

tba

FOSD Meeting 2022 in Vienna | Thomas Thüm | March 31, 2022







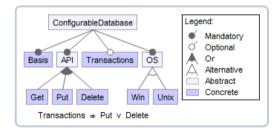
tba: Towards comBinatorial interaction Analysis

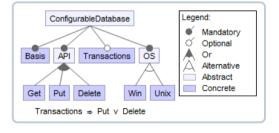




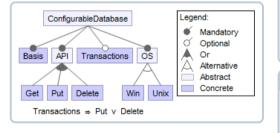
Quality Assurance for Configurable Systems





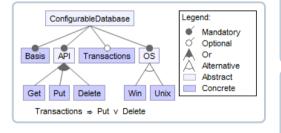


Pairwise Interactions $G \wedge P$ $G \wedge \neg P$ $\neg G \land P$ $\neg G \land \neg P$ $G \wedge D$ $G \wedge \neg D$ $\neg G \wedge D$ $\neg G \land \neg D$ $G \wedge T$ $G \wedge \neg T$ $\neg G \wedge T$ $\neg G \land \neg T$ $G \wedge W$ $\neg G \wedge W$ $\neg G \land \neg W$ $G \wedge \neg W$ $G \wedge U$ $G \wedge \neg U$ $\neg G \wedge U$ $\neg G \land \neg U$ $P \wedge D$ $P \wedge \neg D$ $\neg P \wedge D$ $\neg P \land \neg D$ $P \wedge T$ $\neg P \wedge T$ $\neg P \land \neg T$ $P \wedge \neg T$ $P \wedge W$ $P \wedge \neg W$ $\neg P \wedge W$ $\neg P \land \neg W$ $P \wedge U$ $P \wedge \neg U$ $\neg P \wedge U$ $\neg P \land \neg U$ $D \wedge T$ $D \wedge \neg T$ $\neg D \wedge T$ $\neg D \land \neg T$ $\neg D \land \neg W$ $D \wedge W$ $D \wedge \neg W$ $\neg D \wedge W$ $D \wedge U$ $D \wedge \neg U$ $\neg D \wedge U$ $\neg D \land \neg U$ $T \wedge W$ $T \wedge \neg W$ $\neg T \wedge W \qquad \neg T \wedge \neg W$ $T \wedge II$ $T \wedge \neg H$ $\neg T \wedge H$ $\neg T \land \neg H$ $W \wedge \neg U = \neg W \wedge U$



Pairwise Interactions

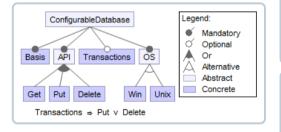
```
{B, P, D, T, W}
{B, G, D, U}
{B, G, P, T, U}
{B, G, W}
{B, P, W}
{B, D, T, U}
```



Pairwise Interactions

```
G \wedge \neg P
                                     \neg G \land P
G \wedge D
                                     \neg G \wedge D
                 G \wedge \neg T
                                     \neg G \wedge T
                                     \neg G \wedge W
                 G \wedge \neg W
G \wedge U
                                                         \neg G \land \neg U
P \wedge D P \wedge \neg D
                                     \neg P \wedge D
P \wedge T
                                                         \neg P \land \neg T
                                                         \neg P \land \neg W
P \wedge W
                 P \wedge \neg U
                                     \neg P \wedge U
D \wedge T
                 D \wedge \neg T
D \wedge W
                 D \wedge \neg W
D \wedge U
                 D \wedge \neg U
T \wedge W
                                                         \neg T \land \neg W
                 T \wedge \neg H
                                     \neg T \wedge H
                 W \wedge \neg U = \neg W \wedge U
```

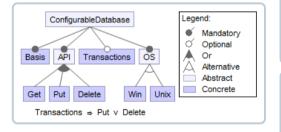
```
{B, P, D, T, W}
{B, G, D, U}
{B, G, P, T, U}
{B, G, W}
{B, P, W}
{B, D, T, U}
```



