Generation of test cases from an operational profile of the software

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Introduction

- It is impossible to completely test most software systems. (exhaustive testing)

- Testers are sampling from the input population of the software under test.

  There are many examples in the literature showing how to exploit sampling results. However, there is little published on how to generate the sample itself.

- Sampling is currently used in many testing methodologies. A good sample needs to be representative of the population from which it is drawn.

- In general, testing methodologies focus on the sampling problem by using heuristics to determine which test cases to construct.

  In such methodologies, no real attempt is made to either define the population or to measure whether usage of the software that falls outside the sample will succeed.

- Some notable exceptions :
  - *Partition Testing* in which inputs are partitioned into equivalence classes.
  - *Statistical Testing* in which inputs are randomly sampled based on a probability distribution representing expected field use.
  - *Stochastic Testing* in which we first define the input population by building a stochastic model that defines the structure of how the target system is stimulated by its environment, and next define a sampling algorithm that produces test cases directly from the model.

Operational Profile

An operational profile is a description of the distribution of input events that is expected to occur in actual software operation.

The operational profile of the software reflects how it will be used in practice.

The operational profile is used to guide testing, but it can also be used to guide managerial and engineering decisions throughout the software life-cycle by highlighting most important alternatives (prioritized operational profile).

Specifying an Operational Profile

- We use process expressions annotated with probabilities
- Probabilities describe how a process may evolve
- Probabilities are associated to operands
- They are different from transition probabilities
- We may compute transition probabilities from process probabilities using inference rules

Choice

- E_1:p_1 | E_2:p_2

  is a choice between process E_1 or process E_2
- E_1 is chosen with probability p_1
- E_2 is chosen with probability p_2
- If a process is a deadlock, the other is chosen
- If both are deadlocks, then no transition can be generated

Parallel Composition

- $E_1{:}p_1 \,|[A{:}p_3]|\, E_2{:}p_2$

  is a parallel composition of E_1 and E_2 with synchronization on actions of set A

- p_1 is the probability of executing E_1 with an action not in A (no synchronization)

- p_2 is the probability of executing E_2 with an action not in A (no synchronization)

- p_3 is the probability of executing E_1 and E_2 with synchronization on an action of A

Interleave

- Special case of |[]|
- $E_1:p_1 ||| E_2:p_2 = E_1:p_1 |[\varnothing:0]| E_2:p_2$

Parallel Composition with Synchronization on Common Events

- Special case of |[]|
- $E_1{:}p_1 \;\|p_3\; E_2{:}p_2 \;=\; E_1{:}p_1 \;|[\alpha E_1 \cap \alpha E_2{:}p_3]|\; E_2{:}p_2$
- αE_1 is the alphabet of process E_1

Iteration

- $E^*: f$

  choose a number of iterations according to probability distribution f

- $E^+: f = E \bullet E^* : f$

Quantification

- | x : p(x) : c(x) : E

  means

  $E[x:=v_1]:p(v_1)$ | ... | $E[x:=v_n]:p(v_n)$ | ....

  With $c(v_1)$, ..., $c(v_n)$, ... Holding

- May also quantify on |[A]|, ||, |||

Transition rules

(***Tn-1***)

$$\frac{\delta \in \Sigma \cup \{\lambda\}}{\delta \xrightarrow{d} \blacksquare}$$

(***Tn-2***)

$$\frac{E_1 \xrightarrow{d} E_1'}{E_1 \bullet E_2 \xrightarrow{d} E_1' \bullet E_2}$$

Transition rules

(***Tn-3***)

$$\frac{E \xrightarrow{d} E'}{\blacksquare \bullet E \xrightarrow{d} E'}$$

(***Tn-4***)

$$\frac{E_1 \xrightarrow{d} E_1'}{E_1{:}p_1 \mid E_2{:}p_2 \xrightarrow{d} E_1'}$$

Transition rules

(*Tn-5*)

$$\frac{E_2 \xrightarrow{d} E_2'}{E_1{:}p_1 \mid E_2{:}p_2 \xrightarrow{d} E_2'}$$

(*Tn-6*)

$$\frac{}{\blacksquare{:}p_1 \mid [A{:}p_3] \mid \blacksquare{:}p_2 \xrightarrow{e} \blacksquare}$$

Transition rules

(***Tn-7***)

$$\frac{E_1 \xrightarrow{d} E_1{}' \wedge \delta \notin A}{E_1{:}p_1 \,|[A{:}p_3]|\, E_2{:}p_2 \xrightarrow{d} E_1{}'{:}p_1 \,|[A{:}p_3]|\, E_2{:}p_2}$$

