EVALUATION OF CAUSE EFFECT GRAPHS BY PETRI NETS

CONTENTS

WHAT ARE CAUSE EFFECT GRAPHS ?
-> EXAMPLE [MYERS 1979, P. 58]

- verbal specification

  The character in column 1 must be an “A” or a “B”.
  The character in column 2 must be a digit.
  In this situation, the file update is made.
  If the first character is incorrect, message X12 is issued.
  If the second character is not a digit, message X13 is issued.

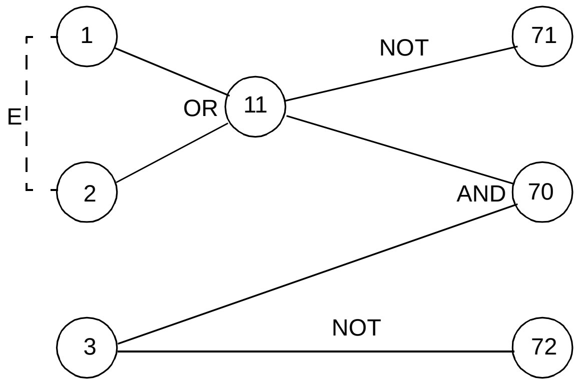
- causes

  1 character in column 1 is “A”
  2 character in column 1 is “B”
  3 character in column 2 is a digit

- effects

  70 file update, update message -> effect1
  71 message X12 is issued-> effect2
  72 message X13 is issued-> effect3

- cause-effect graph



STANDARD EVALUATION PROCEDURE, BASICS

- objective

  -> to get a characteristic set of abstract test cases

- compare

  -> [Myers 1979]

  -> [Liggesmeyer 2002]

- Select an effect to be present (TRUE).

- Trace back through the graph, and
  find all essential combinations of causes that will set this effect to TRUE.

- Doing so, consider suitable heuristics (next slide).

  -> to be efficient

  -> to eliminate situations that tend to be low-yield test cases

- Create a line in the decision table for each combination of causes.

  -> each line stands for a test case

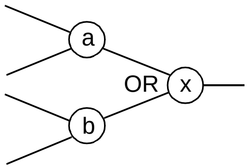
- Determine the states of all other effects.

- Eliminate doubled lines in decision table.

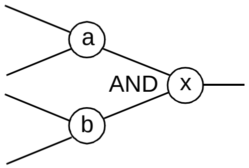
STANDARD EVALUATION PROCEDURE, HEURISTICS

- remember: backward procedure

- if x
  then enumerate all situations, where one input is TRUE & all other inputs are FALSE
  else set all inputs to FALSE
  endif



- if x
  then set all inputs to TRUE
  else enumerate all situations, where one input is FALSE & all other inputs are TRUE
  endif



AN ALTERNATIVE APPROACH

SUPPORTING

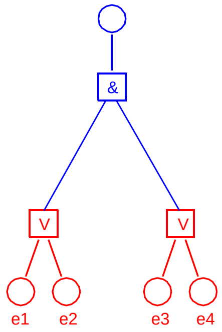
-> ANIMATION
-> AUTOMATIC COMPUTATION

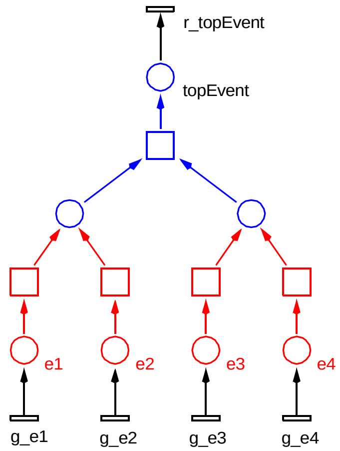
DEFINING

-> A NEW COVERAGE MEASURE

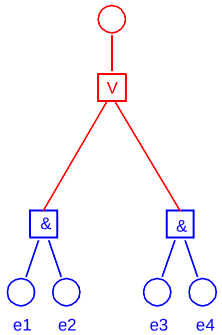
BASIC FAULT TREES

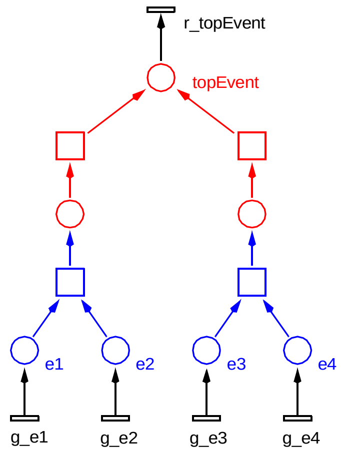
EX1:





EX2:

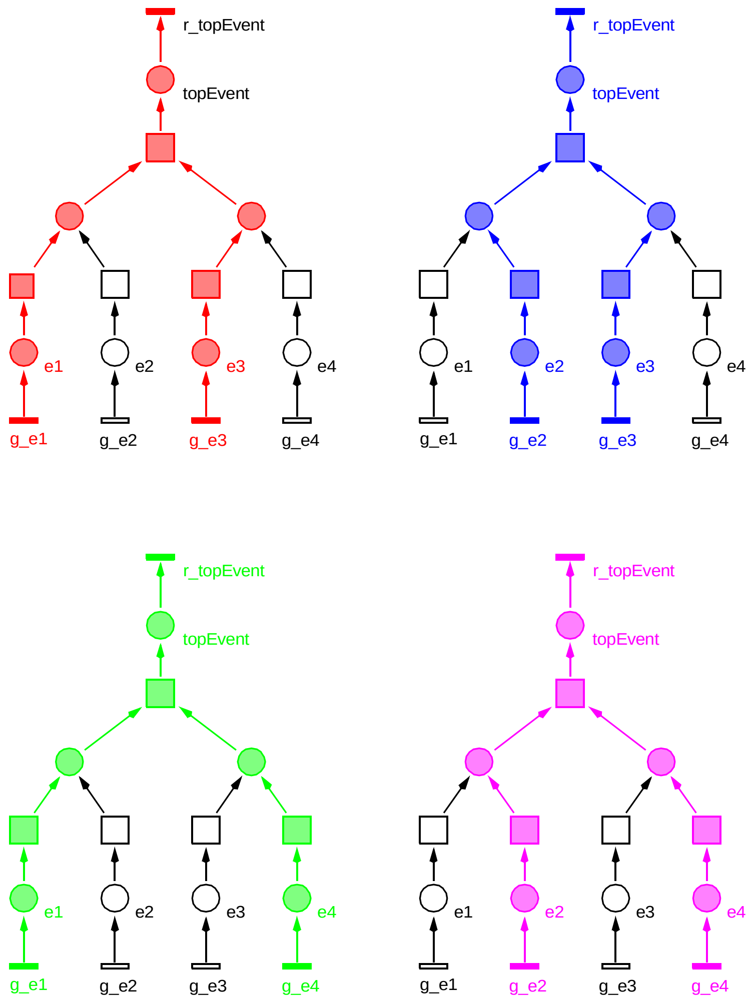




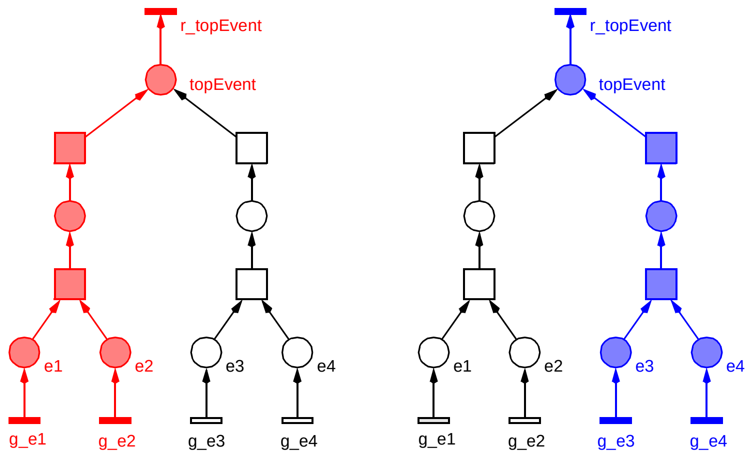
-> minmal cuts ?

-> minimal runs (T-invariants) ?

