Measuring Behaviour Interactions between Product-Line Features

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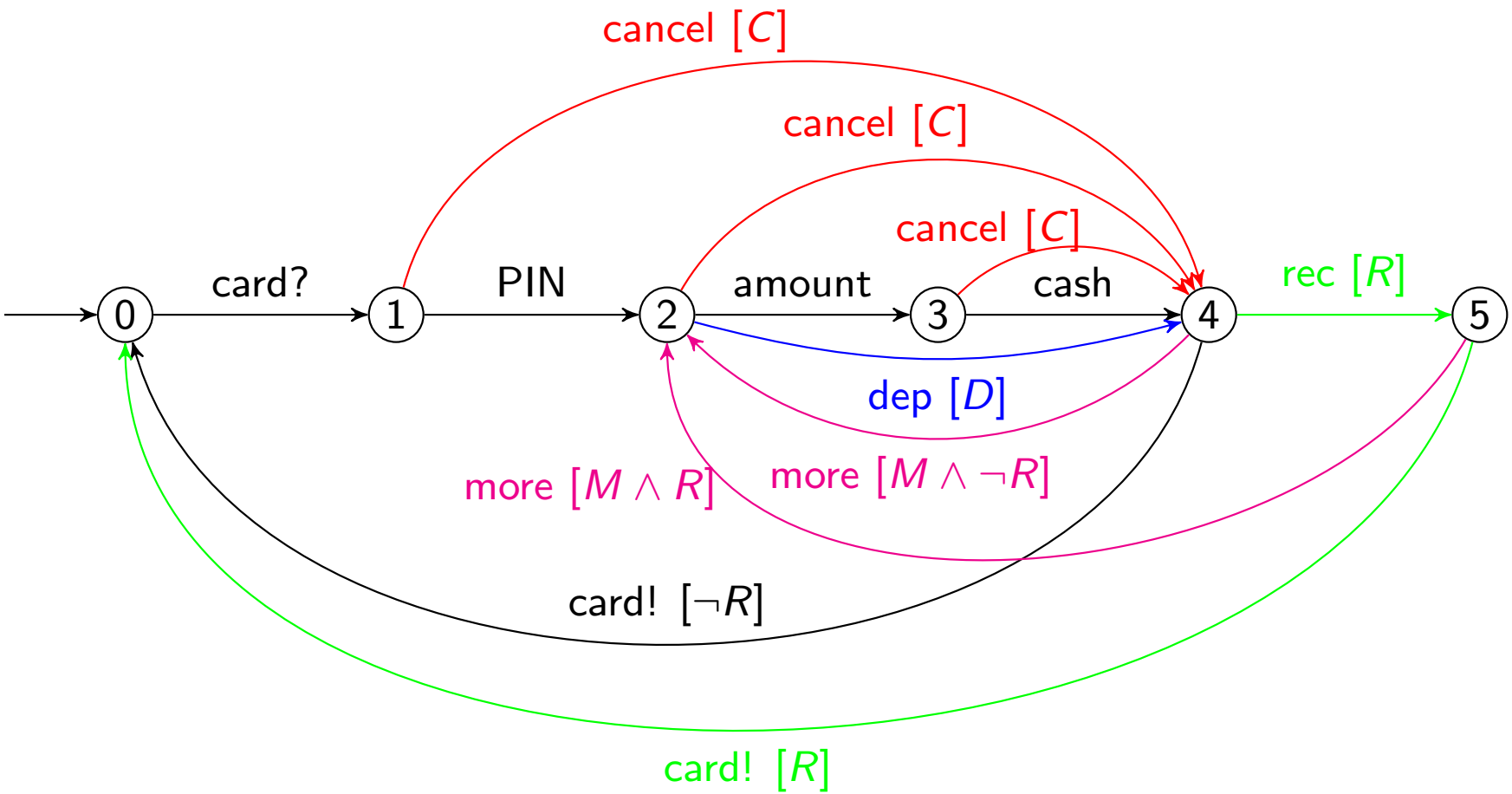
Motivation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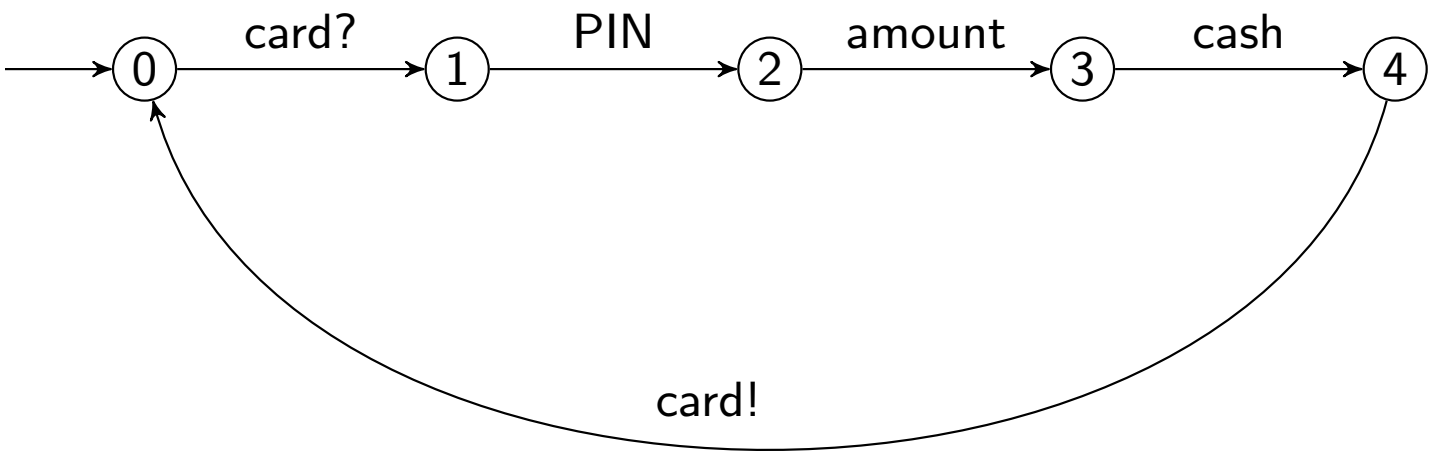

