DESIGN & VERIFICATION DVCON 2014 CONFERENCE & EXHIBITION

Automated Comparison of Analog Behavior in a UVM Environment

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Structure

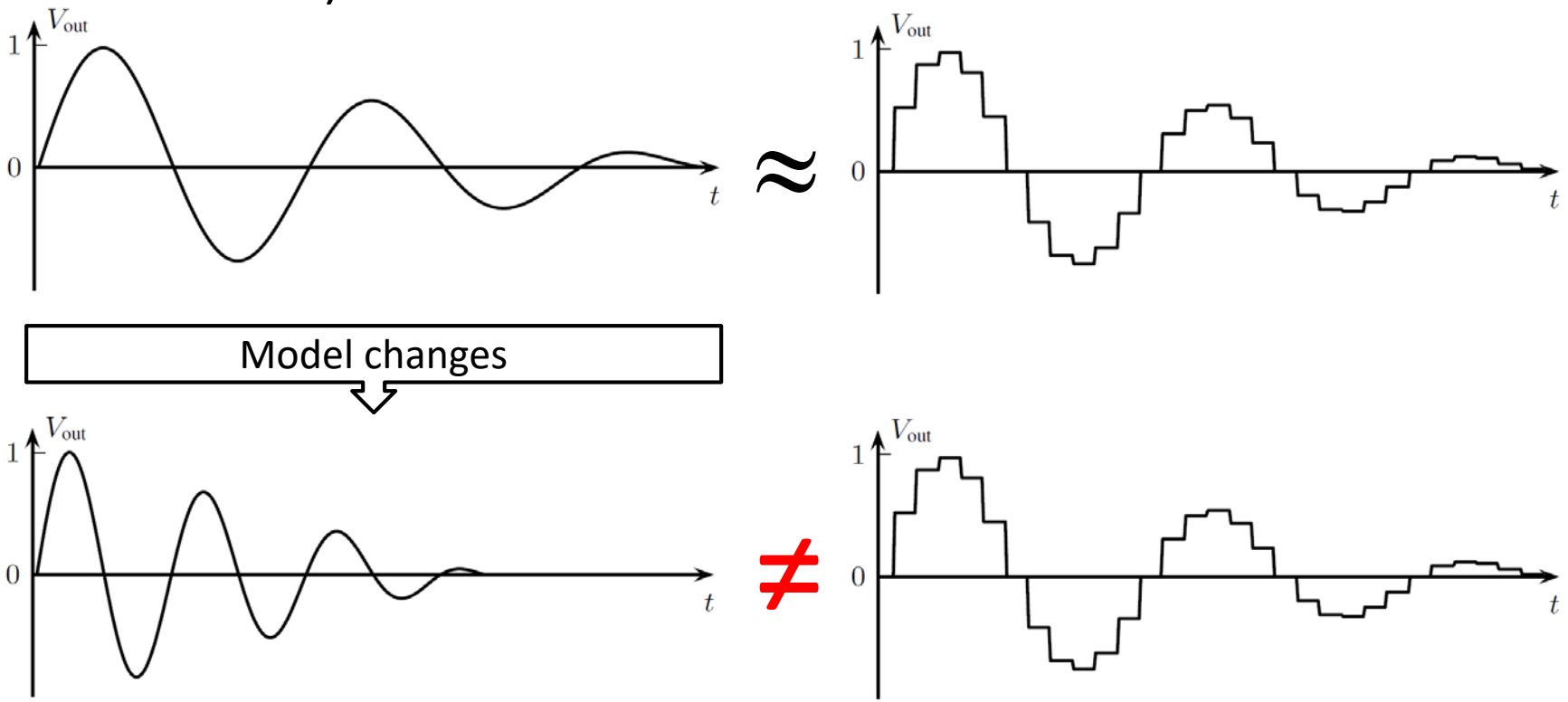
1. Motivation
2. Earth Mover‘s Distance
3. Concept of Automated Comparison
4. Application and Results
5. Conclusion and Outlook

