Minimal Cut Set List Quantification with Mutually Exclusive Events and High Probabilities – An Improvement to the MCS BDD split approach

PSAM 18, PA267

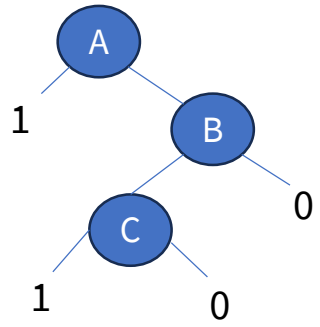
Ola Bäckström, Pavel Krcal, Pengbo Wang

RiskSpectrum AB

Introduction

- Presentation about a recent development of the MCS BDD approach in RiskSpectrum
- Focusing on a potential accuracy issue in corner case scenarios, mostly in seismic risk assessments
- Introduce the approach to increase (solve) the accuracy in these scenarios

BDD approach and overview of RiskSpectrum MCS BDD



- Pivotal decomposition method
- Both failure and success branches are being developed
- When all branches have reached state “1” or “0” the problem is solved
- Example, MCS list: {A, BC}
- Why MCS BDD: Very good accuracy in calculations – also considering success and high probabilities
- RiskSpectrum approach - scalability:
  - Split of the MCS list into a part treated by BDD and a part treated by MCUB
  - Use of exact and approximate BDD nodes
  - Control of number of nodes that are allowed

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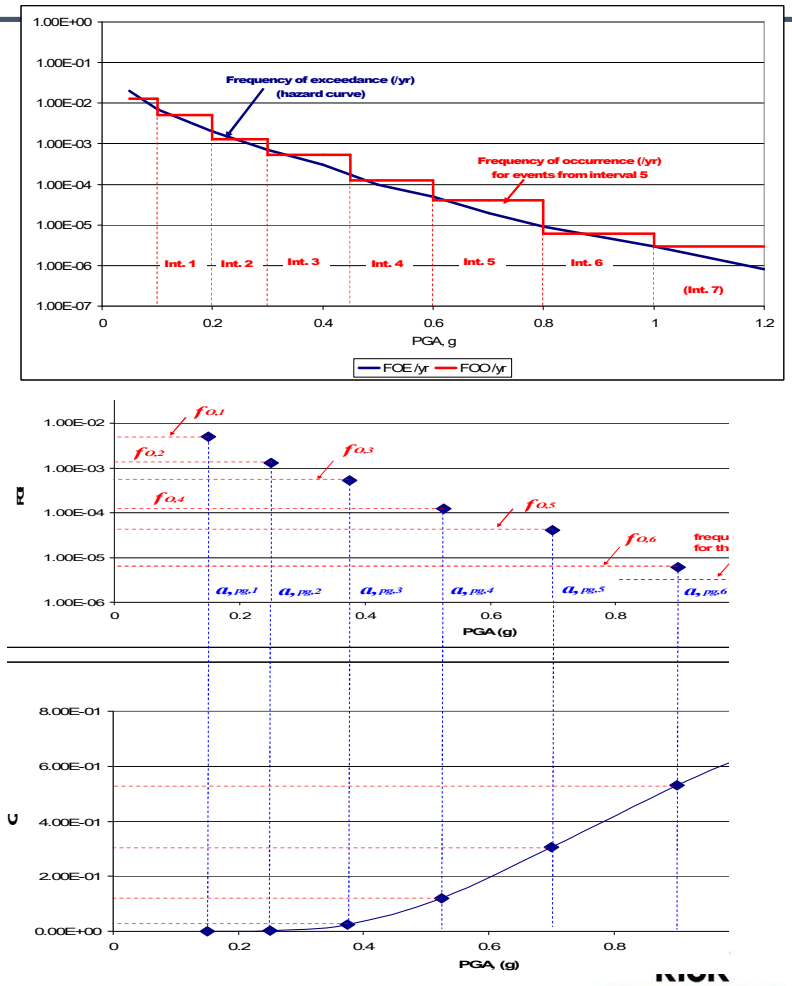
Seismic risk assessment - overview