(***Tn-8***)

$$\frac{E_2 \xrightarrow{d} E_2{}' \wedge \delta \notin A}{E_1{:}p_1 \,|[A{:}p_3]|\, E_2{:}p_2 \xrightarrow{d} E_1{:}p_1 \,|[A{:}p_3]|\, E_2{}'{:}p_2}$$

Transition rules

(***Tn-9***)

$$\frac{E_1 \xrightarrow{d} E_1' \ \wedge\ E_2 \xrightarrow{d} E_2' \ \wedge\ \delta \in A}{E_1{:}p_1 \ |[A{:}p_3]|\ E_2{:}p_2 \xrightarrow{d} E_1'{:}p_1 \ |[A{:}p_3]|\ E_2'{:}p_2}$$

(***Tn-10***)

$$\frac{E_1{:}p_1 \ |[\varnothing{:}0]|\ E_2{:}p_2 \xrightarrow{d} E_3}{E_1{:}p_1 \ |||\ E_2{:}p_2 \xrightarrow{d} E_3}$$

Transition rules

(***Tn-11***)

$$\frac{E_1{:}p_1 \,\|[\alpha E_1 \;\cap\; \alpha E_2{:}p_3]\|\, E_2{:}p_2 \xrightarrow{d} E_3}{E_1{:}p_1 \;\|p_3\; E_2{:}p_2 \xrightarrow{d} E_3}$$

(***Tn-12***)

$$\frac{}{E^0 \xrightarrow{l} \blacksquare}$$

Transition rules

(***Tn-13***)

$$\frac{E \xrightarrow{d} E' \wedge n > 0}{E^{n} \xrightarrow{d} E' \bullet E^{n-1}}$$

(***Tn-14***)

$$\frac{\text{n chosen using } f \wedge E^{n} \xrightarrow{d} E'}{E^{*}: f \xrightarrow{d} E'}$$

Transition rules

(***Tn-15***)

$$\frac{E \xrightarrow{d} E'}{E^{+}: f \xrightarrow{d} E' \bullet E^{*} : f}$$

(***Tn-16***)

$$\frac{c(v) \wedge E[x := v] \xrightarrow{d} E'}{|\ x : p(x) : c(x) : E \xrightarrow{d} E'}$$

Transition rules

(*Tn-17*)

$$\frac{\neg(\exists! x\ c(x)) \ \wedge\ c(v)\ \wedge \quad E[x := v]:p(v) \quad |[A:q]| \quad (|[A:q]|\ x : p(x) : c(x) \wedge x \neq v : E):S\text{-}p(v) \xrightarrow{d} E'}{|[A:q]|\ x : p(x) : c(x) : E \xrightarrow{d} E'}$$

