Stochastic Process Model-Log Quality Dimensions

an experimental study

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Wil van der Aalst and Arthur ter Hofstede

Stochastic Models

Stochastic Models

- Event logs are stochastic

Stochastic Models

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  e.g. the log
  $[\langle a, b\rangle^{20}, \langle a, b, c\rangle^{2}, \langle a, b, c, c\rangle^{1}, \langle e, f\rangle^{1}]$
  ... already has frequency information

Stochastic Models

- Event logs are stochastic
- Simulation, analysis and recommendation need stochastic information

Stochastic Models

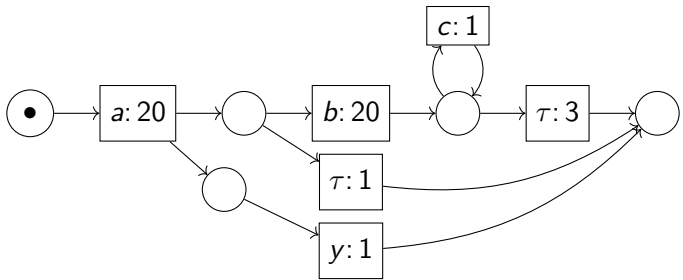
- Event logs are stochastic
- Control-flow models discard stochastic information

- Simulation, analysis and recommendation need stochastic information

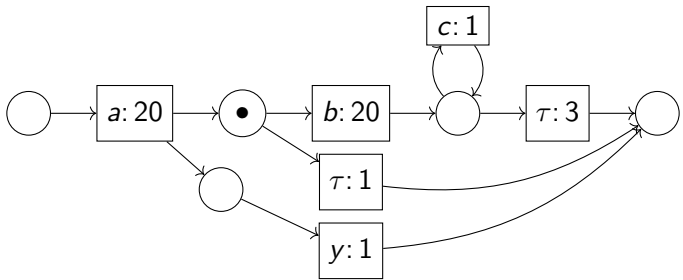
Stochastic Models

- Event logs are stochastic
- Control-flow models discard stochastic information
- Stochastic process models retain stochastic information
- Simulation, analysis and recommendation need stochastic information

A Stochastic Model



A Stochastic Model



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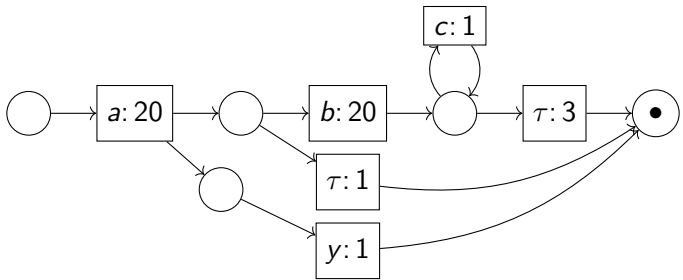

How to compare?

What dimensions describe the quality of stochastic process models?

Stochastic Conformance Checking Measures

Evaluation measures

Stochastic Conformance Checking Measures

Evaluation measures

- Earth-Movers' Stochastic Conformance

Stochastic Conformance Checking Measures

Evaluation measures

- Earth-Movers' Stochastic Conformance
- Entropy recall

Stochastic Conformance Checking Measures

Evaluation measures

- Earth-Movers' Stochastic Conformance
- Entropy recall
- Entropy precision

Stochastic Conformance Checking Measures

Exploration measures (13 new)

- Earth Movers' trace-wise (1)
- Probability mass (2)
- Fitness (6)
- Precision (2)
- Simplicity (3)
- Generalisation (4)

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Discover dimensions

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Discover dimensions

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Identify dimensions

Discovering the Dimensions

1. Use 6 public logs

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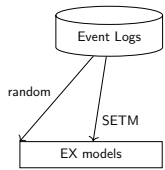
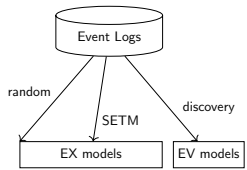
2. 9301 stochastic process models
   random, new genetic algorithm & discovered