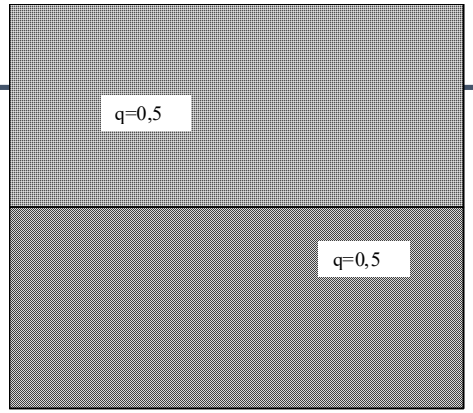
$$f_O^{(i)} = f_{E,L}^{(i)} - f_{E,U}^{(i)}$$

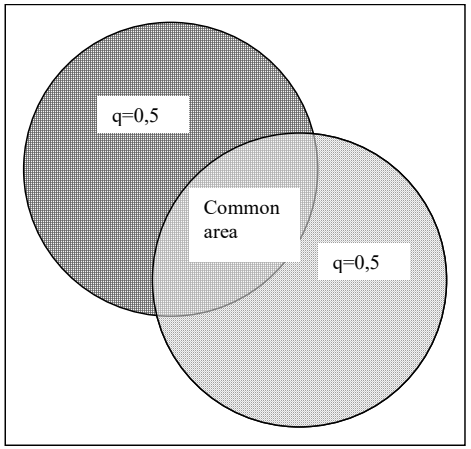
- For representation in a PSA model, the continuum of PGA values with associated frequencies is mostly divided into discrete intervals
  - Continuous range of PGA values is presented by successive seismic intervals
- For each interval the fragility for each component is decided
- Last intervals (high PGA) will cause very high probability of failure for components
- Normally, a standard MCUB solution may be too conservative



Mutual Exclusivity –What is that?

- When for example two events are dependent in following way:
  - $P_b = 1 - P_a$
- When might this be relevant?
  - Time fractions, for example system configuration probabilities
  - Maintenance unavailabilities that cannot occur at the same time
  - (CCF)





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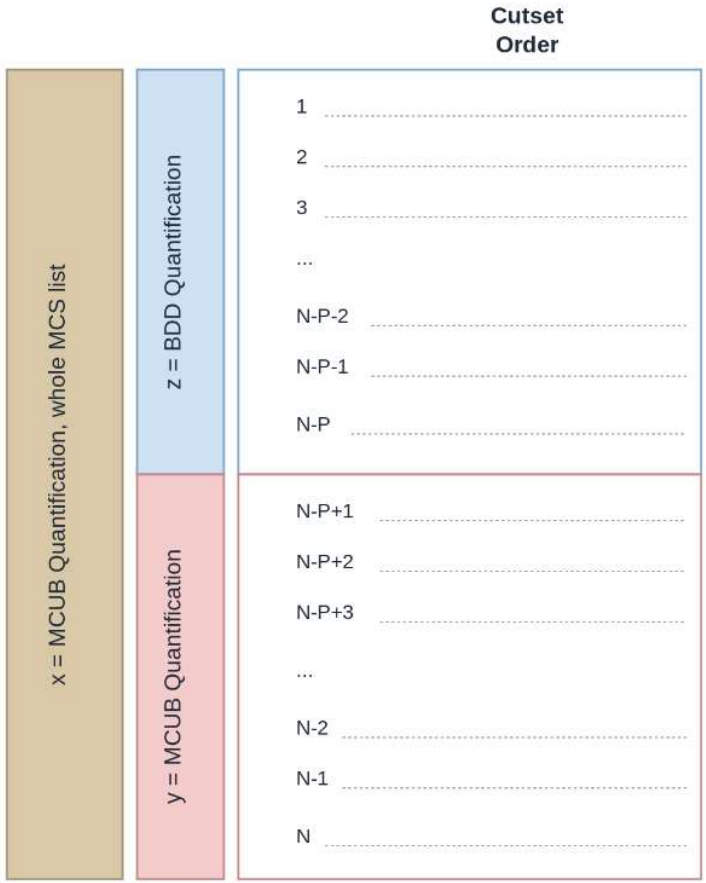
The purpose of this presentation