Pairwise Interactions

```
G \wedge P
                G \wedge \neg P
                                    \neg G \land P
G \wedge D
                G \wedge \neg D
                                    \neg G \wedge D
G \wedge T
                G \wedge \neg T
                                    \neg G \wedge T
                                   \neg G \wedge W
                G \wedge \neg W
G \wedge U = G \wedge \neg U
                                                       \neg G \land \neg U
P \wedge D
                P \wedge \neg D
                                    \neg P \wedge D
P \wedge T
                                                       \neg P \land \neg T
P \wedge W
                P \wedge \neg W
                                                       \neg P \land \neg W
P \wedge U
                P \wedge \neg U
                                    \neg P \wedge U
D \wedge T
                D \wedge \neg T
                                    \neg D \wedge T
                                                       \neg D \land \neg W
D \wedge W
                D \wedge \neg W
D \wedge U
                D \wedge \neg U
                                    \neg D \wedge U
T \wedge W T \wedge \neg W \neg T \wedge W
                                                       \neg T \land \neg W
T \wedge H
                T \wedge \neg H
                                   \neg T \wedge H
                 W \wedge \neg U = \neg W \wedge U
```

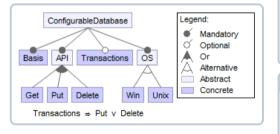
```
 \begin{cases} B, P, D, T, W \\ B, G, D, U \\ B, G, P, T, U \\ B, G, W \\ B, G, W \\ B, D, T, U \end{cases}
```



Pairwise Interactions

```
G \wedge P
                G \wedge \neg P
                                    \neg G \land P
G \wedge D
                G \wedge \neg D
                                    \neg G \wedge D
G \wedge T
                G \wedge \neg T
                                    \neg G \wedge T
G \wedge W
                                   \neg G \wedge W
                G \wedge \neg W
G \wedge U
                G \wedge \neg U
                                                       \neg G \land \neg U
P \wedge D
                P \wedge \neg D
                                    \neg P \wedge D
                                                       \neg P \land \neg D
                                                       \neg P \land \neg T
P \wedge T
                                                       \neg P \land \neg W
P \wedge W
                P \wedge \neg W
                                    \neg P \wedge W
P \wedge U
                P \wedge \neg U
                                    \neg P \wedge U
                                                       \neg P \land \neg U
D \wedge T
                D \wedge \neg T
                                    \neg D \wedge T
                                                       \neg D \land \neg T
                                                       \neg D \land \neg W
D \wedge W
                D \wedge \neg W
                                    \neg D \wedge W
D \wedge U
                D \wedge \neg U
                                    \neg D \wedge U
                                                       \neg D \land \neg U
T \wedge W \qquad T \wedge \neg W
                                   \neg T \wedge W \qquad \neg T \wedge \neg W
T \wedge II
                T \wedge \neg H = \neg T \wedge H
                                                       \neg T \land \neg H
                 W \wedge \neg U = \neg W \wedge U
```

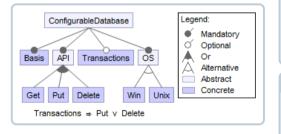
```
 \begin{cases} B, P, D, T, W \\ B, G, D, U \\ B, G, P, T, U \\ B, G, W \\ B, G, W \\ \{B, P, W \} \\ \{B, D, T, U \} \end{cases}
```