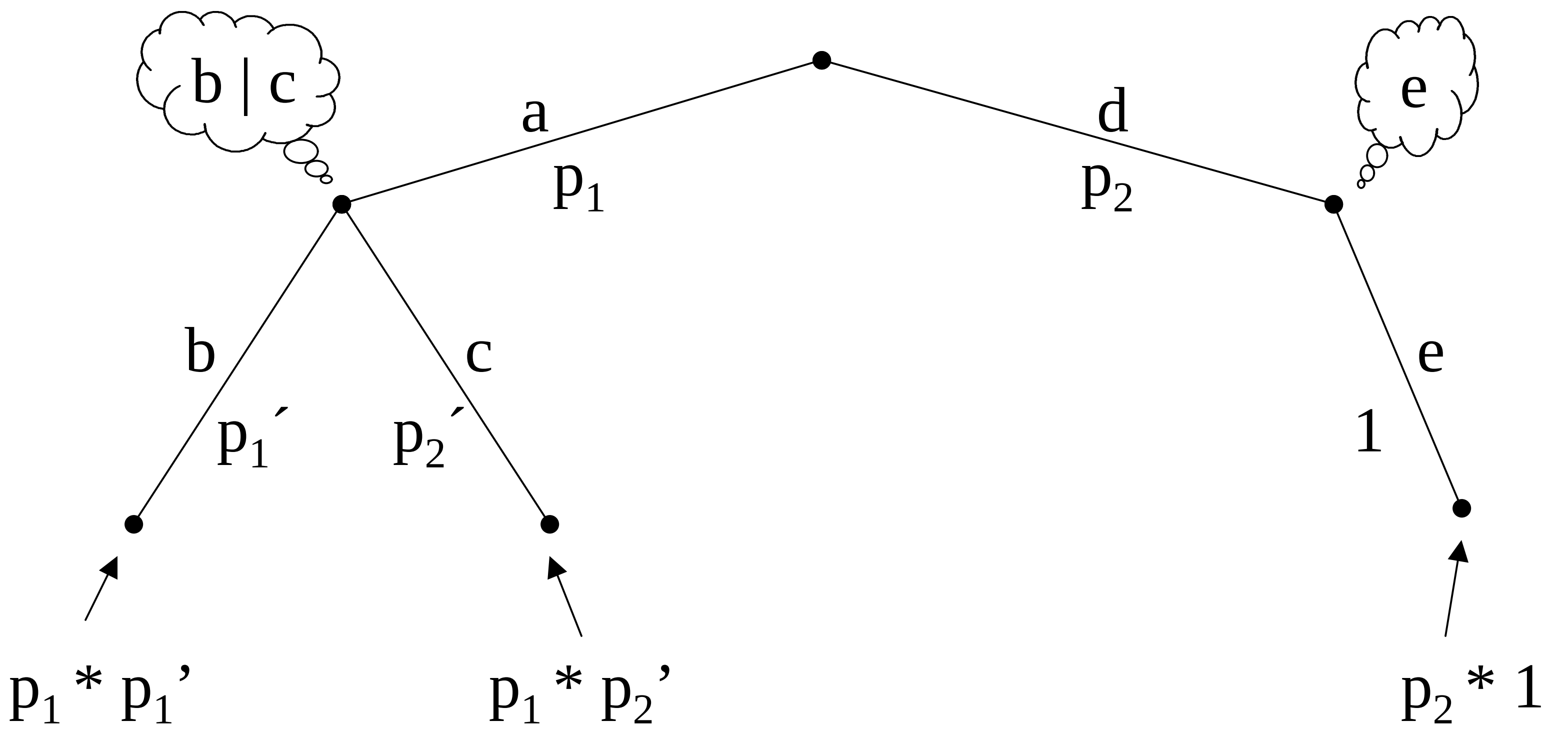
where $S = \sum x : c(x) \wedge x \neq v : p(x)$

Transition rules

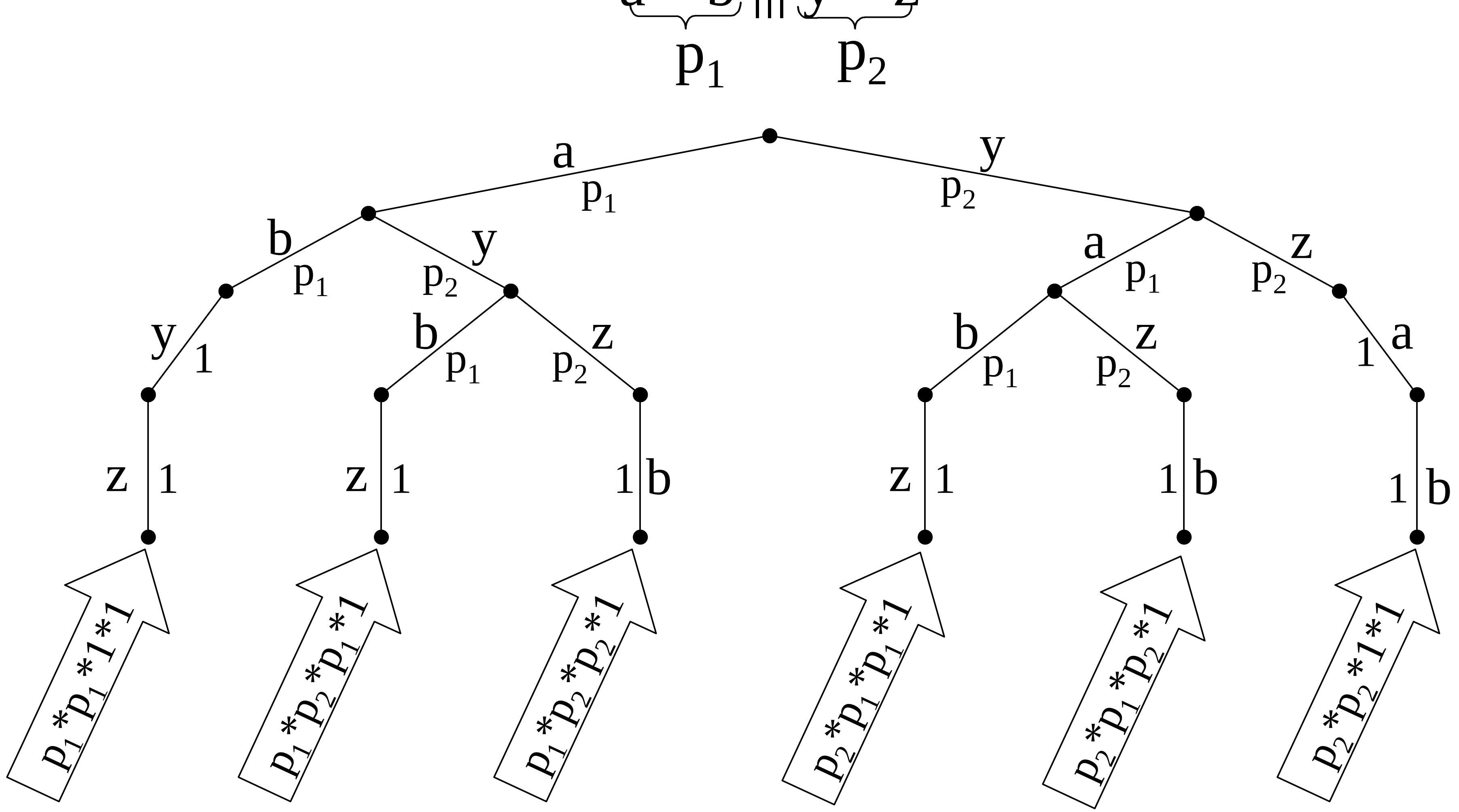
(***Tn-18***)

