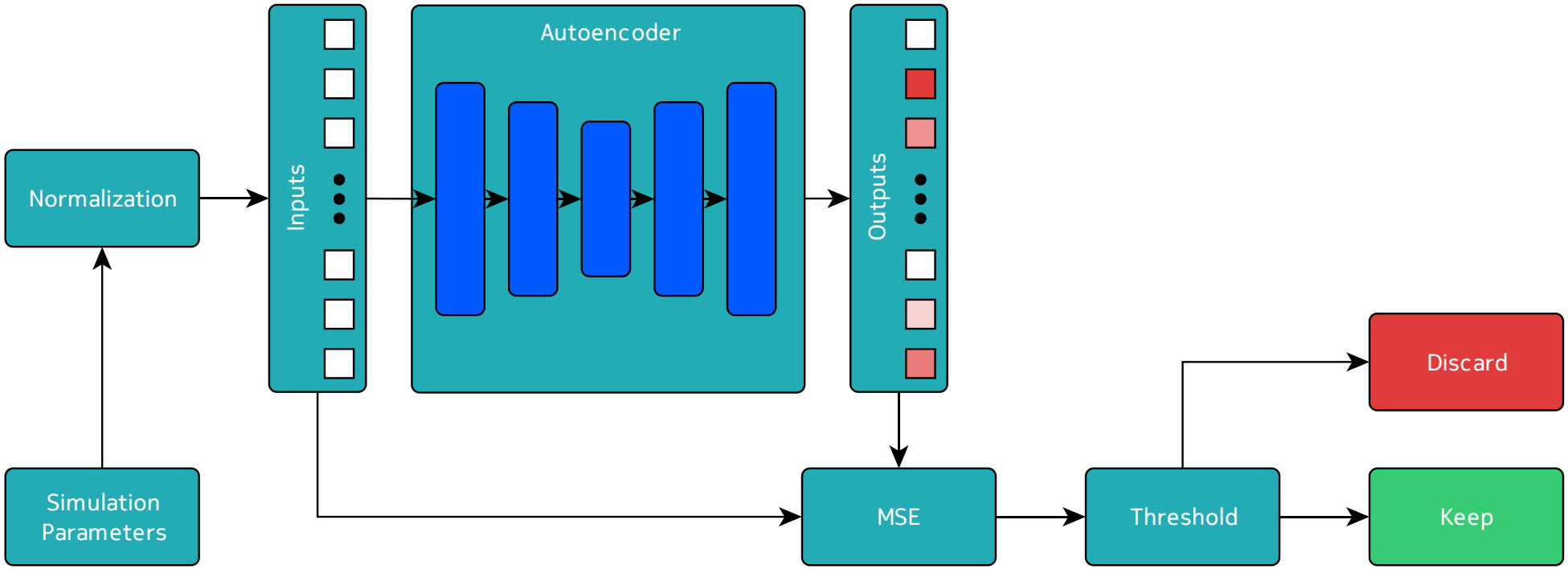
- The problem was later redefined as an **anomaly detection** problem

Autoencoder (1)

