Motivation

Atlee, Fahrenberg, Legay

Measuring Behaviour Interactions between Product-Line Features
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Motivation

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Featured Transition Systems

**Definition**

A transition system (TS) \( S = (S, \Sigma, I, T) \) consists of a set of states \( S \), a set of initial states \( I \subseteq S \), a set of actions \( \Sigma \), and a set of transitions \( T \subseteq S \times \Sigma \times S \).

**Definition**

A featured transition system (FTS) \( F = (S, \Sigma, I, T, \gamma) \) consists of a TS \((S, \Sigma, I, T)\) and a mapping \( \gamma : T \rightarrow B(N) \).

- \( N \): set of features
  - (usually comes with a feature diagram, but we’ll ignore this)
- any subset \( p \subseteq N \): a product
- \( B(N) \): set of feature expressions
  - used to compactly specify sets of products
Definition (Shaker, Atlee: SPLC 2014)

Given an FTS \( \mathcal{F} \), a product \( p \subseteq N \), and a feature \( f \in N \), we say that \( f \) has a behaviour interaction with \( p \) if \( \pi^p(\mathcal{F}) \) and \( \pi^p(\pi^{p\oplus f}(\mathcal{F})) \) are not bisimilar.

- \( \pi^p(\mathcal{F}) \): projection of \( \mathcal{F} \) to product \( p \)
  - delete all transitions which are not enabled with \( p \)
- similarly for \( \pi^{p\oplus f}(\mathcal{F}) \): projection to \( p \) plus \( f \)
Example

\[ \pi^B(\mathcal{F}) \]

\[ \pi^{B \oplus R}(\mathcal{F}) \]

\[ \pi^B(\pi^{B \oplus R}(\mathcal{F})) \]

not bisimilar
Calculate behavioural distance $d(S, S')$ between $TS S = (S, \Sigma, I, T)$ and $S' = (S', \Sigma, I', T')$:

1: var Passed $\leftarrow \emptyset$
2: return $\max_{i \in I} \min_{i' \in I'}$ dist$(i, i')$

3: function dist$(s, s')$
4: Add $(s, s')$ to Passed
5: var $m \leftarrow \infty$, $d \leftarrow 0$
6: for all $s \xrightarrow{a} t$ do
7: if $s' \not\xrightarrow{a}$ then $d \leftarrow d + 1$
8: else
9: for all $s' \xrightarrow{a} t'$ do
10: if $(t, t') \notin$ Passed then $m \leftarrow \min(m, \text{dist}(t, t'))$
11: else $m \leftarrow 0$
12: $d \leftarrow d + m$
13: return $d$

Definition

Given an FTS $\mathcal{F}$, a product $p \subseteq N$, and a feature $f \in N$, the behaviour interaction score of $f$ with $p$ is $d(\pi^p(\mathcal{F}), \pi^p(\pi^p \oplus f(\mathcal{F})))$. 
Example

\[ \pi^M(\mathcal{F}) \]

\[ \pi^{M \oplus R}(\mathcal{F}) \]

\[ \pi^M(\pi^{M \oplus R}(\mathcal{F})) \]

behaviour interaction score: 2
Computing All Scores at Once

Calculate behaviour interaction score \( D_f(\mathcal{F}) \) of feature \( f \) in FTS
\( \mathcal{F} = (S, \Sigma, I, T, \gamma) \):

1: var max ← |T|
2: var \( D : \{0, \ldots, \text{max}\} \rightarrow \mathbb{B}(N) \)
3: var Passed : \( S \times S \rightarrow \mathbb{B}(N) \)
4: for \( n \leftarrow 0 \) to max do
5:  for all \( s, s' \in S \) do
6:     Passed\((s, s')\) ← ff
7:     \( D(n) = \bigwedge_{i \in I} \bigvee_{i' \in I'} \text{fdist}(n, i, i', \text{tt}) \)
8: return \( D \)

9: function \( \text{fdist}(n, s, s', \phi) \)
10: var \( d : \mathbb{B}(N) \)
11: Passed\((s, s')\) ← \( Passed(s, s') \lor \phi \)
12: \( d \leftarrow \text{ff} \)
13: for \( k \leftarrow 0 \) to \( n \) do
14: \( d \leftarrow d \lor \text{upd}(n, s, s', k) \)
15: return \( d \)

\( \text{upd}(n, s, s', k) \leftarrow \bigvee \bigwedge_{T_1 \subseteq \{s \xrightarrow{a} t\}} \bigwedge_{s \xrightarrow{a} t \in T_1} \bigwedge_{\{|s \xrightarrow{a} t\} \setminus T_1| = k} \bigwedge_{\{s \xrightarrow{a} t\} \setminus T_1 = k} \bigwedge_{s' \xrightarrow{a} t'} \gamma(s \xrightarrow{a} t) \Rightarrow \bigvee (\gamma(s' \xrightarrow{a} t') \land (\text{Passed}(t, t') \lor \text{fdist}(n - k, t, t', \gamma(s \xrightarrow{a} t) \land \gamma(s' \xrightarrow{a} t'))))) \)
Example
Example

Motivation

FTS

Interactions

Score

Computation

Conclusion

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0

1

2

3

4

5

¬R

[M ∧ ¬R]

rec [R]

card! [¬R]

more [M ∧ ¬R]
Example

b.i.s. 0: \(\neg B\)  
b.i.s. 1: \(\neg M\)  
b.i.s. 2: \(tt\)
Conclusion

- **behaviour interaction score**: degree to which features within a software product line interact with each other
  - a type of (bi)simulation distance
- algorithm to compute, *in a single run*, behaviour interaction scores between a feature $f$ and all products
- useful as an indicator of the relative amount of work needed to integrate a feature into the products of a product line

**Future work**:
- distinguish between *intended* and *unintended* behaviour interactions
- implement algorithm
  - also to show *where* behaviour interactions occur