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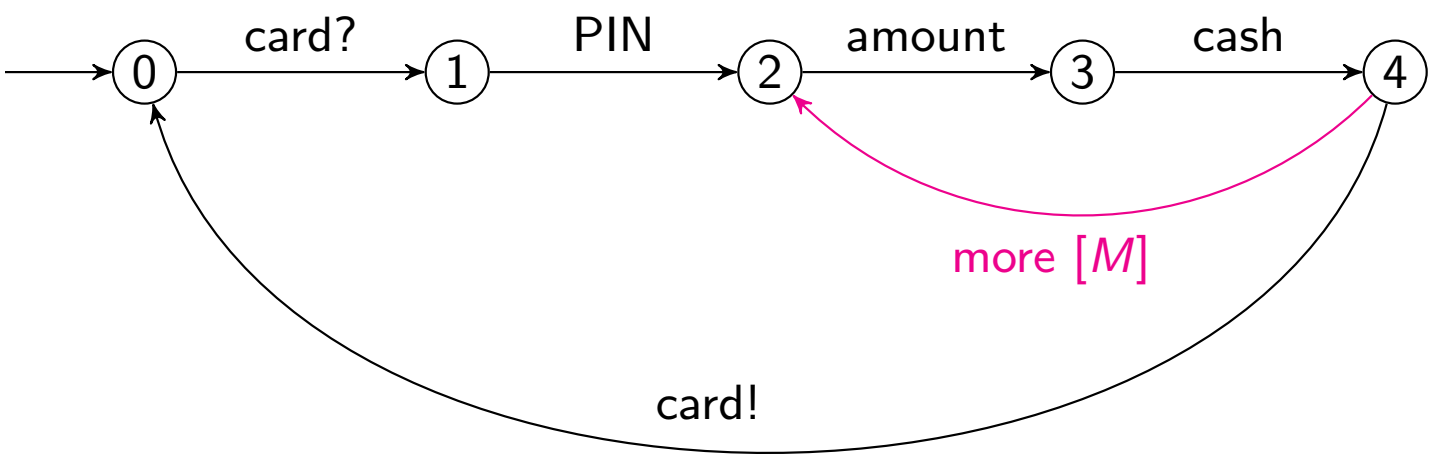