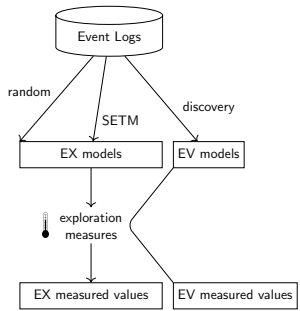
Discovering the Dimensions

1. Use 6 public logs
2. 9301 stochastic process models
3. 18 exploration measures



Discovering the Dimensions

1. Use 6 public logs
2. 9301 stochastic process models
3. 18 exploration measures
4. Dimensional analysis



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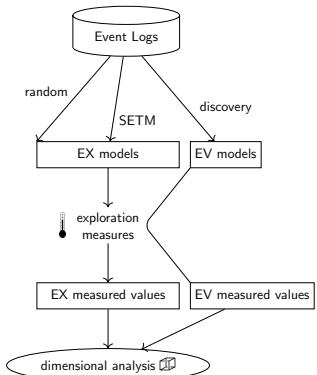

Dimensional Analysis 1: Correlations

- Baselines: 2 log-only measures

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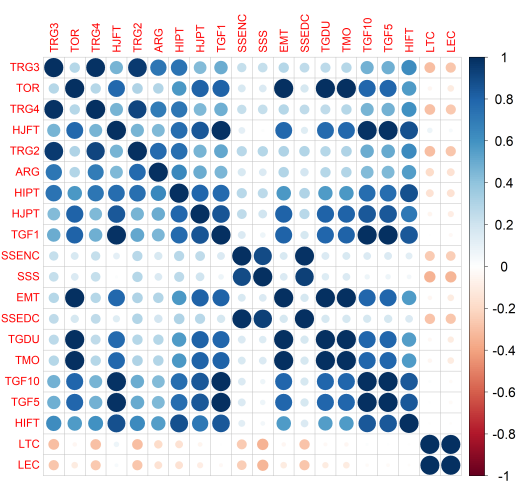

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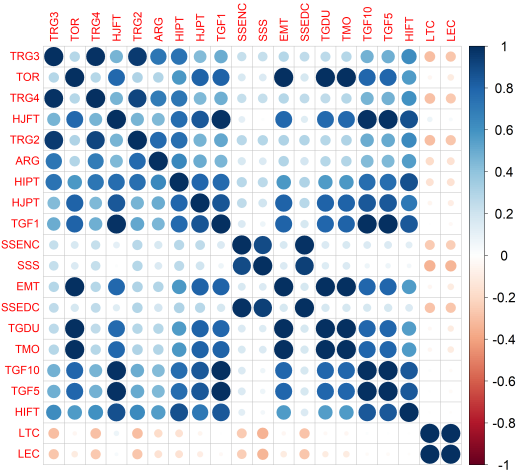

- Baselines: 2 log-only measures
- Remove: 3 too-correlated measures:
  Trace Overlap Ratio,
  Trace Generalization Floor-1,
  Trace Generalization Floor-10

Dimensional Analysis 2: Principal Component Analysis

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- Find linear relation that best describes the data

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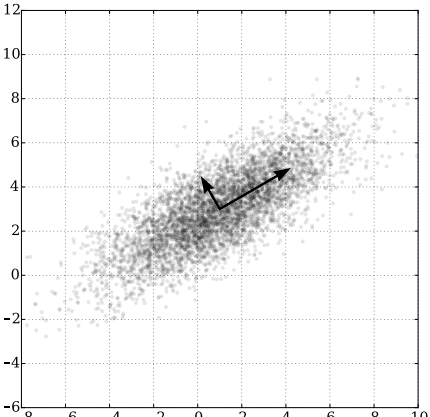
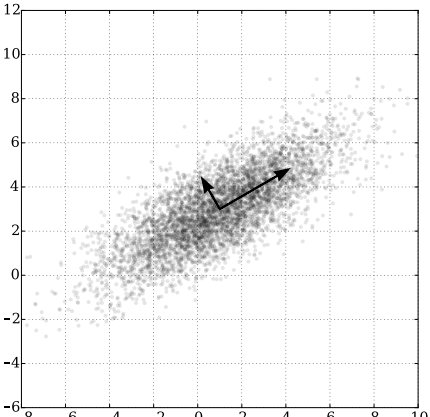


image source: wikipedia

Dimensional Analysis 2: Principal Component Analysis

- Find linear relation that best describes the data
- Find linear relation that best describes the data, orthogonal to first relation
- . . . (15 times)