Motivation

- Increasing number of mixed-signal designs
- **Mixed-signal verification:** time-consuming task compared to digital verification
- **Approach:** replacing accurate SPICE-models with less accurate behavior models
- **Potential problem:** divergence between SPICE-model and behavior model during design process
- Therefore, continuous model validation is indispensable
- **But:** usually done by manual inspections of analog signals/waveforms → error-prone and time-consuming

Motivation

- Example: voltage regulator (SPICE- and SystemVerilog-model)



Motivation

- **Our goal:** automating the comparison between analog signals
- Embedding technique in an analog verification environment which is based on UVM → A-UVM
- Regression tests to ensure consistency between analog models at any time

➢ **Question:** How to determine perceptual similarity?

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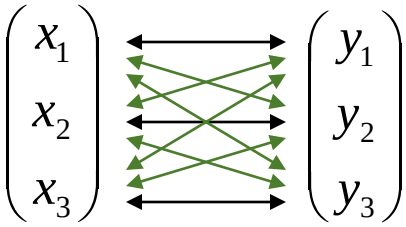
Earth Mover's Distance

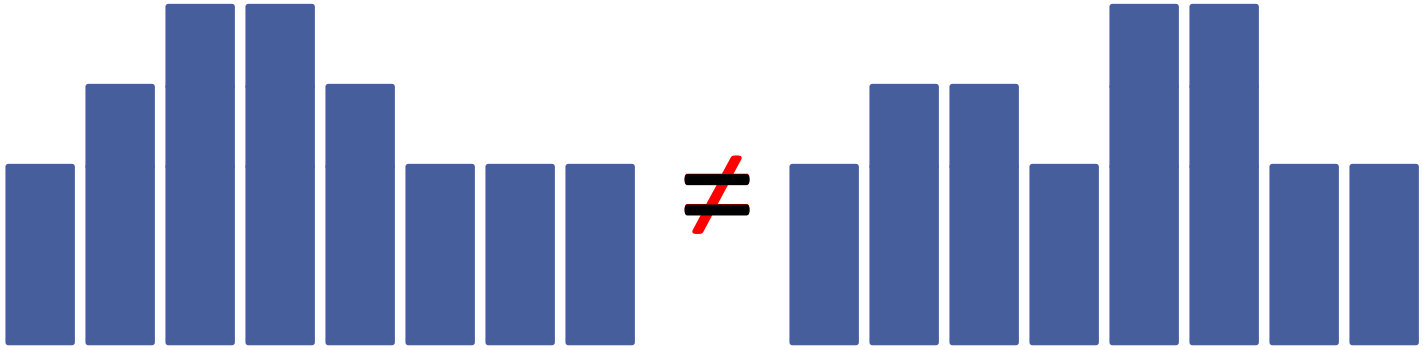
- Similarity can be measured by several metrics (Pearson correlation, cosine similarity, Euclidean distance, …)
- **Deficiency:** bin-by-bin measures do not necessarily match perceptual similarity well



- Leveraging cross-bin measures in order to obtain more meaningful results → **Earth Mover's Distance**

Earth Mover's Distance

- Approach to measure the distance between two distributions
- Visualization: transportation of soil from one pile to another



- Work = distance x amount
- Find minimum flow which equalizes distributions → optimization problem has to be solved