$$\frac{(\exists! x\ c(x)) \ \wedge\ c(v) \ \wedge\ E[x := v] \xrightarrow{d} E'}{|[A:q]|\ x : p(x) : c(x) : E \xrightarrow{d} E'}$$

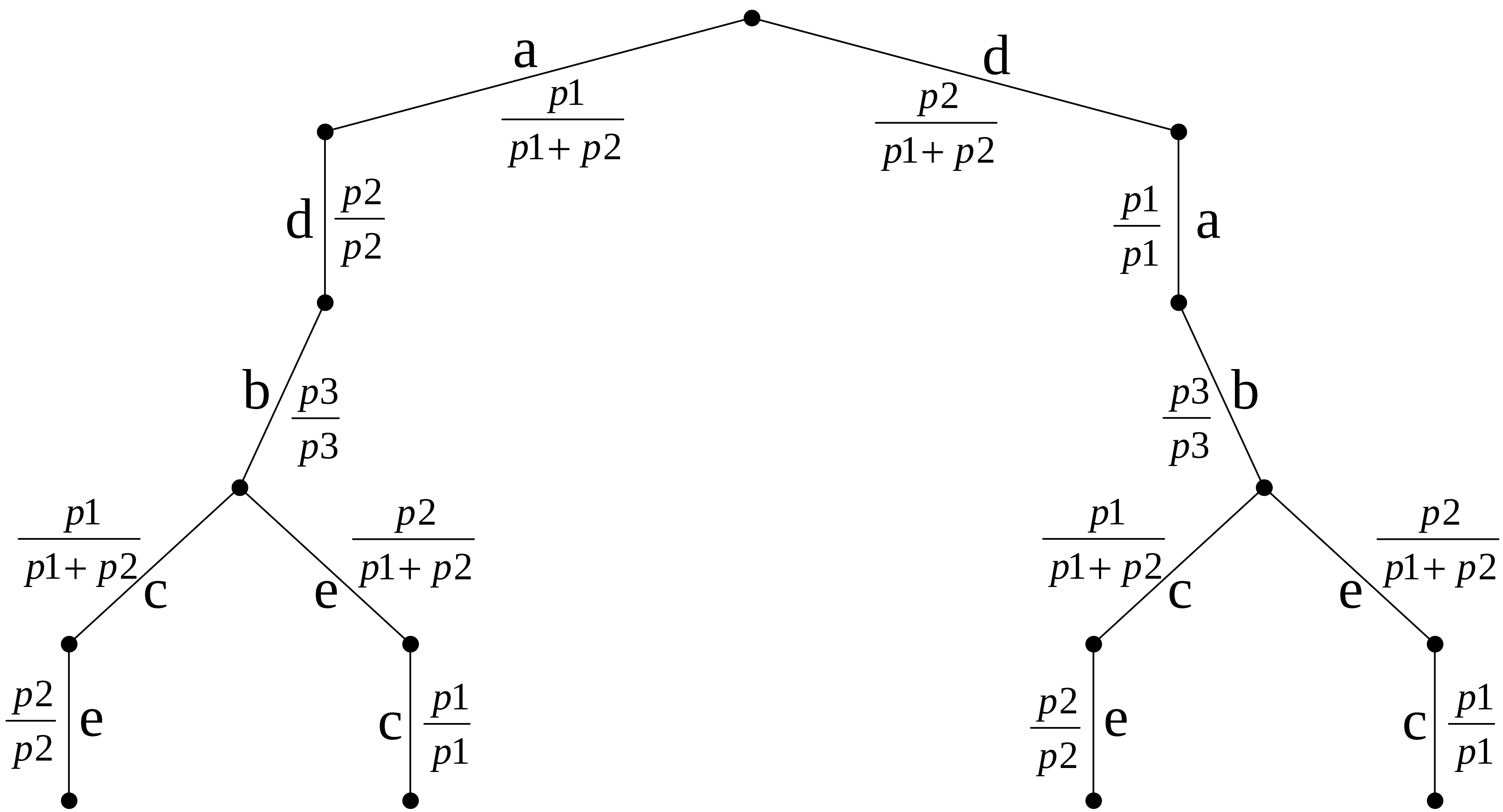
$$\underbrace{a \bullet (\overbrace{b}^{p_1'} \,|\, \overbrace{c}^{p_2'})}_{p_1} \;|\; \underbrace{d \bullet e}_{p_2}$$