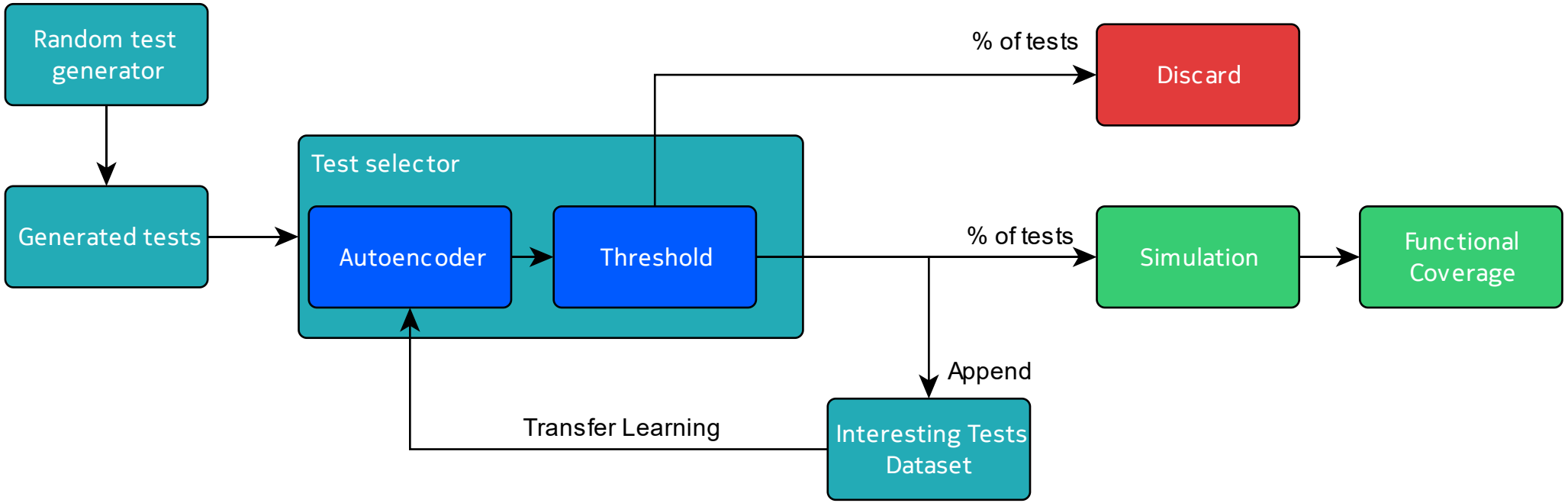
- Simple fully connected autoencoder
- Layer size based on numer of inputs
- Inputs normalized
  - Continuous – 0-1 min/max scaling
  - Discrete – one-hot encoding
- MSE loss for training
- Processing in batches
- Transfer learning is utilized



Autoencoder (2)



Autoencoder (3)



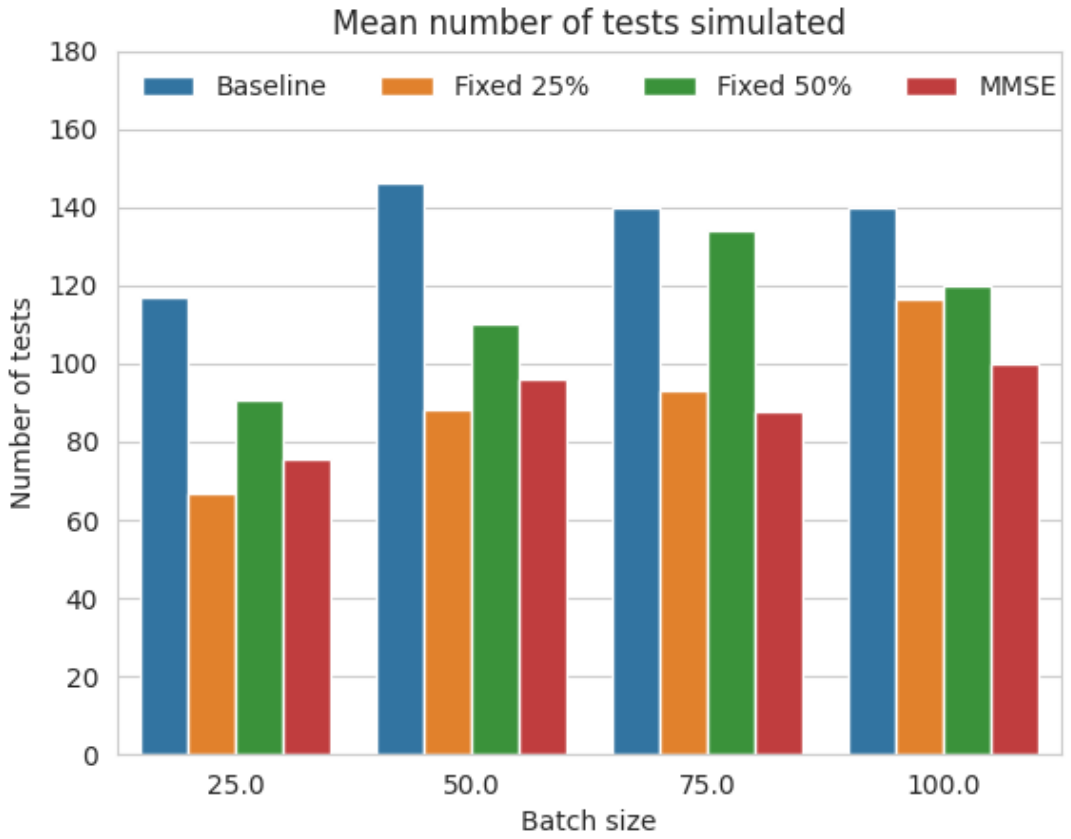
Thresholding

- Two thresholding methods proposed: Fixed and MMSE
- Fixed keeps given percentage of tests
- Moving Mean Square Error (MMSE) based on previous training MSE
- MMSE changes with each batch of tests

