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Risk Management

MCS BDD in RiskSpectrum®

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Introduction - Why MCS BDD?

- **In general: MCS with normal quantification fully sufficient**
- **Some cases: Increased accuracy in computation needed**
  - Level 2
  - Area events
  - Seismic
- **Requirements on speed are essential**

Introduction – different ways to solve a FT/ET model

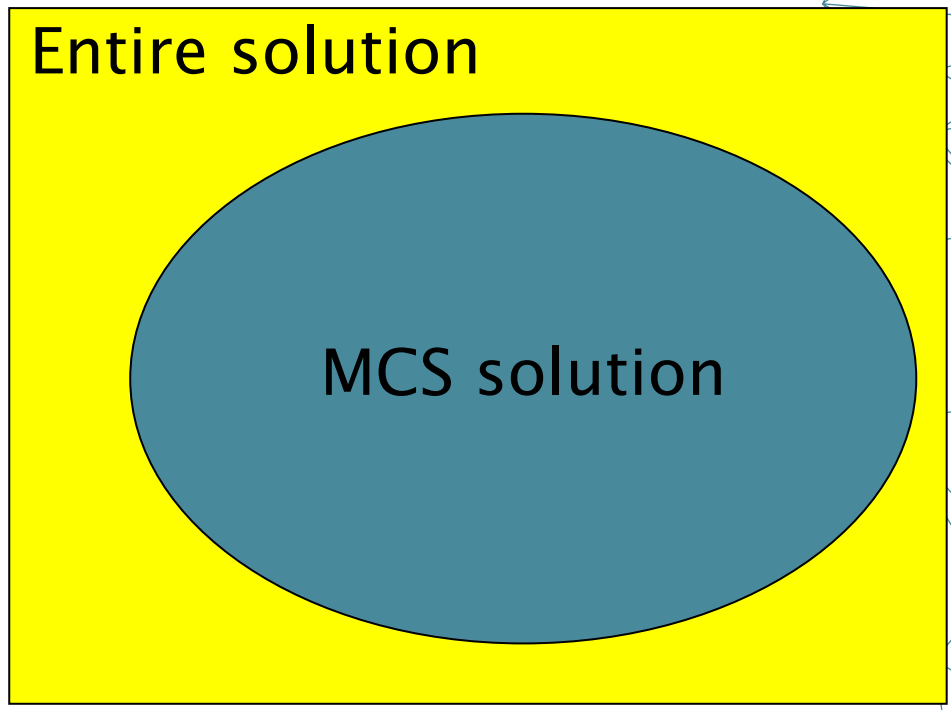
- **Generation of MCS, minimal cut sets**
  - Represents an approximate solution
  - Success events are not part of the result (generally)
  - Algorithms to quantify the top result based on MCS are approximate
  - Cut off
  - ”Quick”
- **Generation of BDD, binary decision diagrams, based on the FT/ET model**
  - Represents the exact solution
  - Is very complex in large cases
    - May require cut-off
  - Time consuming and may not be able to generate results

Why MCS BDD?

- **To use the positive characteristica of MCS generation**
  - Speed!
  - Can always generate results
  - Easy/easier to select pivotal elements
- **Address the main weaknesses**
  - Quantification of the MCS list
    - High probabilities will result in conservative results
    - This quantification problem is treated with MCS BDD
  - Treatment of success events
    - Possibility to use ”simple treatment” of chosen function events (top events in ET)
    - Selected function events (with high failure probability) can be treated numerically

Why MCS BDD, cont´d

- **Remaining ”drawback”**
  - Based on the ”truncated” solution
  - Cutoff have probably been applied
- **The cut off has to be properly set!**