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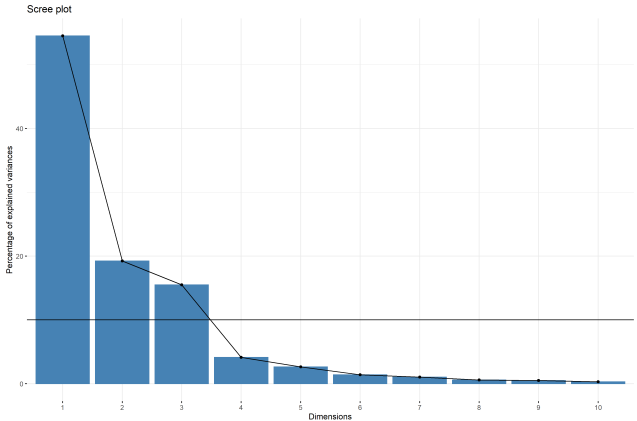

Dimensional Analysis 2: Principal Component Analysis

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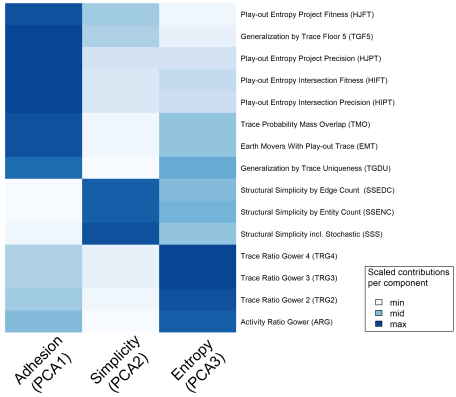


Eigenvector Values For EX

Delete frame? See comment

Standard deviations (1, .., p=15):

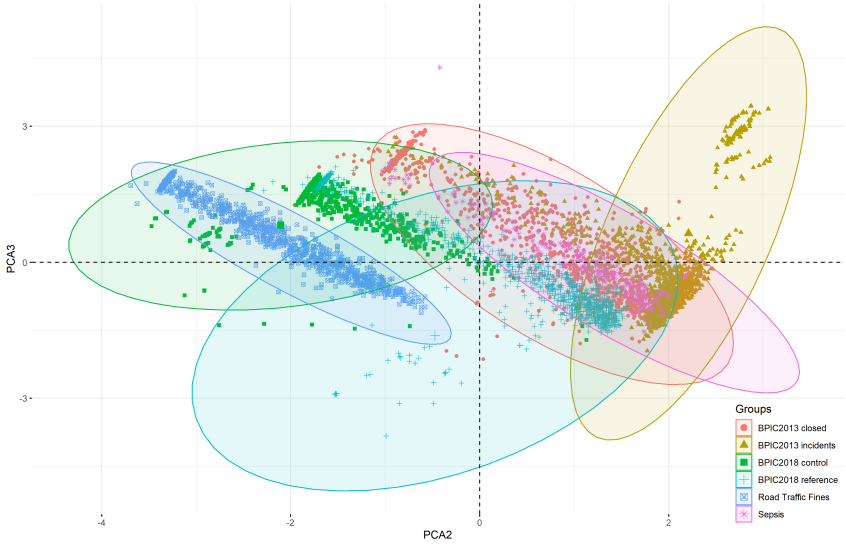
[1] 2.8598595882 1.6990123156 1.5246609206 0.7865665324 0.6297257503 0.4600371044 0.3943236321 0.2941391