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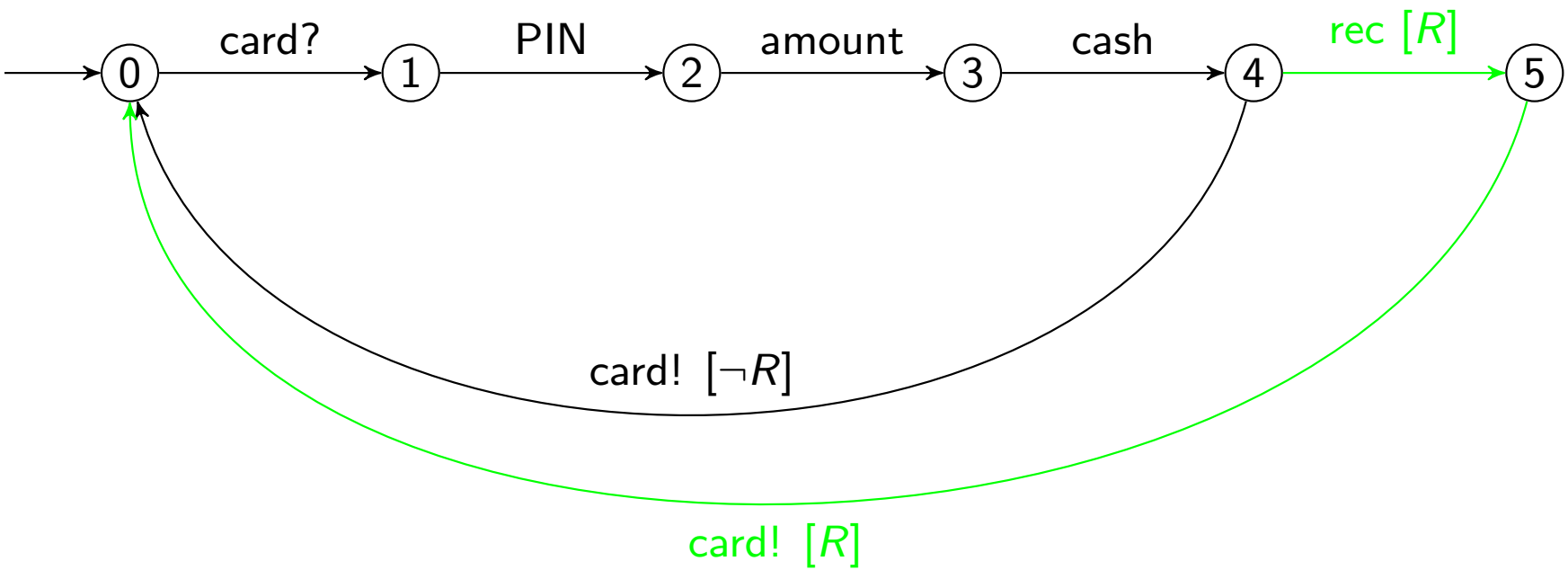