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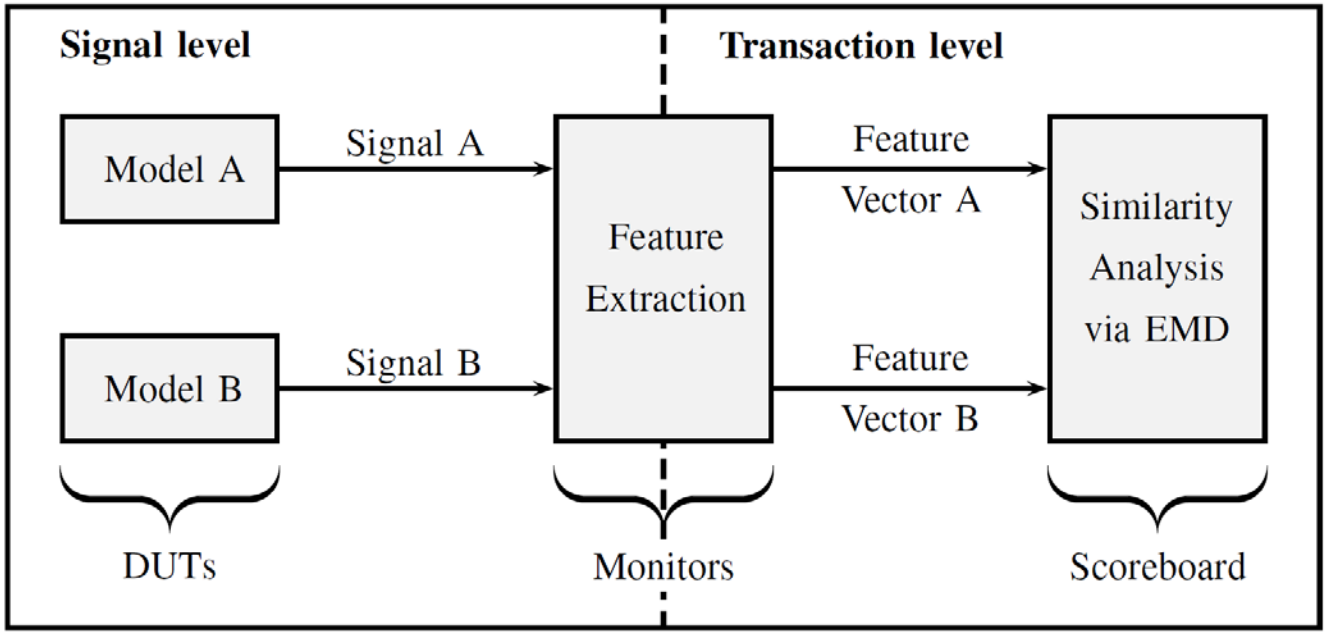
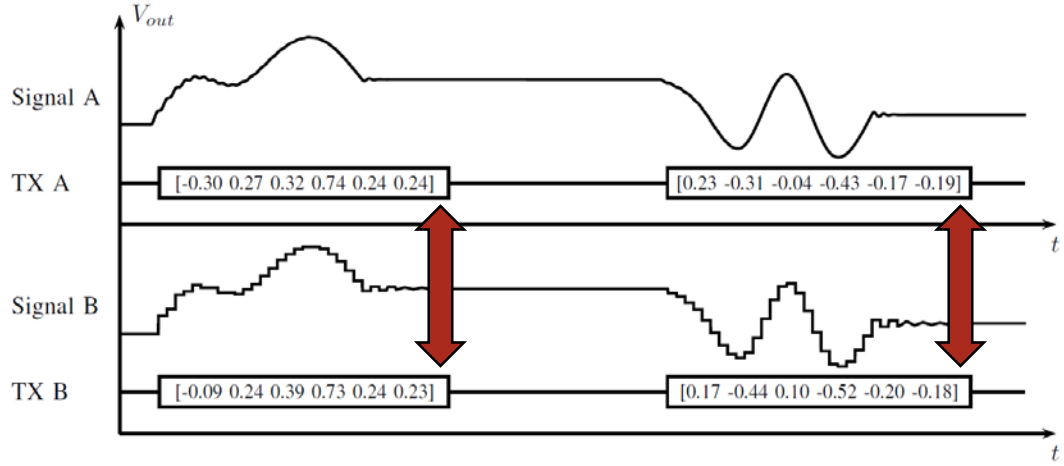
Concept of Automated Comparison

- Generic monitors extract analog transactions = feature vectors
- Extraction types: sampling, FOURIER, sine, ramp, jump
- Similarity analysis implemented with SystemVerilog DPI-C



Concept of Automated Comparison

- Analyzing one pair of transactions results in exactly one value for the Earth Mover‘s Distance