[14] 0.0149595210 0.0001853429

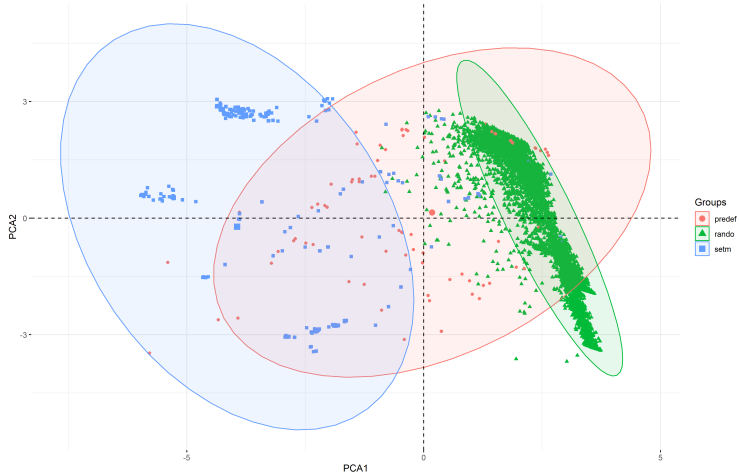
Rotation (n x k) = (15 x 15):

	PC1	PC2	PC3	PC4	PC5
ACTIVITY_RATIO_GOWER	-0.2313639	0.12995624	-0.28884572	-0.20701081	-0.83508956
TRACE_RATIO_GOWER_2	-0.2613284	0.21783178	-0.31657056	-0.17945506	0.09996934
TRACE_RATIO_GOWER_3	-0.25505	0.2061479	-0.34733325	-0.19427176	0.29392609
TRACE_RATIO_GOWER_4	-0.2508668	0.20311204	-0.33629168	-0.19388809	0.3374191
STRUCTURAL_SIMPLICITY_STOCHASTIC	-0.108313	0.45407014	0.32417104	-0.07154331	0.03656602
STRUCTURAL_SIMPLICITY_ENTITY_COUNT	-0.1220488	0.44260934	0.34036722	0.11738966	-0.03241646
STRUCTURAL_SIMPLICITY_EDGE_COUNT	-0.1306636	0.44564103	0.33960221	0.11777642	-0.0214105
TRACE_GENERALIZATION_DIFF_UNIQ	-0.2740367	-0.23386526	0.2618071	-0.31910582	0.05324514
EARTH_MOVERS_TRACEWISE	-0.2773889	-0.22840527	0.25235332	-0.3289332	0.05816939
TRACE_PROBMASS_OVERLAP	-0.2773891	-0.22840708	0.25235245	-0.32892646	0.05817131
ENTROPY_PRECISION_TRACEWISE	-0.3168787	0.04583473	-0.11641767	0.24698472	-0.02870561
ENTROPY_FITNESS_TRACEWISE	-0.2990944	-0.07831206	-0.13219526	0.49549231	0.05756591

Principal Components - Variation By Log

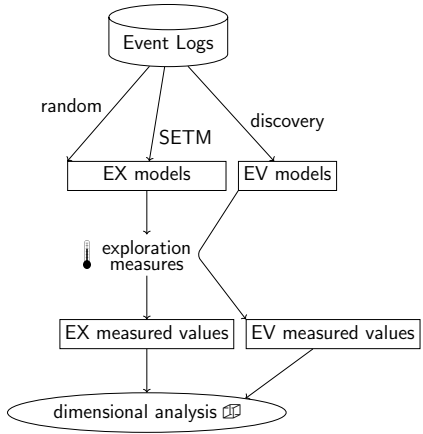


Principal Components - By Model Generator



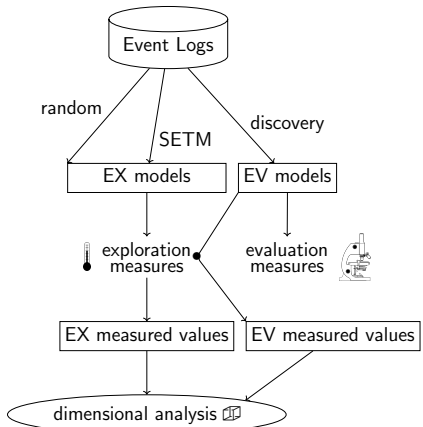
Identifying the Dimensions

- Remove random & genetic models



Identifying the Dimensions

- Remove random & genetic models
- Add the 3 evaluation measures *on EV models only*