Pairwise Interactions

```
G \wedge P
                 G \wedge \neg P
                                    \neg G \land P
G \wedge D
                 G \wedge \neg D
                                    \neg G \wedge D
                                                        \neg G \land \neg D
G \wedge T
                 G \wedge \neg T
                                    \neg G \wedge T
                                                        \neg G \land \neg T
G \wedge W
                                    \neg G \wedge W
                 G \wedge \neg W
G \wedge U
                G \wedge \neg U
                                                       \neg G \land \neg U
P \wedge D
                P \wedge \neg D
                                    \neg P \wedge D
                                                       \neg P \land \neg D
                                                        \neg P \land \neg T
P \wedge T
                 P \wedge \neg T
                                                        \neg P \land \neg W
P \wedge W
                P \wedge \neg W
                                    \neg P \wedge W
P \wedge U
                 P \wedge \neg U
                                    \neg P \wedge U
                                                        \neg P \land \neg U
D \wedge T
                 D \wedge \neg T
                                    \neg D \wedge T
                                                        \neg D \land \neg T
                                                       \neg D \land \neg W
D \wedge W
                D \wedge \neg W
                                    \neg D \wedge W
D \wedge U
                 D \wedge \neg U
                                    \neg D \wedge U \qquad \neg D \wedge \neg U
T \wedge W \qquad T \wedge \neg W
                                    \neg T \wedge W \qquad \neg T \wedge \neg W
T \wedge II
                 T \wedge \neg H = \neg T \wedge H
                                                       \neg T \land \neg H
                 W \wedge \neg U = \neg W \wedge U
```

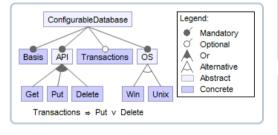
```
{B, P, D, T, W}
{B, G, D, U}
{B, G, P, T, U}
{B, G, W}
{B, P, W}
{B, D, T, U}
```



Pairwise Interactions

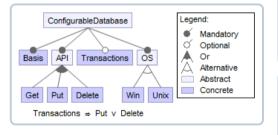
```
G \wedge P
                 G \wedge \neg P
                                    \neg G \land P
                                                        \neg G \land \neg P
G \wedge D
                 G \wedge \neg D
                                    \neg G \wedge D
                                                        \neg G \land \neg D
                                                        \neg G \land \neg T
G \wedge T
                 G \wedge \neg T
                                    \neg G \wedge T
G \wedge W
                                    \neg G \wedge W
                                                        \neg G \land \neg W
                 G \wedge \neg W
G \wedge U
                 G \wedge \neg U
                                    \neg G \wedge U
                                                       \neg G \land \neg U
P \wedge D
                P \wedge \neg D
                                    \neg P \wedge D
                                                       \neg P \land \neg D
                                    \neg P \wedge T
                                                        \neg P \land \neg T
P \wedge T
                 P \wedge \neg T
                                    \neg P \wedge W
                                                        \neg P \land \neg W
P \wedge W
                P \wedge \neg W
P \wedge U
                 P \wedge \neg U
                                    \neg P \wedge U
                                                        \neg P \land \neg U
D \wedge T
                 D \wedge \neg T
                                    \neg D \wedge T
                                                        \neg D \land \neg T
                                                       \neg D \land \neg W
D \wedge W
                D \wedge \neg W
                                    \neg D \wedge W
D \wedge U
                 D \wedge \neg U
                                    \neg D \wedge U \qquad \neg D \wedge \neg U
T \wedge W \qquad T \wedge \neg W
                                    \neg T \wedge W \qquad \neg T \wedge \neg W
T \wedge II
                 T \wedge \neg H \qquad \neg T \wedge H \qquad \neg T \wedge \neg H
                 W \wedge \neg U = \neg W \wedge U
```

```
 \begin{cases} \{B, P, D, T, W\} \\ \{B, G, D, U\} \\ \{B, G, P, T, U\} \\ \{B, G, W\} \\ \{B, P, W\} \\ \{B, D, T, U\} \end{cases}
```



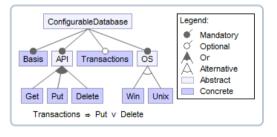
Pairwise Interactions

```
 \begin{cases} \{B,P,D,T,W\} \Rightarrow \text{6 potential interactions} \\ \{B,G,D,U\} \\ \{B,G,P,T,U\} \\ \{B,G,W\} \\ \{B,P,W\} \\ \{B,D,T,U\} \end{cases}
```



