MBD meets Combinatorial Testing for generating an Abductive Diagnosis Model

Ingo Pill, Institute for Software Technology @ TU Graz
joint work with Franz Wotawa

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what to expect?

• what is combinatorial testing?
• why can it help us?
  • where exactly?
• our concept
• are the caveats?
  • questions to solve
testing

„observe and judge whether the system shows the correct behavior for given test scenarios“

“Software testing is an investigation conducted to provide stakeholders with information about the quality of the software product or service under test.”

Kaner, Cem (Nov, 2006). keynote at Quality Assurance Institute Worldwide Annual Software Testing Conference
testing is not exhaustive

input space usually huge

2 inputs with 64 bits each

= $2^{128}$ input combinations

1 ms per test $\rightarrow$ still $1.08 \times 10^{28}$ years
combinatorial testing

be locally exhaustive"
- strength x defines scope

idea: for all variable subsets of size x, *all possible combinations of values* have to appear at least in one test case

example

strength $x=2$

three subsets: $\{i_1, i_2\}$, $\{i_2, i_3\}$, $\{i_3, i_1\}$

<table>
<thead>
<tr>
<th>$i_1$</th>
<th>$i_2$</th>
<th>$i_3$</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>

$\{i_1, i_2\}$ - all 4 combinations ✔
$\{i_2, i_3\}$ - all 4 combinations ✔
$\{i_3, i_1\}$ - all 4 combinations ✔

4 test cases instead of 8
ct: some details

• „Mixed Level Covering Array“ (Def. 4)
  • generate tables for variables with different domains
  • ACTS tool (for free, see also paper https://csrc.nist.gov/projects/automated-combinatorial-testing-for-software)

• strength of $x=6$ seems OK

• usually $x << n$
  • huge reductions possible
    • 6 variables, 2-3 values: 486 $\Rightarrow$ 15 for $x=2$
motivating scenario

- no diagnostic model
  - simulation model available

- DX‘16: create abductive diagnosis model via
  - simulation
  - fault injection
    - compare behavior
    - extract effects

[Abductive Diagnosis Based on Modelica Models, Bernhard Peischl, Ingo Pill, Franz Wotawa, DX’16 Denver, 2016]
DX‘16: simulations for abductive model

activate fault by fault $\rightarrow$ single fault simulations only

which set of faults would lead to observed effects?

iterate over components and their faults

inputs

outputs

compare

extract fault - effect rules

abductive diagnosis model
DX‘16: simulations for abductive model

- exhaustive approach
  - $|\text{Modes}| \times |\text{Components}|$ simulations

- no fault interaction in diagn. model
  - $|\text{Modes}| \times |\text{Components}|$ sim.

exhaustive: 100 components with 5 modes $\Rightarrow 5^{100} = 7.89 \times 10^{69}$ sims
1 ms per sim $\Rightarrow 2.5 \times 10^{59}$ years
DX’17: combinatorial exploration?

```
inputs

correct  mult. faults

outputs

compare

extract fault - effect rules

iterate over MCA

abductive diagnosis model
```
input space for MCA

- fault mode assignments only?
- add parameters
  - e.g. resistor values \( 6k8\pm5\% \)
- inputs
  - behavior scenarios
DX‘17 combinatorial exploration

inputs parameters iterate over MCA

correct mult. faults

outputs compare

extract fault - effect rules

abductive diagnosis model

inputs parameters mode assignments in 1 MCA
combinatorial exploration variant

inputs
parameters
mode assignments
in 1 MCA

and constraints for mode assignments
e.g. $|\Delta| \leq 2$
MCA for some circuit

Table 1: Modeling the input space for the RC circuit.