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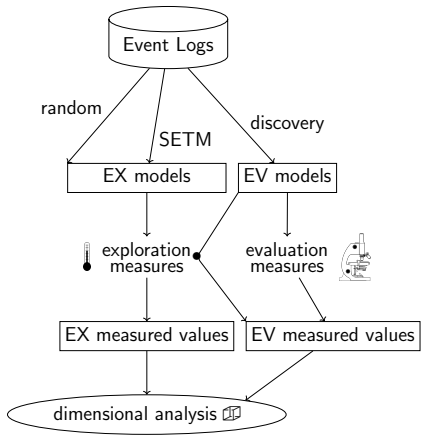
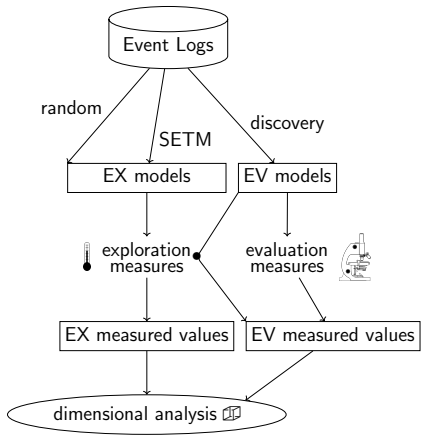


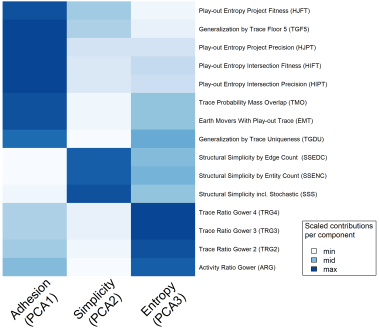
Identifying the Dimensions

- Remove random & genetic models
- Add the 3 evaluation measures *on EV models only*
- Redo principal component analysis



Identifying the Dimensions: comparison

Discovered dimensions



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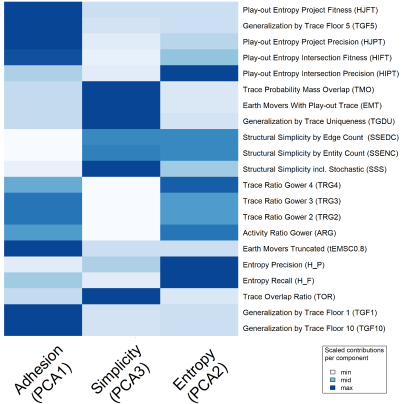

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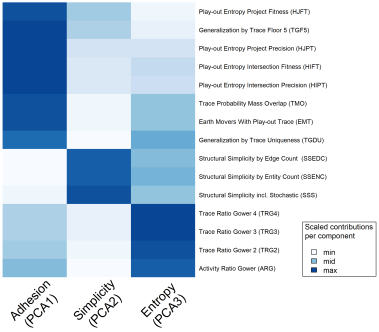

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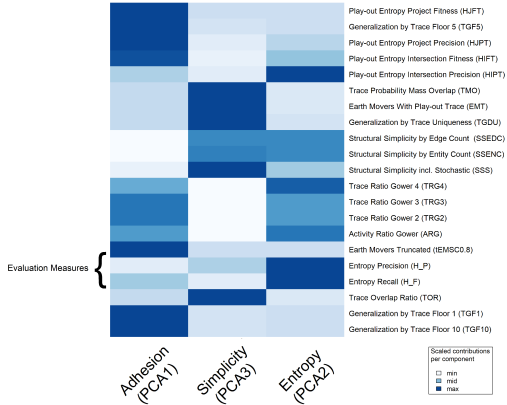