Pairwise Interactions

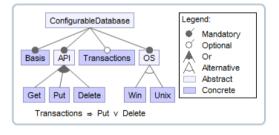
```
 \begin{cases} B,P,D,T,W \rbrace \Rightarrow 6 \text{ potential interactions} \\ \{B,G,D,U \rbrace \Rightarrow 5 \text{ potential interactions} \\ \{B,G,P,T,U \rbrace \\ \{B,G,W \rbrace \\ \{B,D,T,U \rbrace \} \\ \{B,D,T,U \rbrace \}
```



Pairwise Interactions

```
G \wedge P
G \wedge D
G \wedge T
P \wedge D P \wedge \neg D
              P \wedge \neg W
P \wedge U \qquad P \wedge \neg U
              D \wedge \neg T
                                \neg D \wedge T
                                                  \neg D \land \neg W
D \wedge W D \wedge \neg W \neg D \wedge W
               D \wedge \neg U
                                 \neg D \wedge U
T \wedge W T \wedge \neg W \neg T \wedge W \neg T \wedge \neg W
              T \wedge \neg U
                                 \neg T \wedge U
               W \wedge \neg U
                                \neg W \wedge U
```

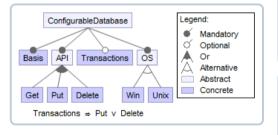
```
 \begin{cases} \{B,P,D,T,W\} \Rightarrow 6 \text{ potential interactions} \\ \{B,G,D,U\} \Rightarrow 5 \text{ potential interactions} \\ \{B,G,P,T,U\} \Rightarrow 7 \text{ potential interactions} \\ \{B,G,W\} \\ \{B,P,W\} \\ \{B,D,T,U\} \end{cases}
```



Pairwise Interactions

```
G \wedge P
G \wedge D
G \wedge T
G \wedge W
               G \wedge \neg U
P \wedge D P \wedge \neg D
                                                    \neg P \land \neg D
               P \wedge \neg W
                                  \neg P \wedge W
P \wedge U \qquad P \wedge \neg U
                                                    \neg P \land \neg U
               D \wedge \neg T
                                  \neg D \wedge T
D \wedge W D \wedge \neg W \neg D \wedge W
                                                    \neg D \land \neg W
               D \wedge \neg U
                                  \neg D \wedge U
T \wedge W T \wedge \neg W \neg T \wedge W
                                                    \neg T \land \neg W
               T \wedge \neg U
                                  \neg T \wedge U
                W \wedge \neg U
                                  \neg W \wedge U
```

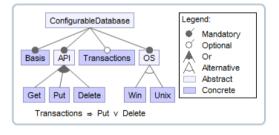
```
 \begin{cases} B,P,D,T,W \rbrace \Rightarrow 6 \text{ potential interactions} \\ \{B,G,D,U \rbrace \Rightarrow 5 \text{ potential interactions} \\ \{B,G,P,T,U \rbrace \Rightarrow 7 \text{ potential interactions} \\ \{B,G,W \rbrace \Rightarrow 5 \text{ potential interactions} \\ \{B,P,W \rbrace \\ \{B,D,T,U \}
```



Pairwise Interactions

G \ P G \ D G \ T G \ W P \ D P \ T P \ W P \ U D \ T W D \ U T \ W	$\begin{array}{c} G \wedge \neg P \\ G \wedge \neg D \\ G \wedge \neg T \\ G \wedge \neg W \\ G \wedge \neg W \\ P \wedge \neg D \\ P \wedge \neg T \\ P \wedge \neg W \\ P \wedge \neg U \\ D \wedge \neg T \\ D \wedge \neg W \\ D \wedge \neg U \\ T \wedge \neg W \\ T \wedge \neg U \\ W \wedge \neg U \\ \end{array}$	$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	$ \begin{array}{cccccccccccccccccccccccccccccccccccc$
--	---	---	---