<table>
<thead>
<tr>
<th>category</th>
<th>variable</th>
<th>alphabet</th>
</tr>
</thead>
<tbody>
<tr>
<td>inputs</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>parameters</td>
<td>( v_B )</td>
<td>4.5V, 5V, 5.5V</td>
</tr>
<tr>
<td></td>
<td>( r )</td>
<td>9k(\Omega), 10k(\Omega), 11k(\Omega)</td>
</tr>
<tr>
<td></td>
<td>( c )</td>
<td>9(\mu F), 10(\mu F), 11(\mu F)</td>
</tr>
<tr>
<td>mode</td>
<td>( B )</td>
<td>ok, empty</td>
</tr>
<tr>
<td>assignments</td>
<td>( R )</td>
<td>ok, short, broken</td>
</tr>
<tr>
<td></td>
<td>( C )</td>
<td>ok, short, broken</td>
</tr>
</tbody>
</table>
Table 2: Scenarios for the RC circuit and strength 2.

<table>
<thead>
<tr>
<th>#</th>
<th>$v_B$</th>
<th>$r$</th>
<th>$c$</th>
<th>$B$</th>
<th>$R$</th>
<th>$C$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4.5V</td>
<td>9kΩ</td>
<td>10 μF</td>
<td>empty</td>
<td>short</td>
<td>short</td>
</tr>
<tr>
<td>2</td>
<td>4.5V</td>
<td>10kΩ</td>
<td>11 μF</td>
<td>ok</td>
<td>broken</td>
<td>broken</td>
</tr>
<tr>
<td>3</td>
<td>4.5V</td>
<td>11kΩ</td>
<td>9 μF</td>
<td>empty</td>
<td>ok</td>
<td>ok</td>
</tr>
<tr>
<td>4</td>
<td>5V</td>
<td>9kΩ</td>
<td>11 μF</td>
<td>ok</td>
<td>ok</td>
<td>short</td>
</tr>
<tr>
<td>5</td>
<td>5V</td>
<td>10kΩ</td>
<td>9 μF</td>
<td>empty</td>
<td>short</td>
<td>broken</td>
</tr>
<tr>
<td>6</td>
<td>5V</td>
<td>11kΩ</td>
<td>10 μF</td>
<td>ok</td>
<td>broken</td>
<td>ok</td>
</tr>
<tr>
<td>7</td>
<td>5.5V</td>
<td>9kΩ</td>
<td>9 μF</td>
<td>empty</td>
<td>broken</td>
<td>short</td>
</tr>
<tr>
<td>8</td>
<td>5.5V</td>
<td>10kΩ</td>
<td>10 μF</td>
<td>ok</td>
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</tr>
<tr>
<td>12</td>
<td>5.5V</td>
<td>10kΩ</td>
<td>11 μF</td>
<td>ok</td>
<td>broken</td>
<td>short</td>
</tr>
<tr>
<td>13</td>
<td>5.5V</td>
<td>11kΩ</td>
<td>11 μF</td>
<td>ok</td>
<td>broken</td>
<td>short</td>
</tr>
<tr>
<td>14</td>
<td>5V</td>
<td>9kΩ</td>
<td>11 μF</td>
<td>empty</td>
<td>broken</td>
<td>broken</td>
</tr>
<tr>
<td>15</td>
<td>4.5V</td>
<td>11kΩ</td>
<td>11 μF</td>
<td>ok</td>
<td>broken</td>
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</tr>
</tbody>
</table>

Table 3: The different scenarios computed for the RC circuit when desiring combinatorial strength 2 and adding a constraint that requires two components to work as expected.

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pros and cons

- automated generation of diagnostic model
- abductive diagnosis model „familiar“
- black box compatible
- with „variant“ control over MCA (constraints)
  - exploration aspects – var. groups, dependencies
- scales with strength
- which parameters to choose (e.g. strength)
- „real“ experiments?
- need empirical results on resulting KB effectiveness
what’s in the paper

- motivation / explanation of combinatorial testing
- new algorithm
  - formal definitions
  - example
- discussion
  - variable treatment
- constraints for MCA
  - mode assignment strength
  - dependencies
- future work
  - experiments, experiments, experiments
thanks

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