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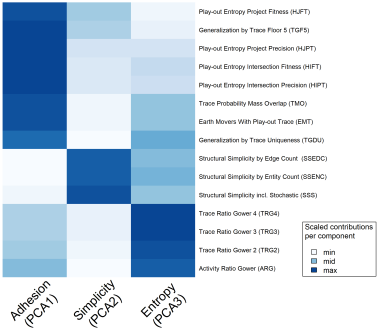

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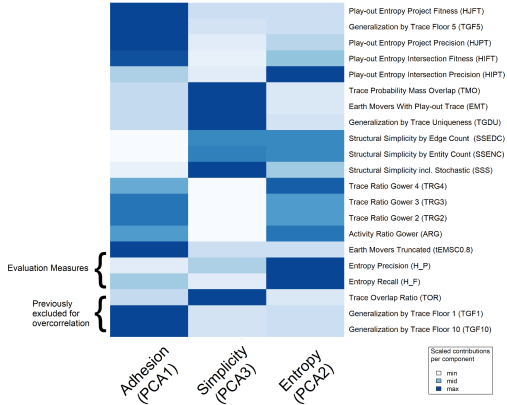

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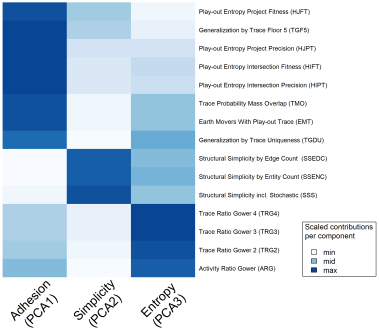

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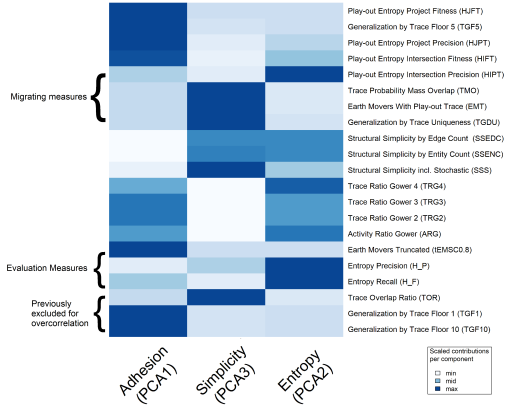
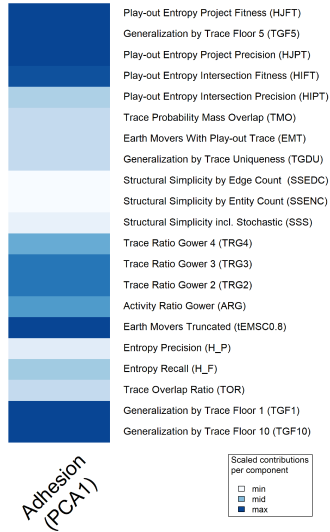


Three Empirical Dimensions

- Adhesion
  How little effort is required to transform one stochastic language into another



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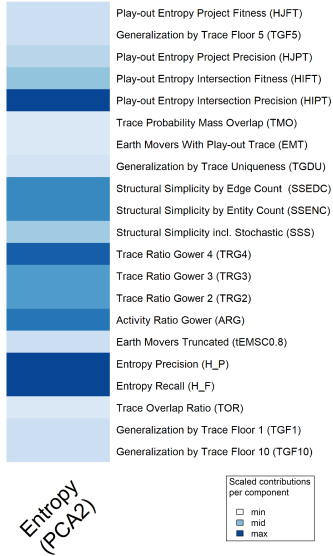
  How little effort is required to transform one stochastic language into another
- Entropy
  The amount of information in a system

In this case, the combination of log and model



Three Empirical Dimensions

- Adhesion
  How little effort is required to transform one stochastic language into another
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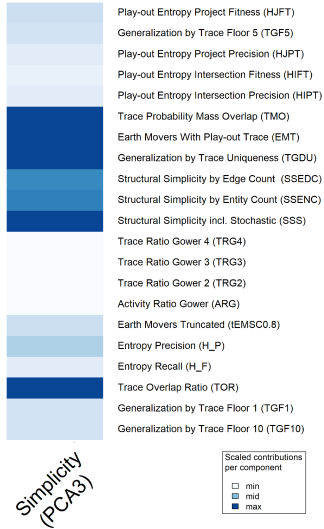
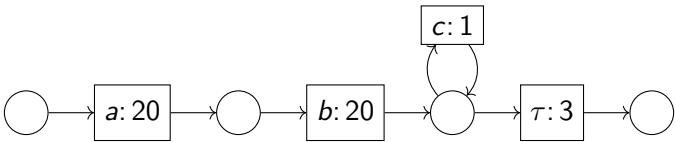
  The amount of information in a system