BASIC FAULT TREES, EX1 -> T-INVARIANTS



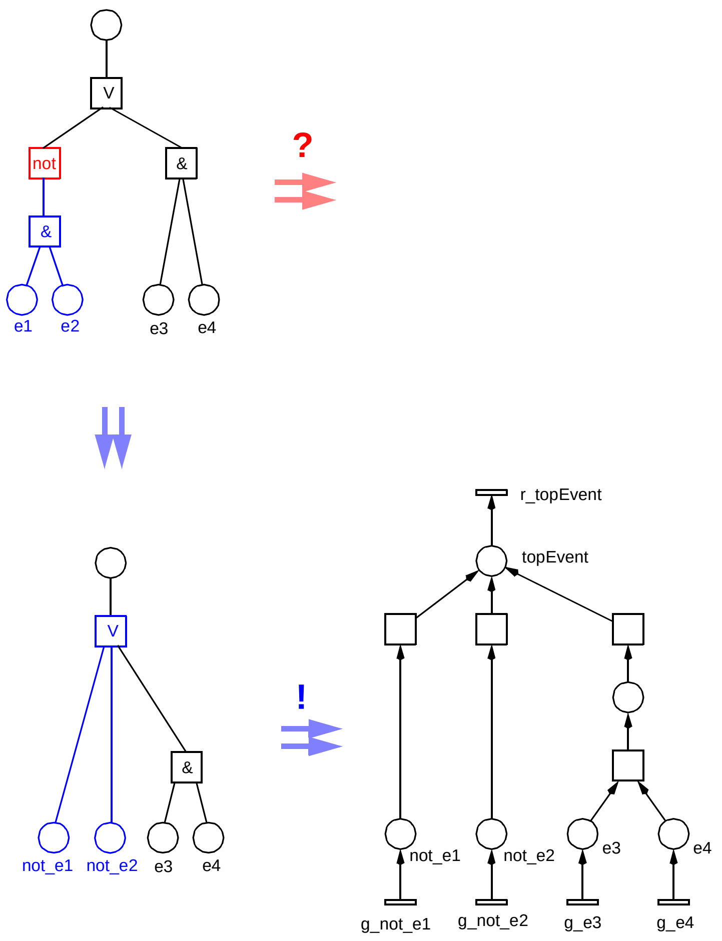
BASIC FAULT TREES, EX2
-> T-INVARIANTS



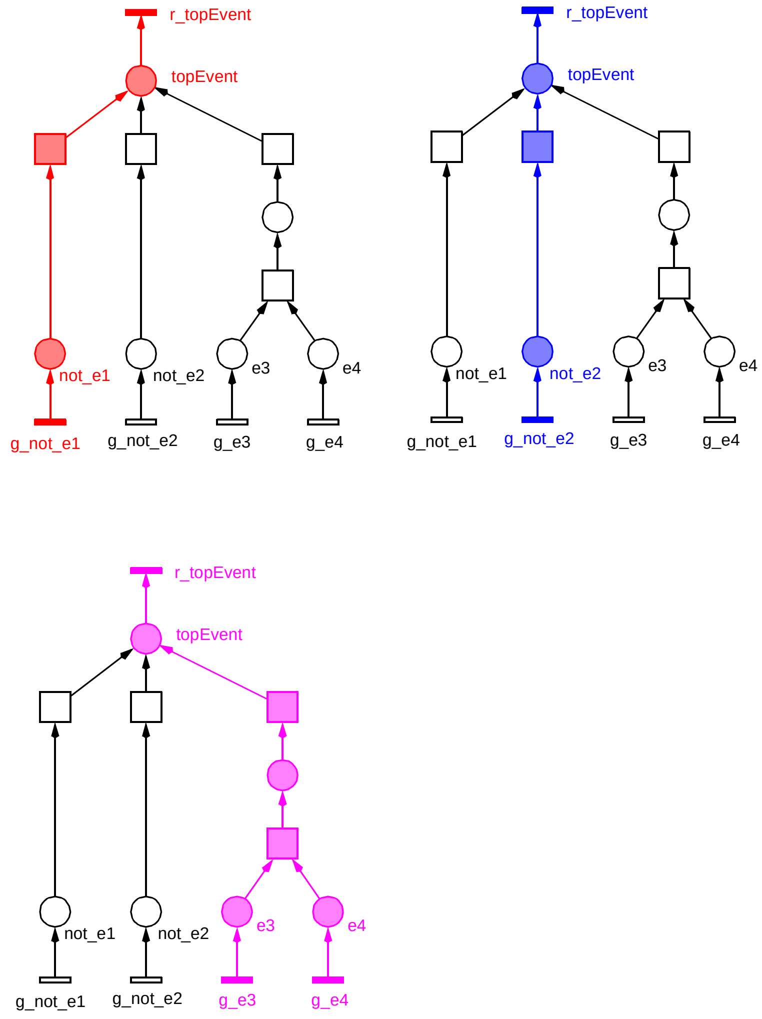
OBSERVATIONS

- (minimal) cut:
  (minimal) set of basic events
  - -> resulting into the top event
- (minimal) T-invariant:
  (minimal) multiset of transitions
  - -> with zero total effect on marking
  - -> reproducing a given marking
  - -> potentially cyclic behaviour
- minimal T-invariants /cuts:
  - -> minimal runs
  - -> basic behaviour
- any behaviour is a non-negative linear combination of basic runs
- (minimal) cuts <-> (minimal) T-invariants <-> (minimal) test case
- CTI - Covered by T-Invariants:
  each transition belongs to a (minimal) T-invariant
  - -> each transition contributes to system behaviour
- decomposition into minimal [cuts / T-invariants / test cases]
  - -> node / branch coverage
  - -> basic behaviour coverage