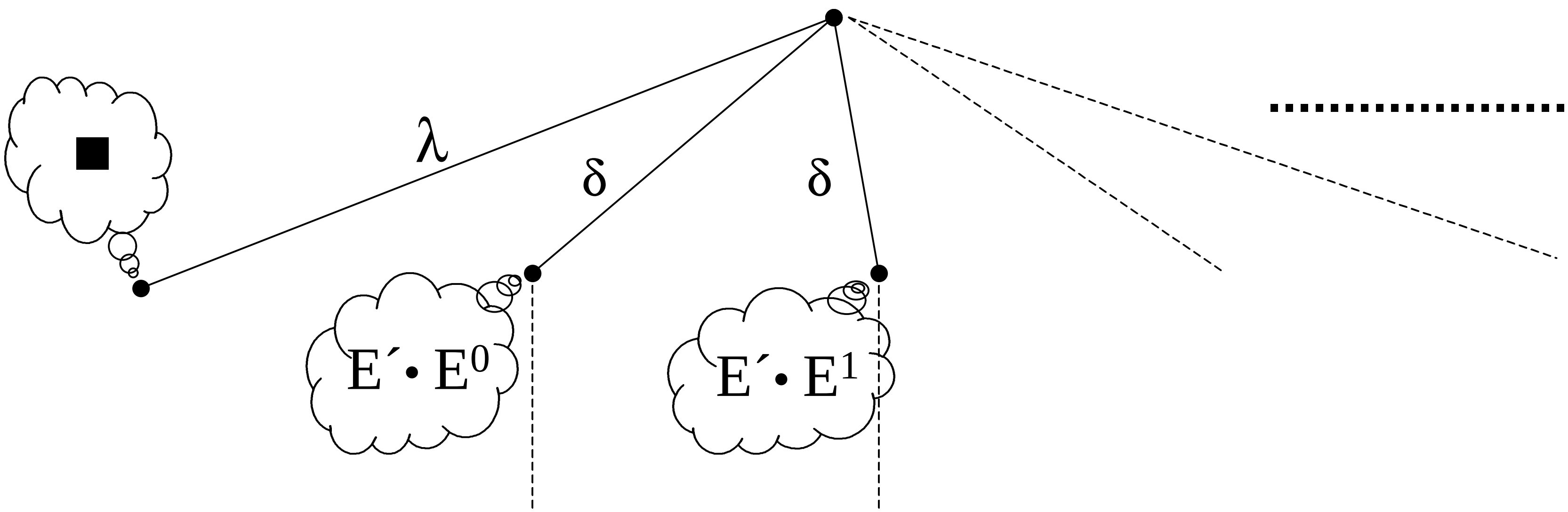
$$a \bullet b \,|||\, y \bullet z$$



$$\underbrace{a \bullet b \bullet c}_{p_1} \,|\underbrace{[b, f]}_{p_3}|\, \underbrace{d \bullet b \bullet e \bullet f}_{p_2}$$



$$E^* : f$$



Constructing Operational Profiles from Observations

- Collect traces from real system
- Prove that traces are acceptable
- Count the number of times an inference rule is invoked for each operand of the specification during the proofs

Conclusion

- Reuse requirements specification for operational profile specification
- Hierarchical specification of operational profiles
- Simple graphical specification of the operational profile
- Amenable to automatic test scenario generation, assuming some restrictions on quantifications
- Amenable to automatic profile construction from existing traces