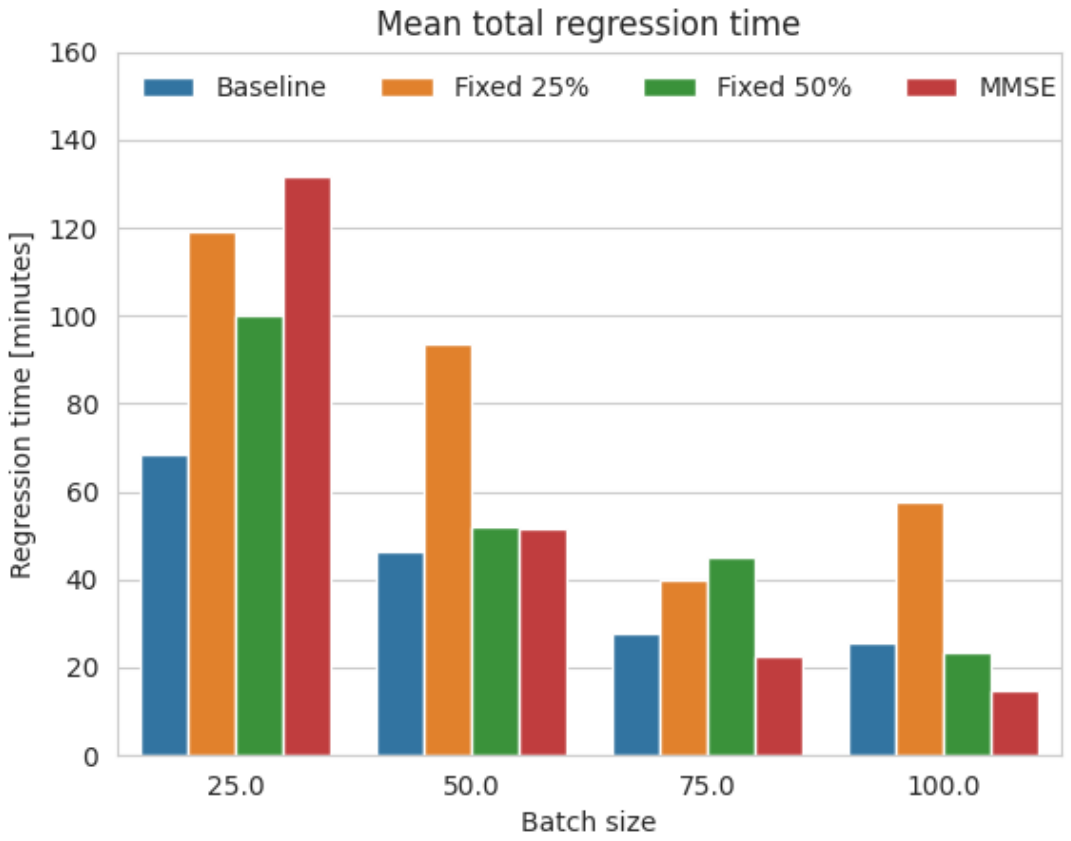
Evaluation

- **DUT:** Physical Uplink Shared Channel (PUSCH) IP estimation block
- **Thresholds:** Fixed 25%, Fixed 50% and MMSE
- **Batches:** 25, 50, 75, 100
- Coverage goal set to 67% due to testbench limitations

Results (1)


Mean number of tests simulated
Baseline
Fixed 25%
Fixed 50%
MMSE
Number of tests
180
160
140
120
100
80
60
40
20
0
25.0
50.0
75.0
100.0
Batch size

Results (2)


Mean total regression time
Baseline
Fixed 25%
Fixed 50%
MMSE
Regression time [minutes]
160
140
120
100
80
60
40
20
0
25.0
50.0
75.0
100.0
Batch size

Conclusions and next steps

- First ML and co-simulation flow tested on commercial IP
- Generic and applicable in software and hardware
- Improvement in numer of simulations for each threshold
- Full flow needs to be improved
- Deeper autoencoder architectures should be tested
- The system will be tested on bigger IPs.

Questions