- The MCS BDD approach is very good – and scalable
  - Much better accuracy than normal MCUB calculation
- One potential issue has been identified:
  - High number of high probability events in combination with very many MCSs
  - Mutual exclusivity between events (not only frequency events)
- A situation where this can be relevant is seismic risk assessment, in the intervals with high PGAs

Basics

MCS BDD – Approximations



Seismic analyses

- MCS BDD
  - MUX
  - High values
  - MCS Limit used

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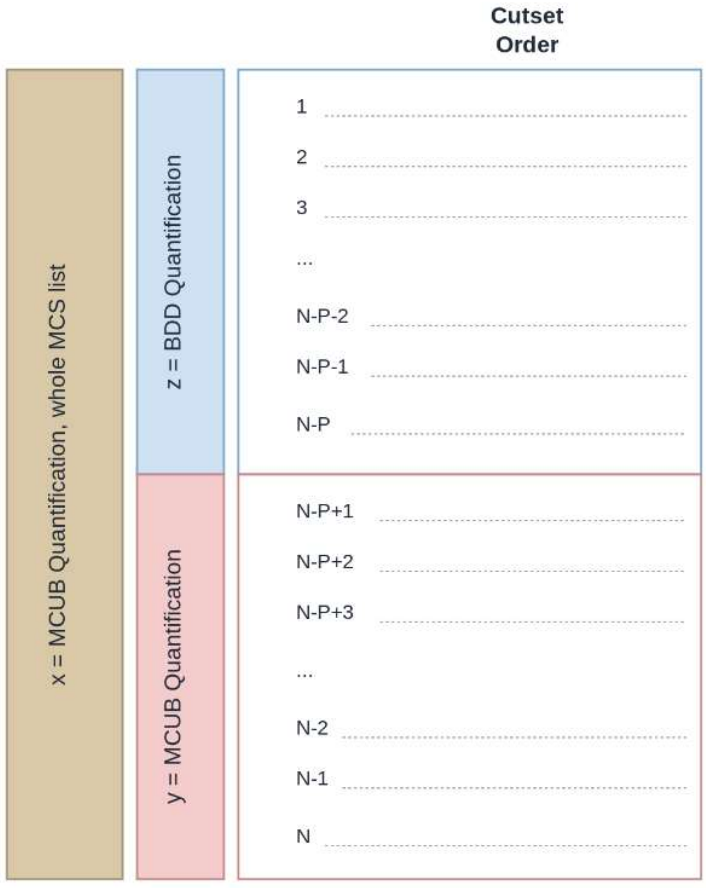
MCS BDD – Difficult Cases