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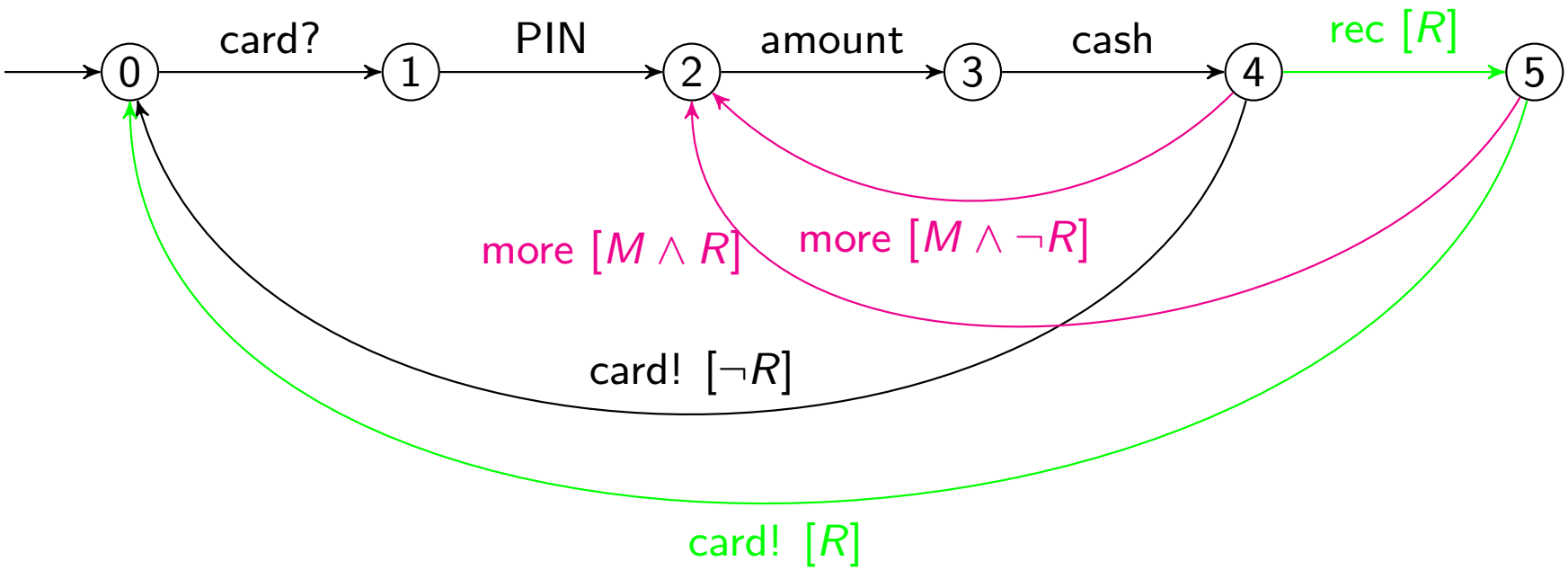


Featured Transition Systems

Definition

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

Definition

A featured transition system (FTS) $\mathcal{F} = (S, \Sigma, I, T, \gamma)$ consists of a TS (S, Σ, I, T) and a mapping $\gamma : T \to \mathbb{B}(N)$.

- N: set of features
  - (usually comes with a feature diagram, but we'll ignore this)
- any subset $p \subseteq N$: a product
- $\mathbb{B}(N)$: set of feature expressions
  - used to compactly specify sets of products

Behaviour Interactions

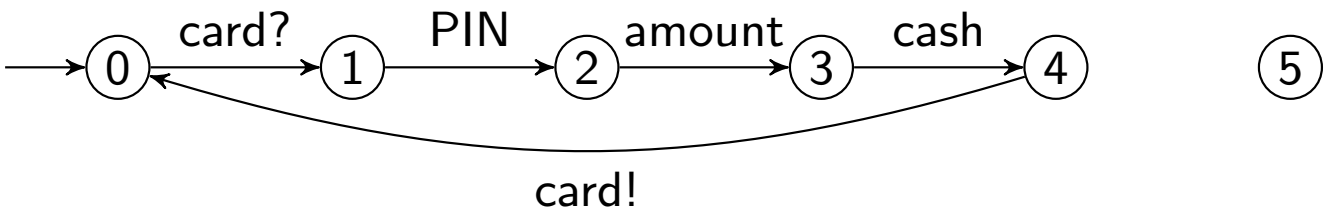
Definition (Shaker, Atlee: SPLC 2014)

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.

