Finding Counterexamples Fast
Lessons learned in the ZULU challenge

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Outline

1. A Configurable Inference Framework
2. Continuous Equivalence Queries
3. Results
Generalized Observation Packs

- Combination of observation packs and reduced table
- Realized as combination of discrimination tree and observation table
- New words are sifted into the table
- Allows different strategies to handle counterexamples
Analyzing Counterexamples

- Binary search over counterexample will end in position shown above
- Counterexample contains new suffix and information about which component to split
The set $S \cup SA$ defines a monotonically growing spanning tree of the target automaton.

Usually only local modifications between two equivalence queries (especially for non-uniform sets of distinguishing suffixes).
Continuous Equivalence Queries

- **Select transition:** randomly from set of non-blocked
- **Generate future:** randomly with increasing length. Initially $\max\left\{\frac{\log(n)}{2}, 3\right\}$.
- **Book keeping:**
  - E.H Blocking: transitions excluded from subsequent tests.
  - E.H Weighted: weights on transitions are increased.
- **Termination:** ZULU limit
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<table>
<thead>
<tr>
<th>Algorithm</th>
<th>Dist. Set</th>
<th>Equivalence</th>
<th>Training (Avg.)</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>E.H.Blocking</td>
<td>{ε}</td>
<td>block transitions</td>
<td>89.38</td>
<td>1</td>
</tr>
<tr>
<td>E.H.Weighted Random</td>
<td>no</td>
<td>weight transitions</td>
<td>89.26</td>
<td>2</td>
</tr>
<tr>
<td>Random</td>
<td>no</td>
<td>random walks</td>
<td>88.93</td>
<td>6</td>
</tr>
<tr>
<td>run_random</td>
<td>{ε} ∪ Σ</td>
<td>random walks</td>
<td>80.17</td>
<td>14</td>
</tr>
<tr>
<td>run_blocking1</td>
<td>yes</td>
<td>block transitions</td>
<td>79.89</td>
<td>15</td>
</tr>
<tr>
<td>run_weighted1</td>
<td>yes</td>
<td>weight transitions</td>
<td>79.65</td>
<td>16</td>
</tr>
</tbody>
</table>

- Uniform DFA: ca. 83
- non-uniform Mealy: ca. 85
### Detailed Training Example: Problem 49763507

<table>
<thead>
<tr>
<th>Algorithm</th>
<th>New Membership Queries</th>
<th>Rounds</th>
<th>States</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Close</td>
<td>Analyze</td>
<td>Search</td>
<td></td>
</tr>
<tr>
<td>E.H.Blocking</td>
<td>6,744</td>
<td>358</td>
<td>999</td>
<td>259</td>
</tr>
<tr>
<td>E.H.Weighted</td>
<td>6,717</td>
<td>349</td>
<td>1,035</td>
<td>262</td>
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<tr>
<td>Random</td>
<td>6,586</td>
<td>519</td>
<td>996</td>
<td>228</td>
</tr>
<tr>
<td>run_random</td>
<td>8,080</td>
<td>14</td>
<td>7</td>
<td>5</td>
</tr>
<tr>
<td>run_blocking1</td>
<td>8,074</td>
<td>11</td>
<td>16</td>
<td>6</td>
</tr>
<tr>
<td>run_weighted1</td>
<td>8,077</td>
<td>9</td>
<td>15</td>
<td>6</td>
</tr>
</tbody>
</table>

- **ZULU limit:** 8,101
- **MQs / EQ:** 1-3 (uniform), ca. 3.9 (non-uniform), ca. 4.36 (random)
- **MQS / State:** ca. 25 (uniform), ca. 19 (non-uniform)
- **Random Walks:** higher costs for analyzing counterexamples
Asymptotic Costs per State

A Configurable Inference Framework
Continuous Equivalence Queries
Results
Concluding Remarks

- We built good general frameworks and customized these to reflect ZULU requirements
- Overall strategy: use as few queries per state as possible
  - Non-uniform table
  - Treating counterexamples
  - Evolving hypothesis

Next Steps:
- Find future generators for different classes of systems
- Formulate termination / quality criteria
Regular Extrapolation of Reactive Systems

- applications of active learning
- common benchmarks

- Oct, 17th: RERS Day
- Oct, 19th: Learning Techniques for Software Verification and Validation, hosted by Dimitra Giannakopoulou and Corina Pasareanu (NASA Ames and CMU)
- Early registration still open!