  In this case, the combination of log and model
- Simplicity
  Structural simplicity of the model



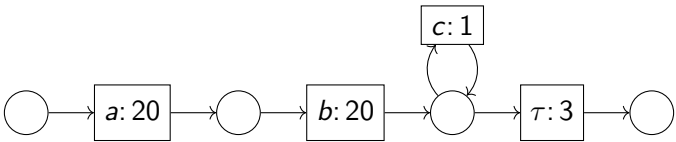
Example 1

Adhesion entropy simplicity



Example 1

Adhesion + entropy simplicity



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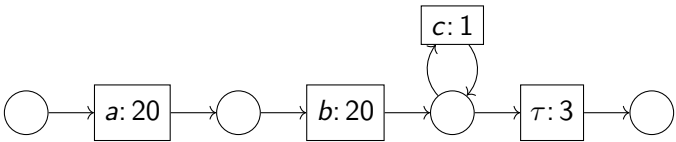

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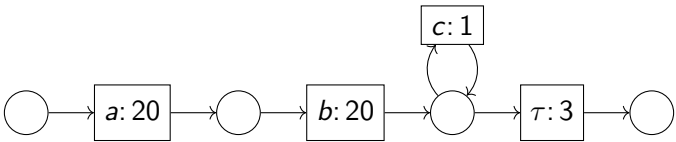
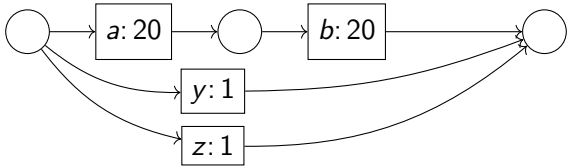
Adhesion + entropy + simplicity +



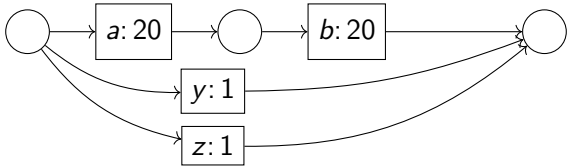
Example 2

Adhesion entropy simplicity



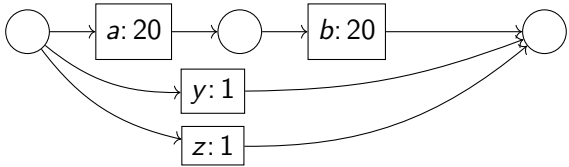
Example 2

Adhesion + entropy $\quad$ simplicity



Example 2

Adhesion + entropy - simplicity



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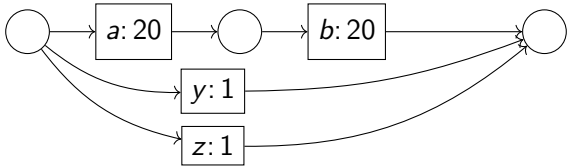
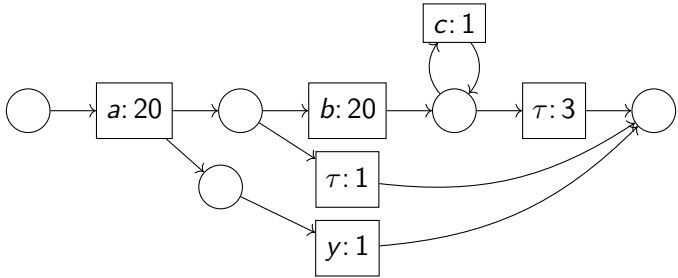
Adhesion + entropy - simplicity +