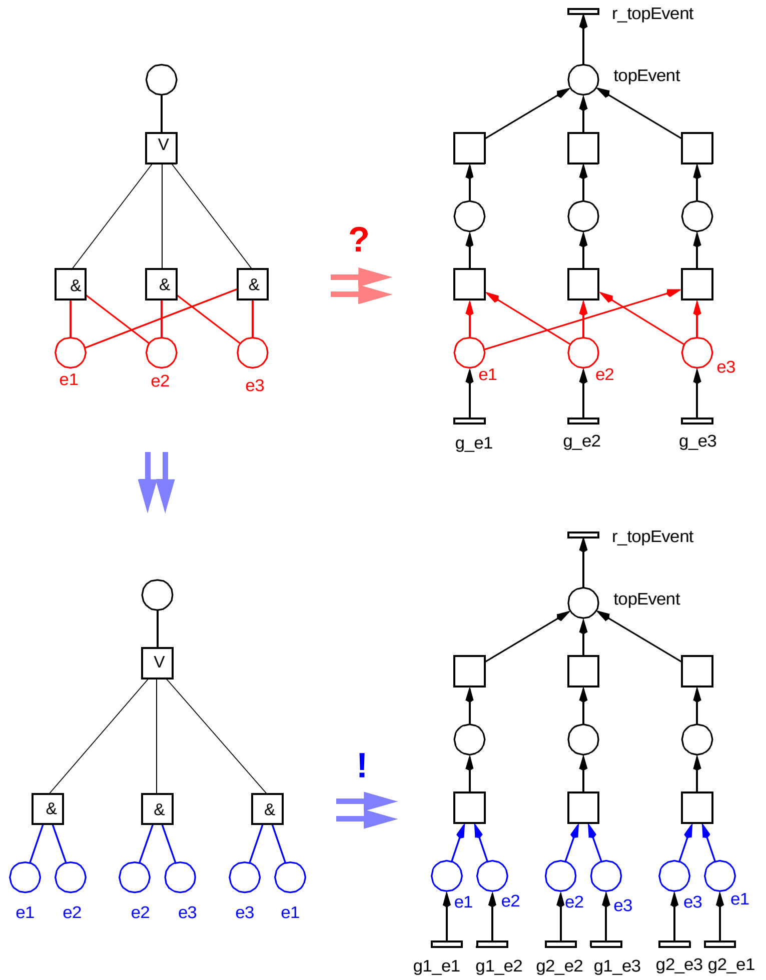
ADVANCED FAULT TREES, EX1
-> PROBLEM: NEGATION



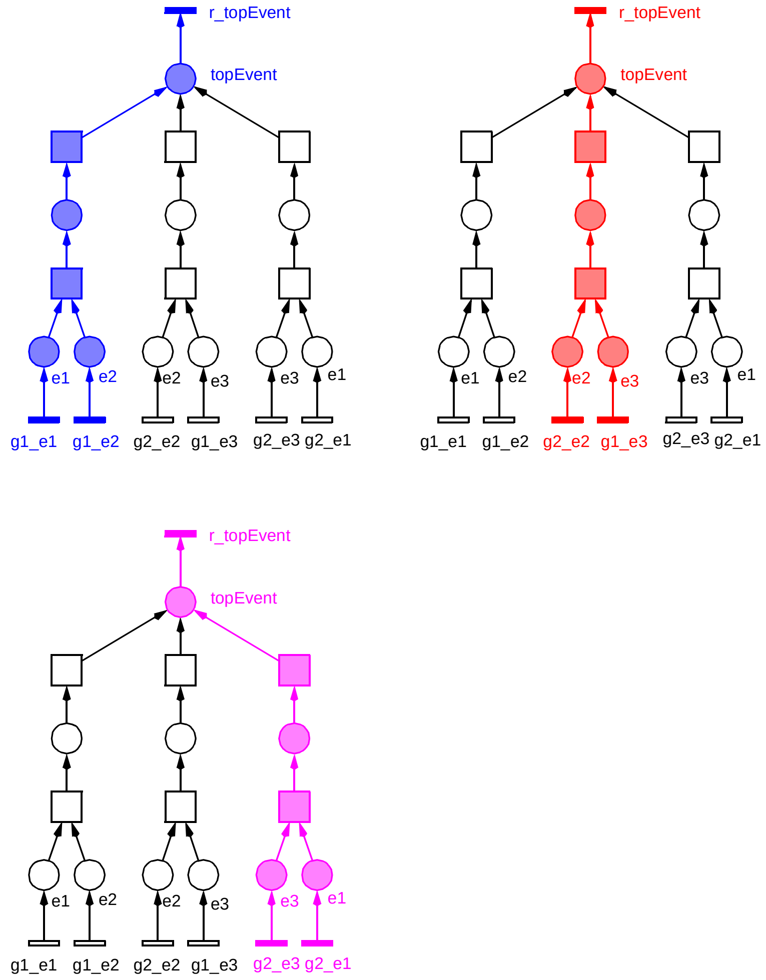
ADVANCED FAULT TREES, EX1
-> T-INVARIANTS