The method

- **Generate MCS**
  - Based on normal analysis criteria
  - Observe that negated events may be allowed in the solution
  - Define ”simple quantitative treatment” of function events if necessary
- **Split of MCS list**
  - Part to be treated with BDD
  - Part that can be treated with MCUB
    - Remember that MCUB is a conservative treatment

$$Q_{TOP,MCUB} = 1 - \prod_{i=1}^{n}(1 - Q_{MCS,i})$$

Generation of the BDD

- **The part of the MCS treated with BDD**
  - Exact BDD treatment
  - Approximate BDD treatment
- **Exact BDD**
  - The normal BDD way of analyzing the problem
- **Approximate BDD**
  - An approximate solution
  - Very efficient in reducing the problem – short run times

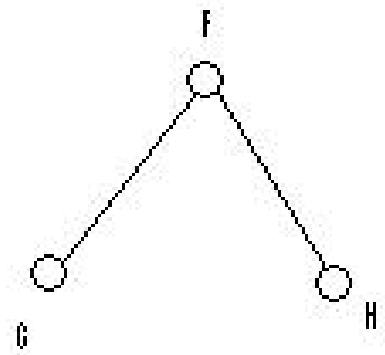
Approximate BDD, cont´d

- **When an event is failed only MCS where the event is included is considered further (in that branch)**
  - All the MCS not containing the event will be a part of the success branch
  - Can not be used when the event is negated in the cut set list
  - Require modification of the quantificiation algorithm
- **Conservative - dependencies between MCS are not treated exact. Error is very small if the pivotal element has low probability.**
- **The use of the approximate treatment is optional and is actuated by two different triggers:**
  - FV importance below a specified level, default 1E-3
  - Unavailability below a specified level, default 1E-3

Quantification

- **Exact BDD**
  - For events that are above criteria

$$P_F \cdot P_G^1 + (1 - P_F) \cdot P_H^0$$



- **Approximate BDD**
  - For events that match none of the criterion
    - Pf * (Pg + Ph - Pg * Ph) + (1 - Pf) * Ph

$$P_F \cdot P_G^1 + (1 - P_F \cdot P_G^1) \cdot P_H^0$$

- **MCUB for ”remainder”**
  - Specified by the user, e.g. 0,1%

Examples of results

Analysis case: CD	Value
Exact MCS BDD	2.4356E-004
Approximate MCS BDD	2.4365E-004
MinCutUpperBound	2.4466E-004
1st order approximation	2.4471E-004

Analysis case: Anonymous	Value
Exact MCS BDD	1.0487E-006
Approximate MCS BDD	1.0487E-006
MinCutUpperBound	1.0731E-006
1st order approximation	1.0732E-006

Example, quantification time

	MCUB	Threshold 1E-1	Threshold 1E-2	Threshold 5E-3	Threshold 2E-3
Result	**2,75E-5**	**2,676E-5**	**2,674E-5**	**2,673E-5**	**2,673E-5**
BDD Runtime	**-**	**0,1**	**0,6**	**6,1**	**217**

Inclusion of success events in the MCS List and BDD

- **RiskSpectrum includes possibility to use ”simple treatment” of success**
- **Together with a BDD quantification this is very powerful**
  - The ”simple quantification” is enhanced significantly
  - The BDD structure for the success event can be quantified conditional other events
  - The “simple” quantitative will represent a very good quantification

Example, Success Treatment

	MCS; AB	MCS; A + C				
INITIATING EVENT	FE1	FE2	No.	Freq.	Conseq.	Code
			1			
			2			FE2
			3			FE1

- **The MCS list for sequence 2 is:**
  - A –FE1
  - C –FE1
- **When quantifying FE1 it is dependent on the other events in the MCS**
  - This is considered in the MCS BDD
    - A –B
    - C –(AB)
- **It shall be noted that this is only of relevance when dependencies exists between different function events.**

Conclusions

- **The MCS BDD provides a very fast and powerful tool to remove the main potential problems of a quantification**
- **It is an excellent choice when high probability events are included (e.g. level 2, seismic analyses etc)**
- **The use of the MCS BDD will enhance the treatment of the simplified success treatment used in RiskSpectrum PSA**
  - Actually, if the amount of MCSs generated in the success events are small (can be completely represented by a MCS list) and homogenous the method will generate an exact BDD of the complete problem.

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