Example 3

Adhesion entropy simplicity



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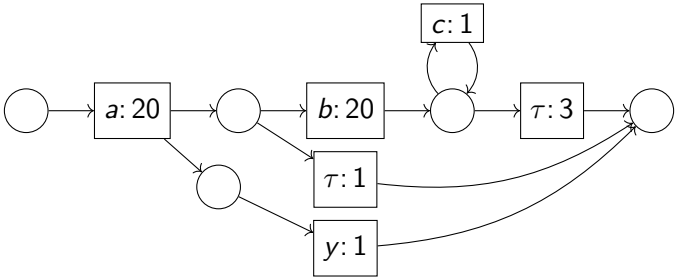
Adhesion $\sim$ entropy simplicity



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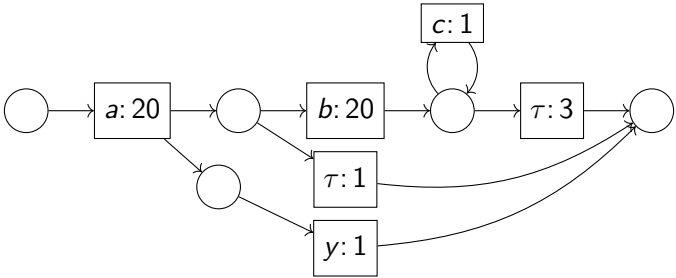
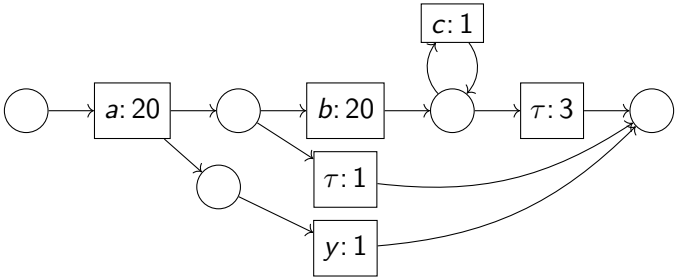
Adhesion $\sim$ entropy $\sim$ simplicity



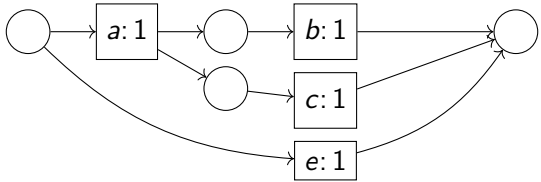
Example 3

Adhesion $\sim$ entropy $\sim$ simplicity -



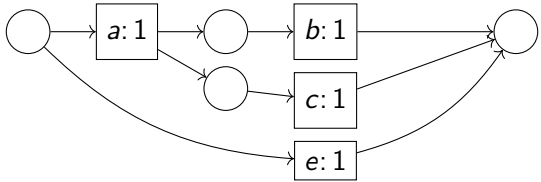
Example 4

Adhesion entropy simplicity



Example 4

Adhesion - entropy simplicity



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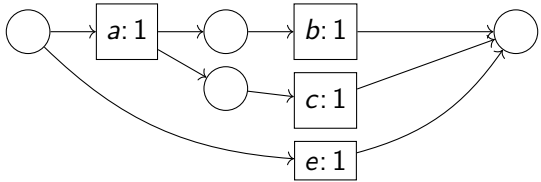
Adhesion - entropy - simplicity



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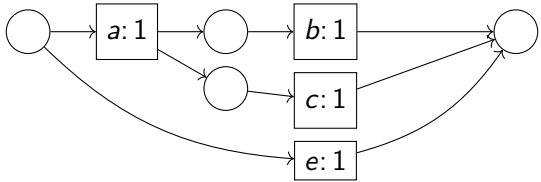
Adhesion - entropy - simplicity $\sim$



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- Largest log 200 000 traces

Conclusion / Future Work

- Three empirically derived dimensions
- Focus on empirical and orthogonality
- Other measures and principles may be *non-orthogonal* but still *useful*, eg recall and precision entropy measures
- Future work
  - Theoretical grounded measures for these dimensions
  - Further tests