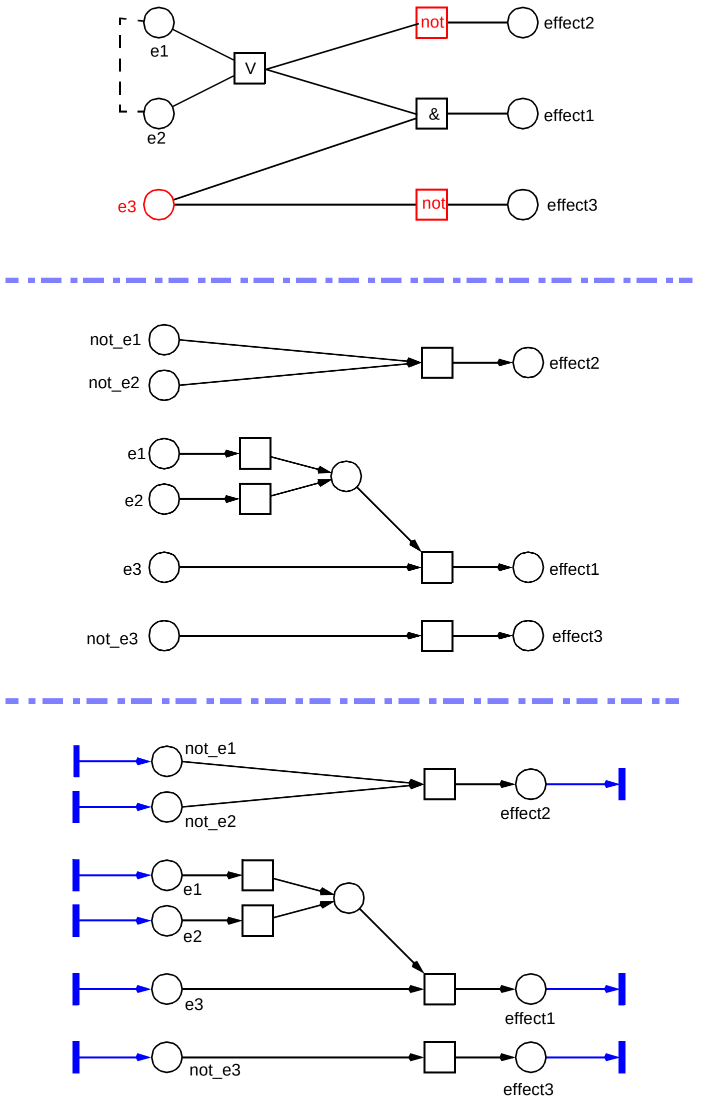
ADVANCED FAULT TREES, EX2
-> PROBLEM: BRANCHING PLACES



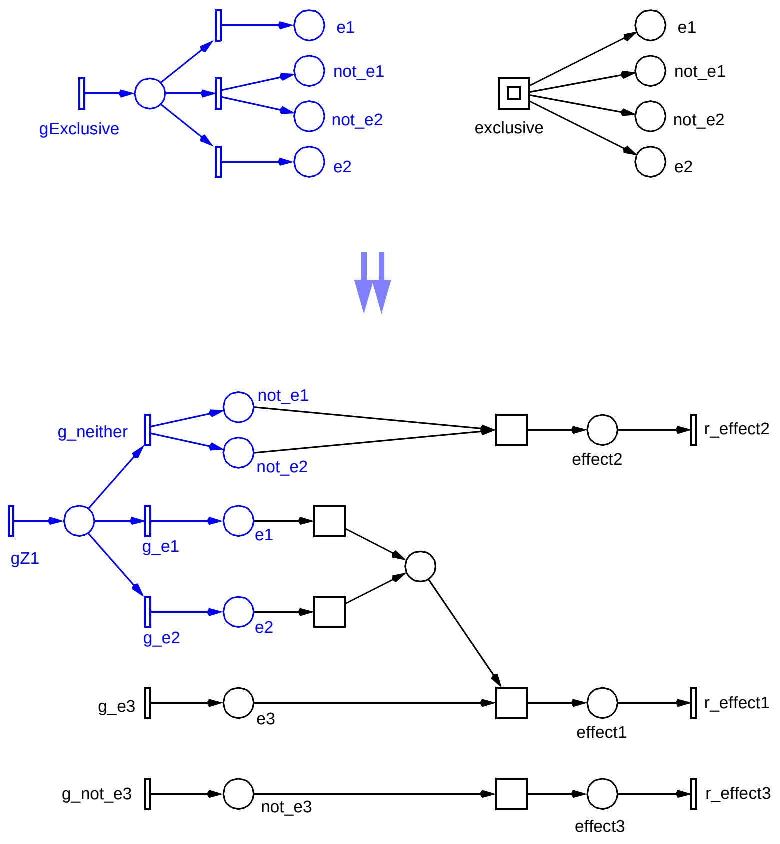
ADVANCED FAULT TREES, EX2
-> T-INVARIANTS



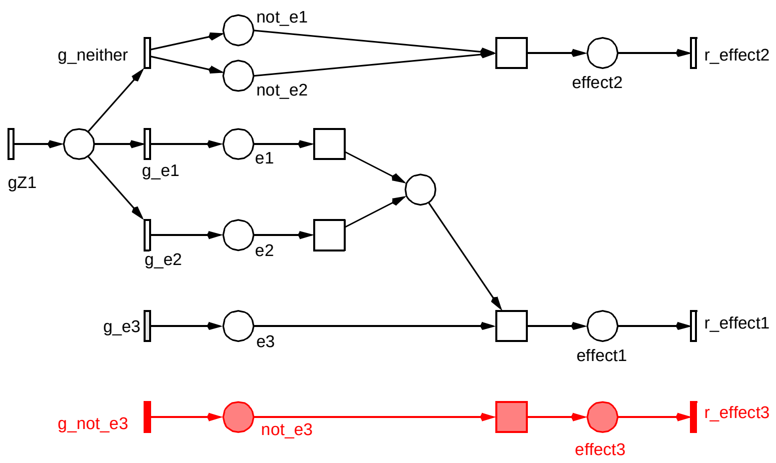
CAUSE EFFECT GRAPH, [MYERS 1979]

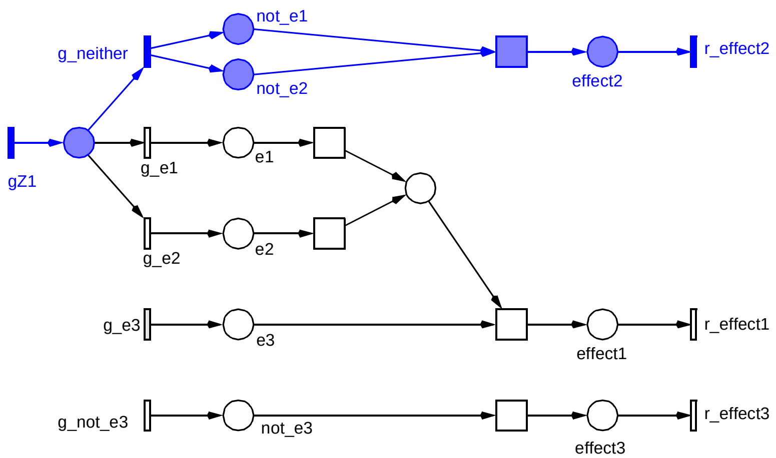


CAUSE EFFECT GRAPH, [MYERS 1979]