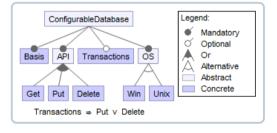
```
 \begin{array}{l} \{B,P,D,T,W\} \Rightarrow 6 \text{ potential interactions} \\ \{B,G,D,U\} \Rightarrow 5 \text{ potential interactions} \\ \{B,G,P,T,U\} \Rightarrow 7 \text{ potential interactions} \\ \{B,G,W\} \Rightarrow 5 \text{ potential interactions} \\ \{B,P,W\} \Rightarrow 3 \text{ potential interactions} \\ \{B,D,T,U\} \end{array}
```



Pairwise Interactions

G \ P G \ D G \ T G \ W G \ U P \ D P \ T P \ W P \ U D \ T D \ W D \ U T \ W	$\begin{array}{c} G \wedge \neg P \\ G \wedge \neg D \\ G \wedge \neg T \\ G \wedge \neg W \\ G \wedge \neg U \\ P \wedge \neg D \\ P \wedge \neg T \\ P \wedge \neg W \\ P \wedge \neg U \\ D \wedge \neg T \\ D \wedge \neg W \\ D \wedge \neg U \\ T \wedge \neg W \\ T \wedge \neg U \\ W \wedge \neg U \\ \end{array}$	$\begin{array}{c} \neg G \wedge P \\ \neg G \wedge D \\ \neg G \wedge W \\ \neg G \wedge W \\ \neg P \wedge T \\ \neg P \wedge W \\ \neg P \wedge V \\ \neg D \wedge U \\ \neg D \wedge V \\ \neg D \wedge U \\ \neg T \wedge W \\ \neg T \wedge W \\ \neg W \wedge U \end{array}$	$ \begin{array}{cccccccccccccccccccccccccccccccccccc$
---	---	--	---

```
 \begin{array}{l} \{B,P,D,T,W\} \Rightarrow 6 \text{ potential interactions} \\ \{B,G,D,U\} \Rightarrow 5 \text{ potential interactions} \\ \{B,G,P,T,U\} \Rightarrow 7 \text{ potential interactions} \\ \{B,G,W\} \Rightarrow 5 \text{ potential interactions} \\ \{B,P,W\} \Rightarrow 3 \text{ potential interactions} \\ \{B,D,T,U\} \Rightarrow 4 \text{ potential interactions} \end{array}
```



Pairwise Interactions

```
G \wedge P
                G \wedge \neg P
                                    \neg G \wedge P
                                                       \neg G \land \neg P
G \wedge D
                                   \neg G \wedge D
                                                       \neg G \land \neg D
                G \wedge \neg D
G \wedge T
                                                       \neg G \land \neg T
                G \wedge \neg T
                                   \neg G \wedge T
G \wedge W
                G \wedge \neg W
                                   \neg G \wedge W
                                                       \neg G \land \neg W
G \wedge U
                G \wedge \neg U
                                    \neg G \wedge U
                                                      \neg G \land \neg U
P \wedge D P \wedge \neg D \neg P \wedge D
                                                      \neg P \land \neg D
P \wedge T P \wedge \neg T
                                   \neg P \wedge T
                                                      \neg P \land \neg T
P \wedge W
                P \wedge \neg W
                                    \neg P \wedge W
                                                      \neg P \land \neg W
P \wedge II
                P \wedge \neg II \qquad \neg P \wedge II
                                                   \neg P \land \neg H
D \wedge T
                D \wedge \neg T \qquad \neg D \wedge T \qquad \neg D \wedge \neg T
D \wedge W
                D \wedge \neg W \qquad \neg D \wedge W \qquad \neg D \wedge \neg W
D \wedge H
                D \wedge \neg U = \neg D \wedge U = \neg D \wedge \neg U
T \wedge W T \wedge \neg W \neg T \wedge W \neg T \wedge \neg W
T \wedge U \qquad T \wedge \neg U \qquad \neg T \wedge U
                                                      \neg T \land \neg U
                W \wedge \neg H = \neg W \wedge H
```