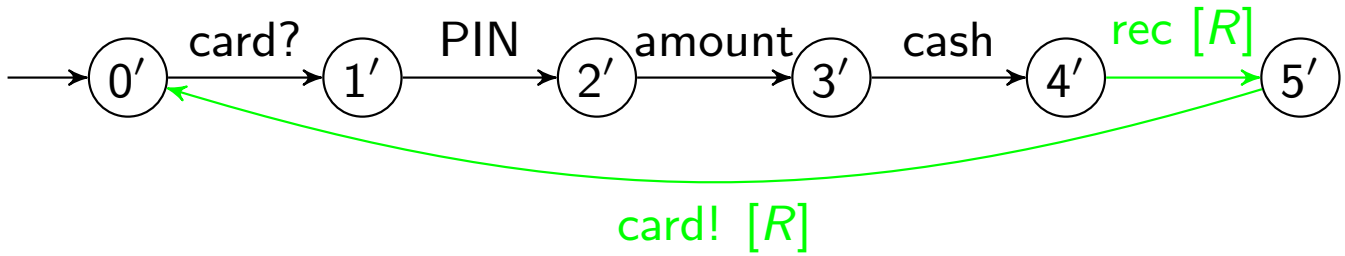
- $\pi^p(\mathcal{F})$: projection of $\mathcal{F}$ to product p
  - delete all transitions which are not enabled with p
- similarly for $\pi^{p \oplus f}(\mathcal{F})$: projection to p plus f

Example

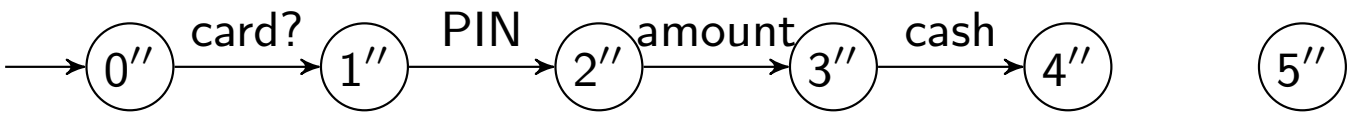
$\pi^B(\mathcal{F})$



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



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



not bisimilar

Behavioural Distance

Calculate behavioural distance $d(\mathcal{S}, \mathcal{S}')$ between TS $\mathcal{S} = (S, \Sigma, I, T)$ and $\mathcal{S}' = (S', \Sigma, I', T')$:

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

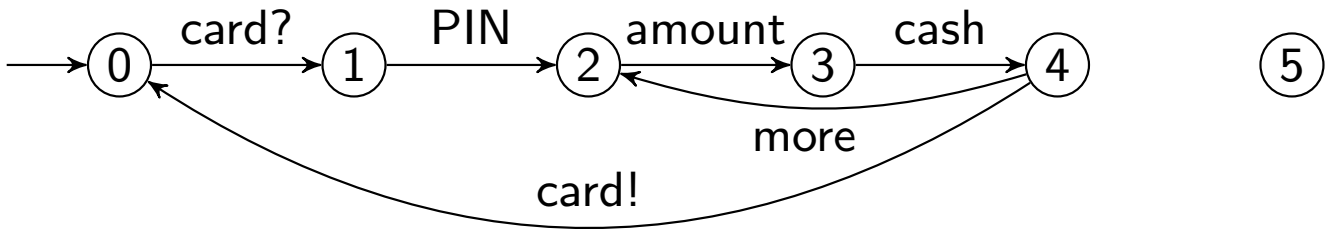
3: **function** $dist(s, s')$
4: Add (s, s') to $Passed$
5: var $m \leftarrow \infty$, $d \leftarrow 0$
6: **for all** $s \xrightarrow{a} t$ **do**
7: **if** $s' \not\xrightarrow{a}$ **then** $d \leftarrow d + 1$
8: **else**
9: **for all** $s' \xrightarrow{a} t'$ **do**
10: **if** $(t, t') \notin Passed$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