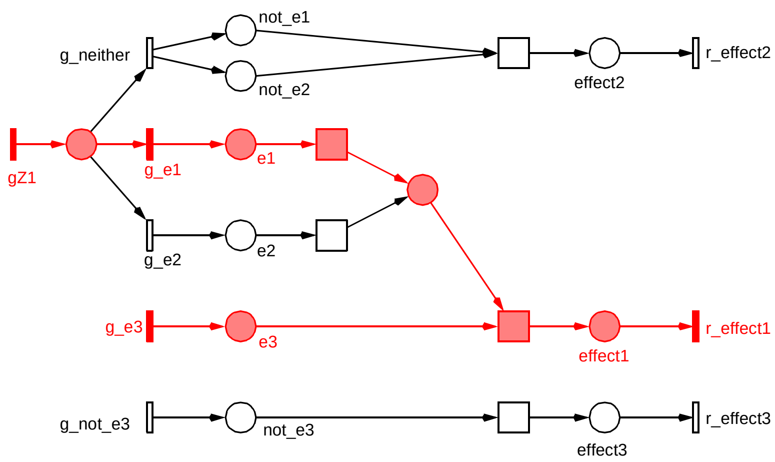


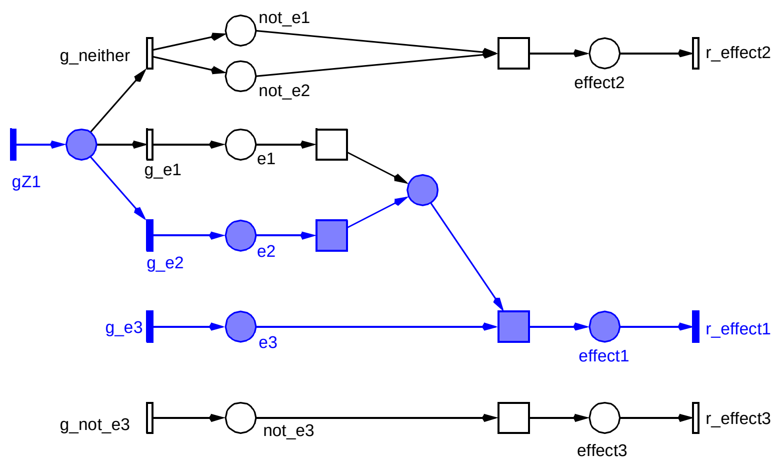
CAUSE EFFECT GRAPH, [MYERS 1979] -> T-INVARIANTS 1, 2





CAUSE EFFECT GRAPH, [MYERS 1979] -> T-INVARIANTS 3, 4





CAUSE EFFECT GRAPH, [MYERS 1979] -> EVALUATION OF TEST CASES

- T-invariant 1 -> test case 1:

  abstract test case: not_e3, don't-care: e1/e2 -> effect3

  real test case: *A, A -> X13 message*

- T-invariant 2 -> test case 2

  abstract test case: not_e1 and not_e2, don't-care: e3 -> effect2

  real test case: *C, 1 -> X12 message*

- T-invariant 3 -> test case 3

  abstract test case: e1 and e3 -> effect1

  real test case: *A, 1 -> update message*

- T-invariant 4 -> test case 4

  abstract test case: e2 and e3 -> effect1

  real test case: *B, 1 -> update message*

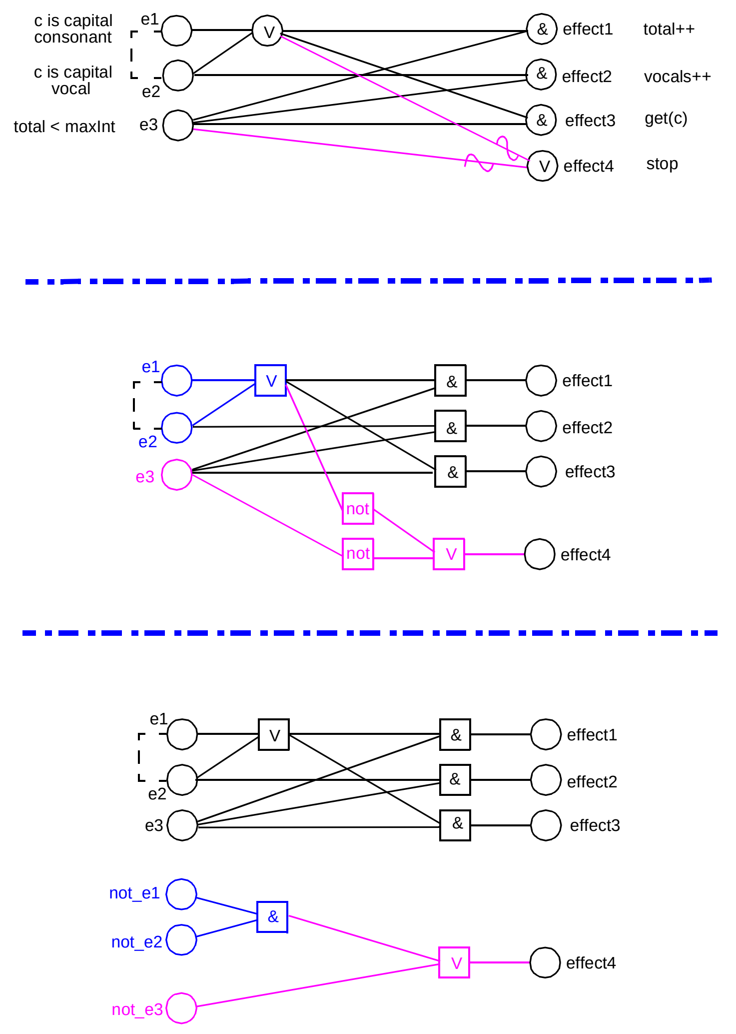
- these four test cases guarantee basic behaviour coverage