- Range: $0 \leq d_{EM} \leq 1$ (where 1 implies a full match)
- **Basic idea for regression:** defining a lower bound for d_{EM}
- Once d_{EM} falls below this bound, the regression test fails and the regarding transactions can be examined

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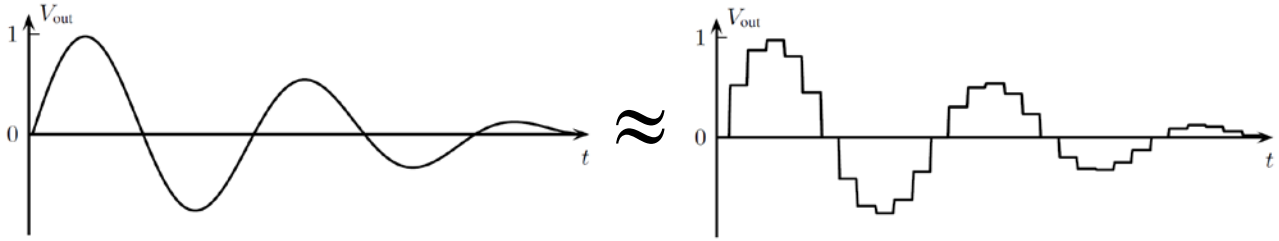
Application and Results

- Application to the aforementioned voltage regulators



- Three parameters of the second model will be modified in the following testcases

Test case	Sample time	Scale factor	Offset
1	10 ns	1.0	0.0 V
2	**40 ns**	1.0	0.0 V
3	10 ns	**3.0**	0.0 V
4	10 ns	1.0	**3.0 V**

Application and Results

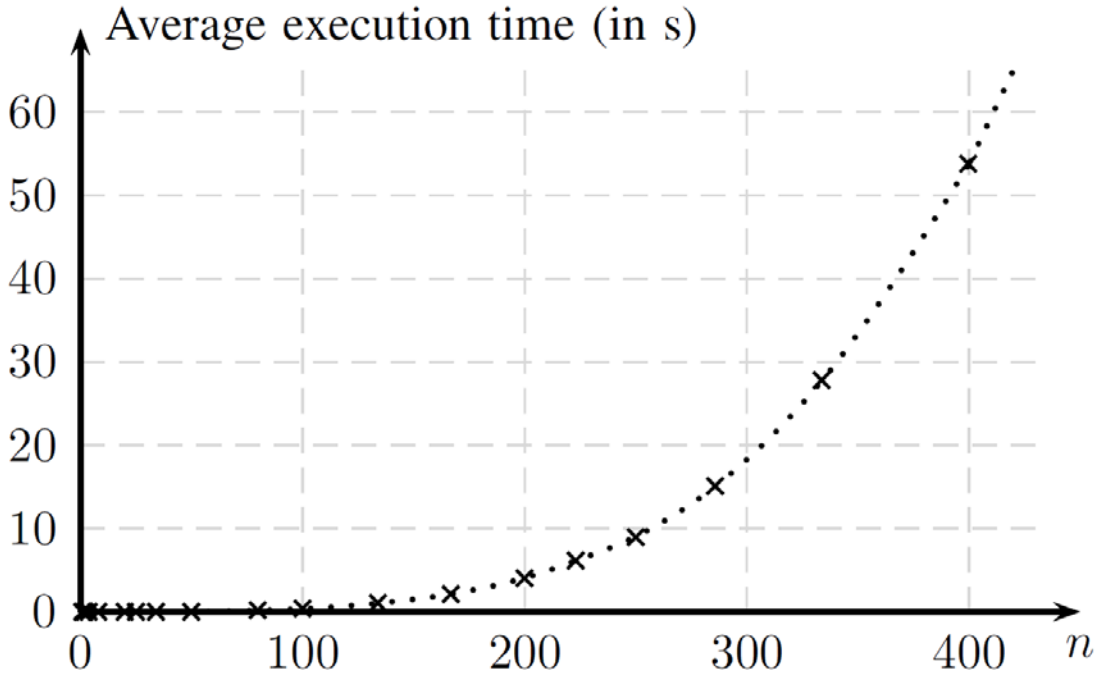
- Assumption for regression: $d_{EM} > 0.95$

d_{EM} (case 1)	d_{EM} (case 2)	d_{EM} (case 3)	d_{EM} (case 4)
…	…	…	…
0.9863	0.9693	0.6380	0.3993
0.9815	0.9649	0.6742	0.4675
0.9752	0.9635	0.6518	0.2524
0.9771	0.9305	0.6671	0.3283
0.9793	0.9622	0.6437	0.3305
…	…	…	…