Potential Pairwise Interactions

```
 \begin{array}{l} \{B,P,D,T,W\} \Rightarrow 6 \text{ potential interactions} \\ \{B,G,D,U\} \Rightarrow 5 \text{ potential interactions} \\ \{B,G,P,T,U\} \Rightarrow 7 \text{ potential interactions} \\ \{B,G,W\} \Rightarrow 5 \text{ potential interactions} \\ \{B,P,W\} \Rightarrow 3 \text{ potential interactions} \\ \{B,D,T,U\} \Rightarrow 4 \text{ potential interactions} \end{array}
```

28 interactions occur in more than one configuration

Phase 1

- Caused by a single feature? (feature-wise)
- If no: Caused by a pairwise interaction
- If no: Caused by a 3-wise interaction?
- ...

Result

set of potential feature interactions (or single features)

Faulty Features

```
 \begin{cases} B, P, D, T, W \\ \{B, G, D, U \} \\ \{B, G, P, T, U \} \\ \{B, G, W \} \\ \{B, P, W \} \\ \{B, D, T, U \} \end{cases}
```

Phase 1

- Caused by a single feature? (feature-wise)
- If no: Caused by a pairwise interaction
- If no: Caused by a 3-wise interaction?
- ...

Result

set of potential feature interactions (or single features)

Faulty Features

```
G ¬G ¬P ¬P ¬D ¬D ¬T ¬T W ¬W ¬W ∪
```

```
 \begin{cases} \{B, P, D, T, W\} \\ \{B, G, D, U\} \\ \{B, G, P, T, U\} \\ \{B, G, W\} \\ \{B, P, W\} \\ \{B, D, T, U\} \end{cases}
```

Phase 1

- Caused by a single feature? (feature-wise)
- If no: Caused by a pairwise interaction
- If no: Caused by a 3-wise interaction?
- ...

Result

set of potential feature interactions (or single features)

Faulty Features

```
G ¬G
P ¬P
D ¬D
T ¬T
W ¬W
U ¬U
```

```
 \begin{cases} B, P, D, T, W \\ \{B, G, D, U \} \\ \{B, G, P, T, U \} \\ \{B, G, W \} \\ \{B, P, W \} \\ \{B, D, T, U \} \end{cases}
```

Phase 1

- Caused by a single feature? (feature-wise)
- If no: Caused by a pairwise interaction
- If no: Caused by a 3-wise interaction?
- ...

Result

set of potential feature interactions (or single features)

Faulty Features

```
 \begin{cases} B, P, D, T, W \\ \{B, G, D, U \} \\ \{B, G, P, T, U \} \\ \{B, G, W \} \\ \{B, P, W \} \\ \{B, D, T, U \} \end{cases}
```

Phase 1

- Caused by a single feature? (feature-wise)
- If no: Caused by a pairwise interaction
- If no: Caused by a 3-wise interaction?
- ...

Result

set of potential feature interactions (or single features)

Applicability

t-wise sample, uniform sample, user-defined configurations, configurations in the field, . . .

Faulty Features

```
 \begin{cases} B, P, D, T, W \\ \{B, G, D, U \} \\ \{B, G, P, T, U \} \\ \{B, G, W \} \\ \{B, P, W \} \\ \{B, D, T, U \} \end{cases}
```

Phase 2

- Divide-and-conquer strategy / binary search
- Compute configuration containing half of the potential interactions
- Continue until feature interaction is isolated

Result

one potential feature interaction (or single feature)

Pairwise Interactions

```
\{B, G, W\}
\{B, D, W\}
\{B, G, U\}
```

Phase 2

- Divide-and-conquer strategy / binary search
- Compute configuration containing half of the potential interactions
- Continue until feature interaction is isolated