- don't care's: prefer TRUE assignment;

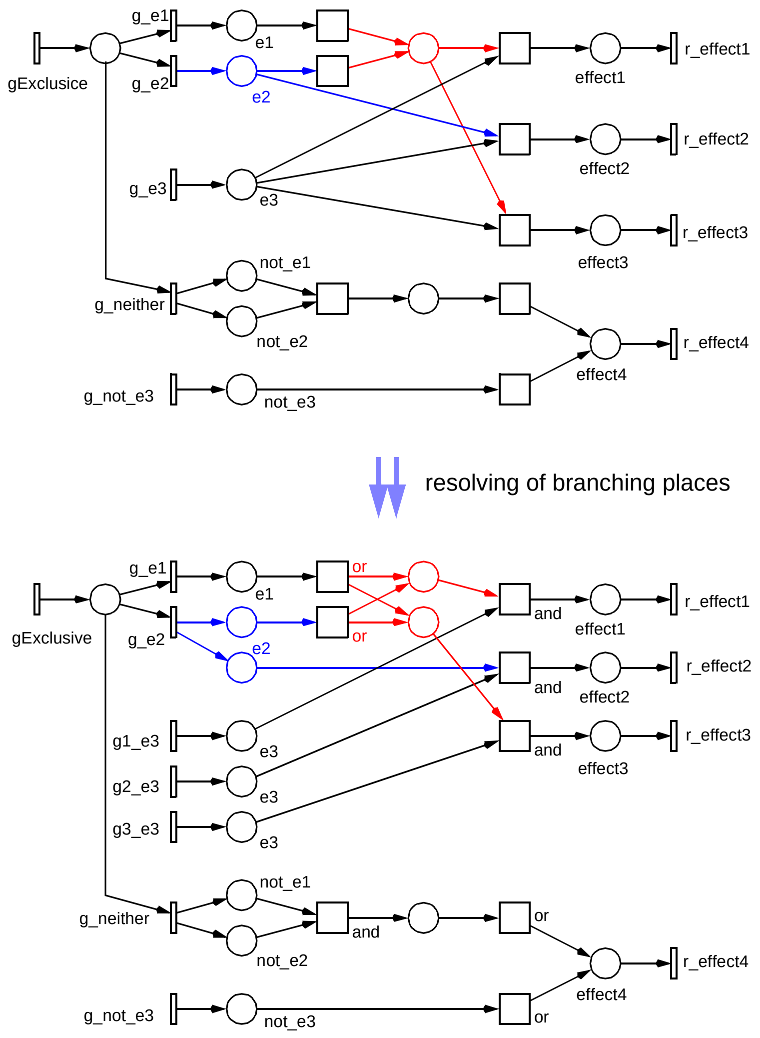
  -> to avoid fault masking

- **THESE ARE EXACTLY THE FOUR TEST CASES WE GET BY THE STANDARD EVALUATION PROCEDURE**

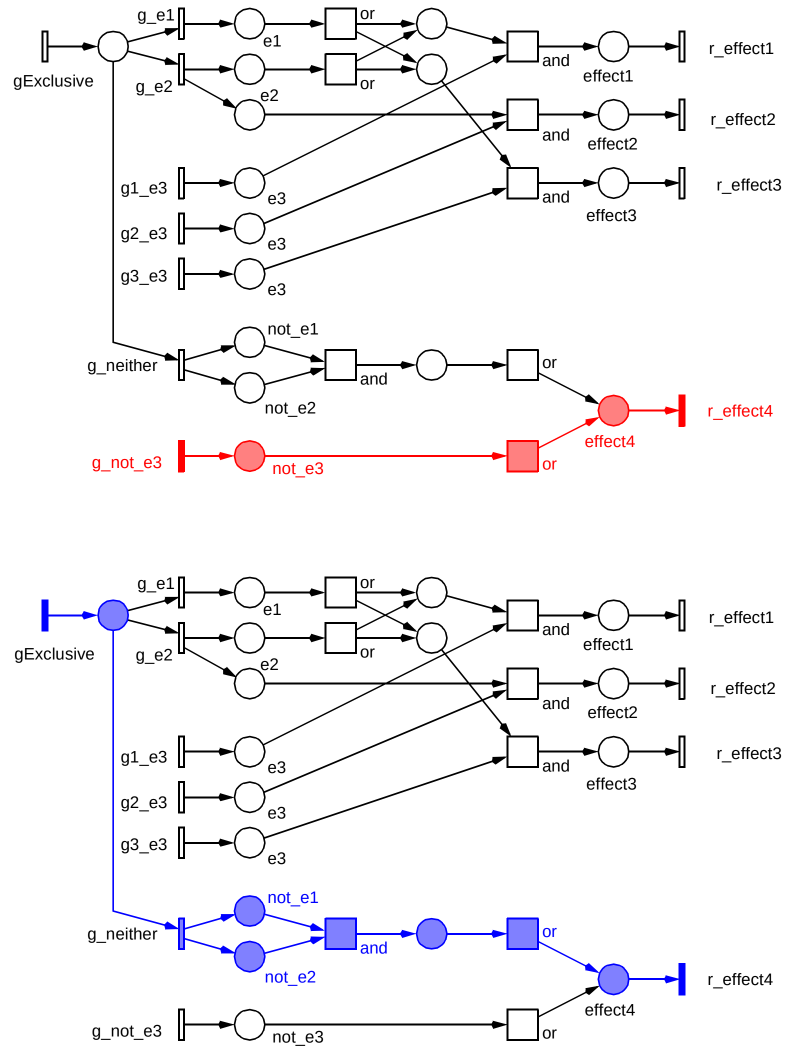
CAUSE EFFECT GRAPH, [LIGGESMEYER 2002]