Definition

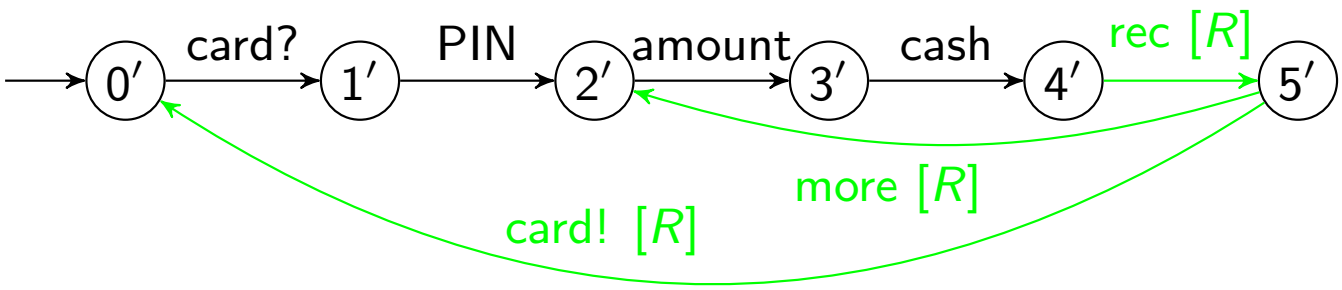
Given an FTS $\mathcal{F}$, a product $p \subseteq N$, and a feature $f \in N$, the behaviour interaction score of f with p is $d(\pi^p(\mathcal{F}), \pi^p(\pi^{p \oplus f}(\mathcal{F}))$.

Example

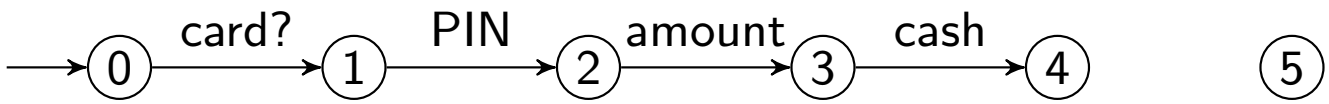
$\pi^{M}(\mathcal{F})$



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



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



behaviour interaction score: 2

Computing All Scores at Once

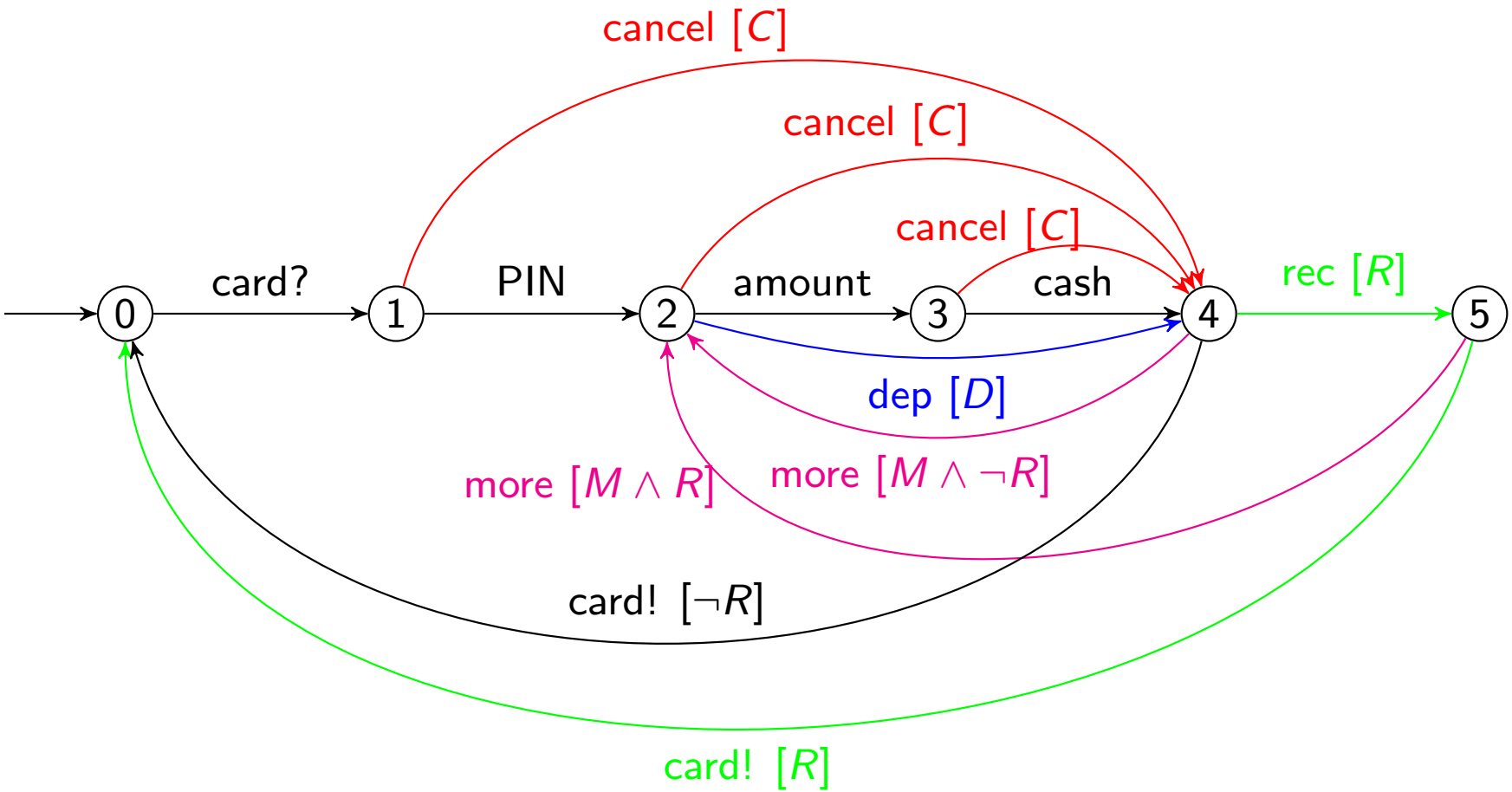
Calculate behaviour interaction score $D_f(\mathcal{F})$ of feature f in FTS $\mathcal{F} = (S, \Sigma, I, T, \gamma)$:

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

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

$$upd(n, s, s', k) \leftarrow \bigvee_{\substack{T_1 \subseteq \{s \xrightarrow{a} t\} \\ |\{s \xrightarrow{a} t\} \setminus T_1| = k}} \bigwedge_{s \xrightarrow{a} t \in T_1} \Big(\gamma(s \xrightarrow{a} t) \Rightarrow \bigvee_{s' \xrightarrow{a} t'} \big(\gamma(s' \xrightarrow{a} t') \wedge f \wedge (Passed(t, t') \vee fdist(n - k, t, t', \gamma(s \xrightarrow{a} t) \wedge \gamma(s' \xrightarrow{a} t')) \big) \Big)$$

Example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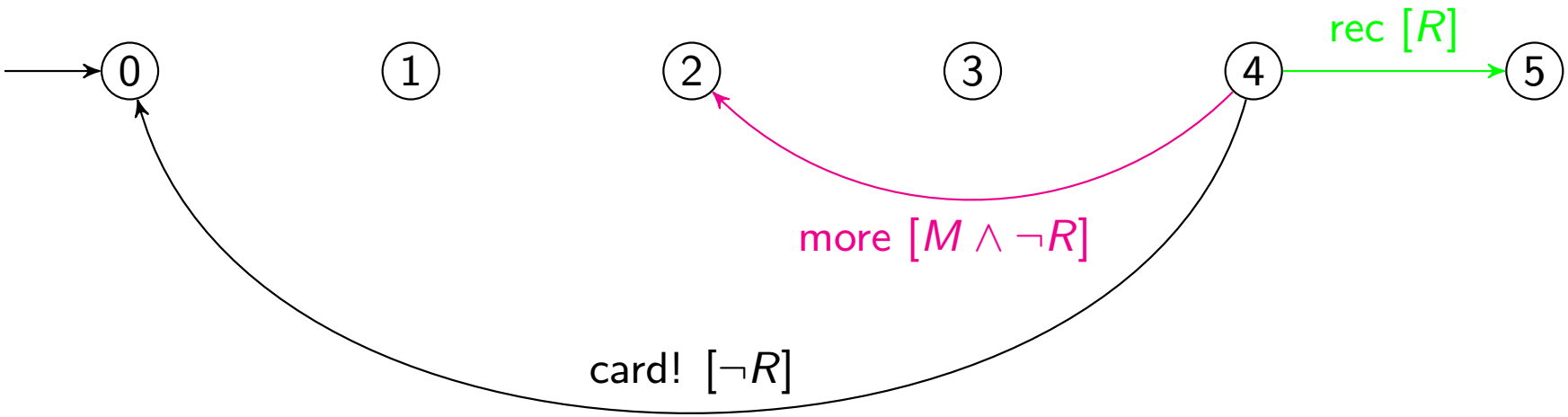