Result

one potential feature interaction (or single feature)

Pairwise Interactions

```
 \begin{cases} B,\,G,\,W \rbrace \Rightarrow \text{failure} \Rightarrow \text{5 potential interactions} \\ \{B,\,D,\,W \rbrace \\ \{B,\,G,\,U \} \end{cases}
```

Phase 2

- Divide-and-conquer strategy / binary search
- Compute configuration containing half of the potential interactions
- Continue until feature interaction is isolated

Result

one potential feature interaction (or single feature)

Pairwise Interactions

```
\{B, G, W\} \Rightarrow \text{failure} \Rightarrow 5 \text{ potential interactions} 
\{B, D, W\} 
\{B, G, U\}
```

Phase 2

- Divide-and-conquer strategy / binary search
- Compute configuration containing half of the potential interactions
- Continue until feature interaction is isolated

Result

one potential feature interaction (or single feature)

Pairwise Interactions

```
\{B, G, W\} \Rightarrow \text{failure} \Rightarrow 5 \text{ potential interactions}
\{B, D, W\} \Rightarrow \text{no failure} \Rightarrow 3 \text{ potential interactions}
\{B, G, U\}
```

Phase 2

- Divide-and-conquer strategy / binary search
- Compute configuration containing half of the potential interactions
- Continue until feature interaction is isolated

Result

one potential feature interaction (or single feature)

Pairwise Interactions

```
\{B, G, W\} \Rightarrow \text{failure} \Rightarrow 5 \text{ potential interactions} 
\{B, D, W\} \Rightarrow \text{no failure} \Rightarrow 3 \text{ potential interactions} 
\{B, G, U\}
```

Phase 2

- Divide-and-conquer strategy / binary search
- Compute configuration containing half of the potential interactions
- Continue until feature interaction is isolated

Result

one potential feature interaction (or single feature)

Pairwise Interactions

```
\{B, G, W\} \Rightarrow \text{failure} \Rightarrow 5 \text{ potential interactions}
\{B, D, W\} \Rightarrow \text{no failure} \Rightarrow 3 \text{ potential interactions}
\{B, G, U\} \Rightarrow \text{failure} \Rightarrow 1 \text{ isolated interaction}
```

Phase 2

- Divide-and-conquer strategy / binary search
- Compute configuration containing half of the potential interactions
- Continue until feature interaction is isolated

Result

one potential feature interaction (or single feature)

Pairwise Interactions

Isolating Pairwise Interactions

```
\{B,G,W\}\Rightarrow \text{failure}\Rightarrow 5 \text{ potential interactions}
```

 $\{B, D, W\} \Rightarrow$ no failure \Rightarrow 3 potential interactions

6+2 configurations tested, pairwise feature interaction isolated

Phase 2

- Divide-and-conquer strategy / binary search
- Compute configuration containing half of the potential interactions
- Continue until feature interaction is isolated

Result

one potential feature interaction (or single feature)

Applicability

if new configurations can be generated + tested

Pairwise Interactions

$G \wedge P$	$G \wedge \neg P$	$\neg G \land P$	$\neg G \land \neg P$
$G \wedge D$		$\neg G \land D$	
$G \wedge T$	$G \wedge \neg T$	$\neg G \wedge T$	$\neg G \land \neg T$
$G \wedge W$	$G \wedge \neg W$	$\neg G \wedge W$	$\neg G \land \neg W$
$G \wedge U$			
$P \wedge D$	$P \wedge \neg D$	$\neg P \wedge D$	$\neg P \wedge \neg D$
$P \wedge T$	$P \wedge \neg T$	$\neg P \wedge T$	$\neg P \land \neg T$
$P \wedge W$	$P \wedge \neg W$	$\neg P \wedge W$	$\neg P \land \neg W$
$P \wedge U$	$P \wedge \neg U$	$\neg P \wedge U$	$\neg P \land \neg U$
$D \wedge T$	$D \wedge \neg T$	$\neg D \wedge T$	$\neg D \land \neg T$
$D \wedge W$	$D \wedge \neg W$	$\neg D \wedge W$	$\neg D \land \neg W$
$D \wedge U$			
$T \wedge W$	$T \wedge \neg W$	$\neg T \wedge W$	$\neg T \wedge \neg W$
$T \wedge U$	$T \wedge \neg U$	$\neg T \wedge U$	$\neg T \wedge \neg U$
	$W \wedge \neg U$	$\neg W \wedge U$	