- **Result:** as expected, only the first test case passes
- Remaining test cases would flag a model inconsistency

Application and Results

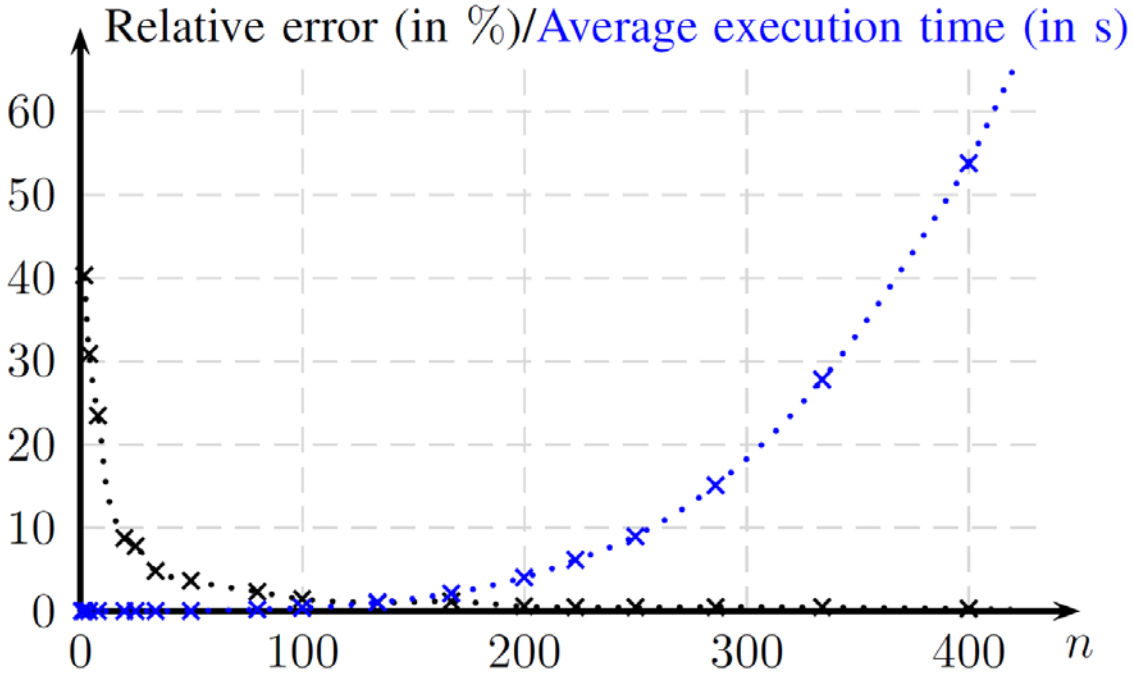
- Performance is determined by solver engine
- 90% of time is used for solving the optimization problem



(n = size of feature vectors)

Application and Results

- Accuracy can be improved by increasing size of feature vectors
- Trade-off between accuracy and performance



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Conclusion and Outlook

- We presented a new approach for comparing analog behavior based on the Earth Mover‘s Distance
- **Idea:** quantifying a degree of perceptual similarity
- **Advantages:**
  - Model validation can be accomplished by automated regression tests
  - Effort for manually checking waveforms can be tremendously reduced
  - Approach does not depend on the type of circuitry → universally applicable

Conclusion and Outlook

- **Our future work regarding this approach:**
  - Validation of further models which are used in mixed-signal designs
  - Performance improvement
  - Implementation of additional distance measures

- **Overall goal:** UVM-based model kit for simulation and verification of analog designs

Thank you for your attention!