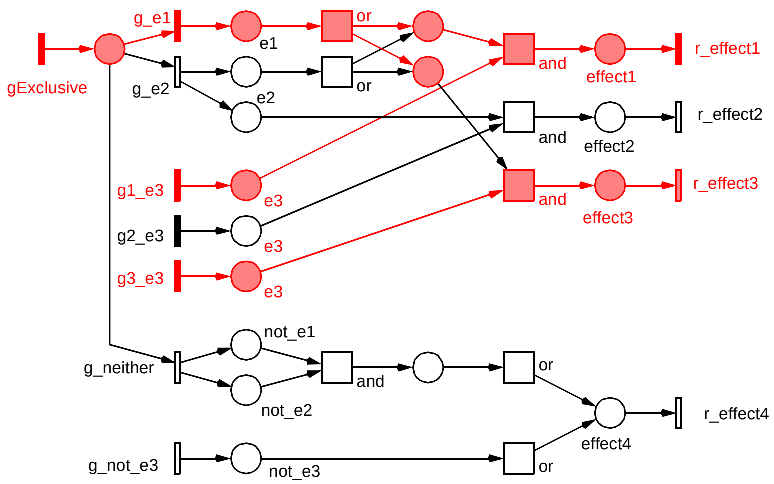
CAUSE EFFECT GRAPH, [LIGGESMEYER 2002]

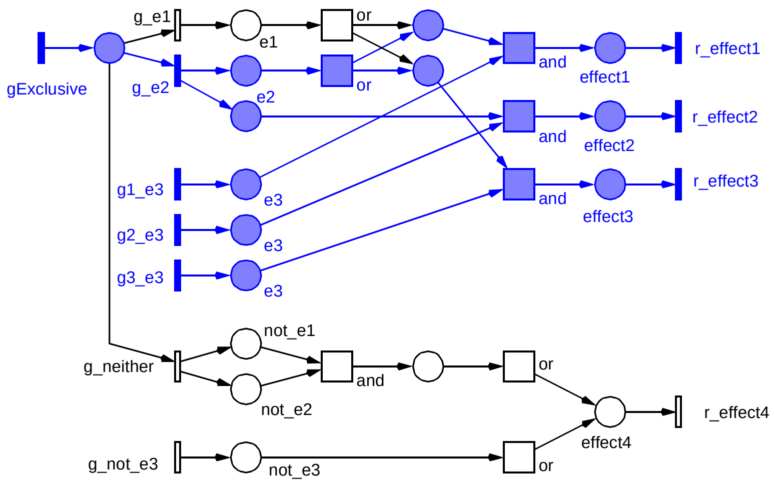


CAUSE EFFECT GRAPH, [LIGGESMEYER 2002] -> T-INVARIANTS 1, 2



CAUSE EFFECT GRAPH, [LIGGESMEYER 2002] -> T-INVARIANTS 3, 4





CAUSE EFFECT GRAPH, [LIGGESMEYER 2002] -> EVALUATION OF TEST CASES

- T-invariant 1 -> test case 1:
  - *abstract test case:* not_e3, don't-care: e1/e2 -> effect4
  - *real test case:* total = MAXINT; B
- T-invariant 2 -> test case 2
  - *abstract test case:* not_e1 and not_e2, don't care: e3 -> effect4
  - *real test case:* total < MAXINT; 0
- T-invariant 3 -> test case 3
  - *abstract test case:* e1 and e3 -> effect1, effect3
  - *real test case:* total < MAXINT; B
- T-invariant 4 -> test case 4
  - *abstract test case:* e2 and e3 -> effect1, effect2, effect3
  - *real test case:* total < MAXINT; A
- these four test cases guarantee basic behaviour coverage
- again: don't care's get TRUE assignment;
- standard evaluation procedure splits test case 1 into two cases:
  - e1 and not_e3 (and not_e2) -> effect4
  - e2 and not_e3 (and not_e1) -> effect4
  - -> compare [Liggesmeyer 2002, p. 68]

FINAL QUESTION

HOW
TO
COMPUTE

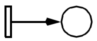
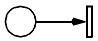
MINIMAL
T-INVARIANTS ?

-> BASICS OF
PETRI NET THEORY
[LAUTENBACH 1973]

-> RELIABLE TOOL SUPPORT
AVAILABLE, E. G. CHARLIE

cause-effect graphing *2017/12/05*

SUMMARY

- cause effect graphs can be represented adequately by Petri nets
- straightforward transformation
  - -> automatic translation
- minimal T-invariants in Petri net representation correspond to minimal abstract test cases in cause effect graph representation
  - -> input transitions - causes g_cause  cause
  - -> output transitions - effects effect  r_effect
- covering by T-invariants corresponds to covering by abstract test cases
  - -> **BASIC BEHAVIOUR COVERAGE**
- computation of all minimal T-invariants
  - -> there can be exponentially many
  - -> reliable tool support available, e. g. Charlie (inspired by INA)

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