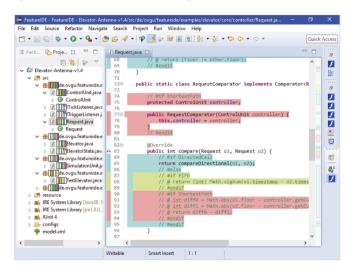
Isolating Pairwise Interactions

```
\{B, G, W\} \Rightarrow failure \Rightarrow 5 potential interactions
```

 $\{B, G, U\} \Rightarrow \text{failure} \Rightarrow 1 \text{ isolated interaction}$

6+2 configurations tested, pairwise feature interaction isolated

How To Adapt to the Solution Space?



Combinatorial Interaction Analysis – Research Questions

How many configurations are needed for isolation?

How fast is the generation?

Can we give guarantees by construction?

How to handle sporadic/flaky tests? Linux STENT_DIMA_SIZE BUK_DEV_INITED STOP_MACHINE X86_POPAO_DK TEXTSEARCH_FSM CONSTRUCTORS MFD_TMIO SCLP_PT20_TTY XFS_FS X86_64_SMP SERIAL_M32R_SIO DMI SS8_POHOST SYNC ARCH_HAVE_ME IDEDMA BLK DEV CS5520 BLK DEV IT8213 BLK DEV BUDDHA BLK DEV IDEPCI. BLK DEV GAYLE IDE H8300 BLK DEV GALDE BLK DEV GALDE BLK DEV SELLEB BLK DEV DETAPE BLK DEV BLK DEV CS553 VT220_TTY XFS_FS X86_64_SMP DEX NET CLS BASIC NET CLS FLOW NET CLS PW NET EMATCH NET SCH MULTID NET SCH GRED NET CLS U32 NET CLS GSVP NET SCH TRE M CLS NET SCH DSMARK NET SCH WIMAX DEBU 8753 SND SOC AK4104 SND SOC WM8750 SND PXA2XX SOC IMOTE2 SND 8F5XX TDM SND SOC C54270 SND SOC ALL CODECS SND SOC ZYLONITE SND SOC TPA6130A2 SND SOC TLY320A DELTA SND BLK DEV JMICRON BLK DEV OF AFFRSOR SND 4732 SDC PLAYPAG SND 47MF SDC SSC SND 4791 SDC 550 SND 4792 SDC 4073311 SND 8F5xx SDC 4073311 S DEC CONEXANT THE PANEL LOD WIDTHE PANEL LOD HAVIDTHE PSS ROOT FILE TRIX BROTT FILE SCREEN CHROMBASE SCREEN LOTY SCREEN CORD SAND RESKY BESET ORD NIME SAND ATTRESTOR PLAYPAD SLAVE SAVE DEFAULT | SN RSVP NET_SCH_TBF N PANEL LCD PIN RS PANEL LCD PIN RW PANEL LCD PIN SDA PANEL LCD PIN SCL PANEL LCD PIN E

Slide Overview

Quality Assurance for Configurable Systems
Pairwise Interaction Testing
Pairwise Interaction Analysis
Combinatorial Interaction Analysis: Phase 1
Combinatorial Interaction Analysis: Phase 2
How To Adapt to the Solution Space?
Combinatorial Interaction Analysis – Research Questions