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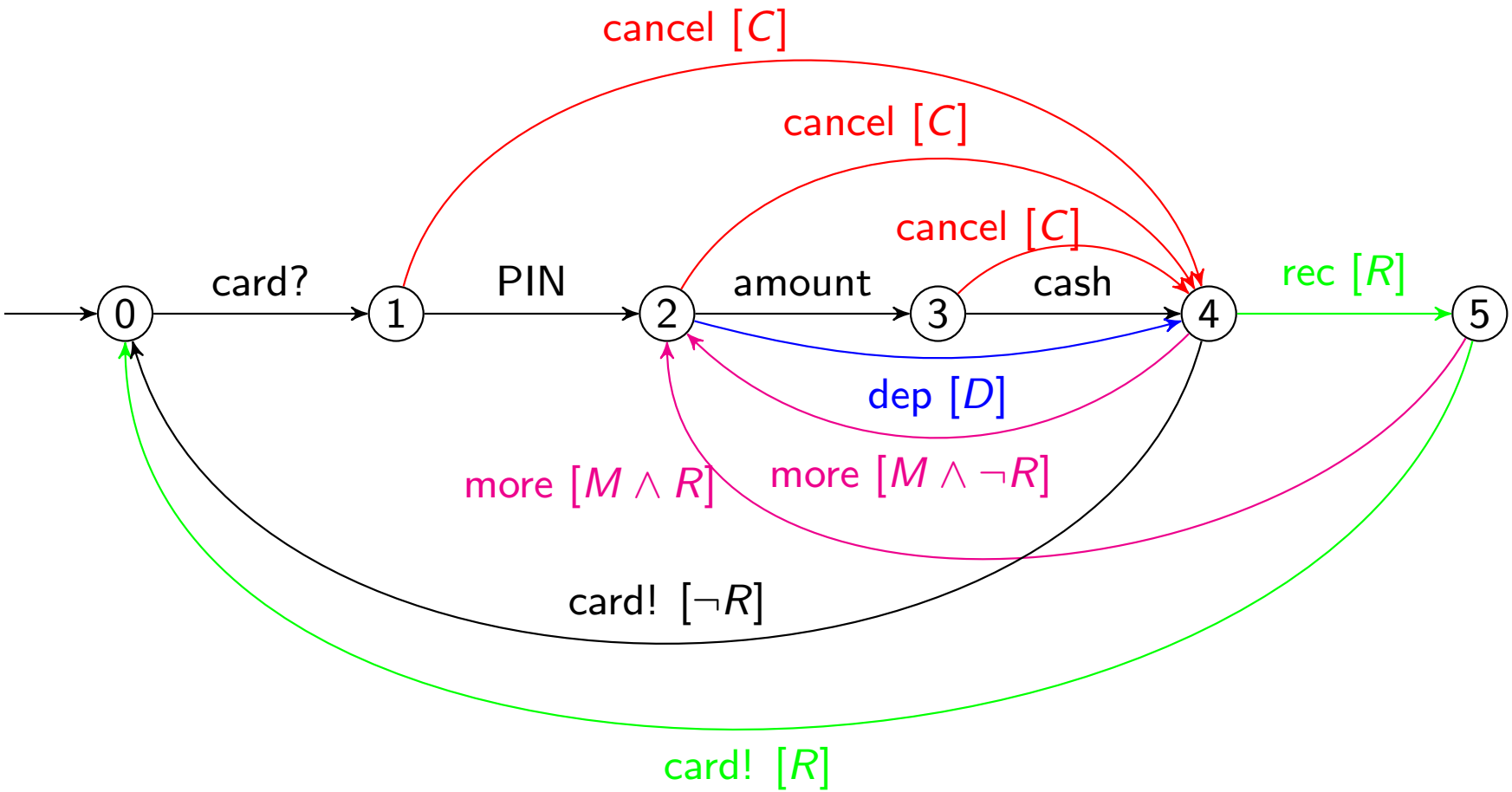

b.i.s. 0: $\neg B$ b.i.s. 1: $\neg M$ b.i.s. 2: **tt**

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