CCDP close to 1.0

CCDP very high

Seismic analyses

- MCS BDD
  - MUX
  - High values
  - MCS Limit used

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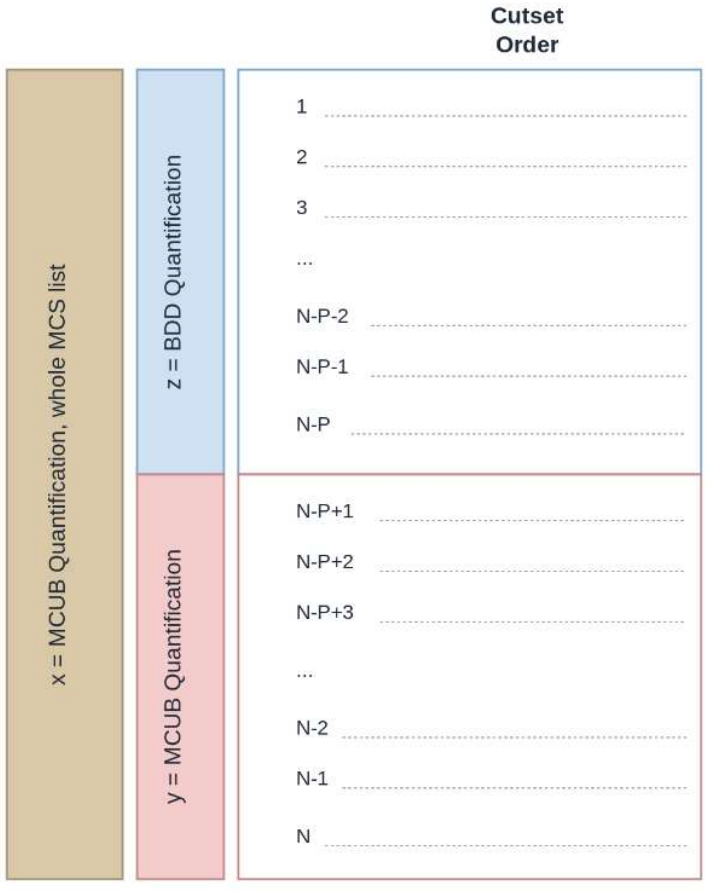
MCS BDD – Difficult Cases, but can be managed – no MUX



CCDP close to 1.0

+

CCDP very high

−

Intersection between the parts

Seismic analyses

- MCS BDD
  - (MUX)
  - High values
  - MCS Limit used

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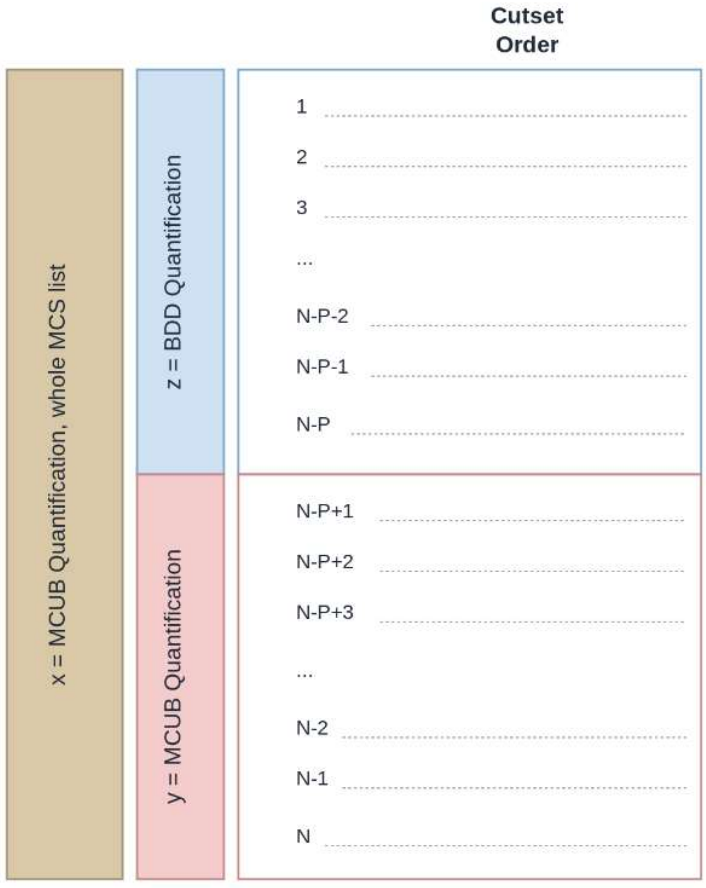
MCS BDD – Difficult Cases - MUX



CCDP close to 1.0

+

CCDP very high

Seismic analyses

- MCS BDD
  - MUX
  - High values
  - MCS Limit used

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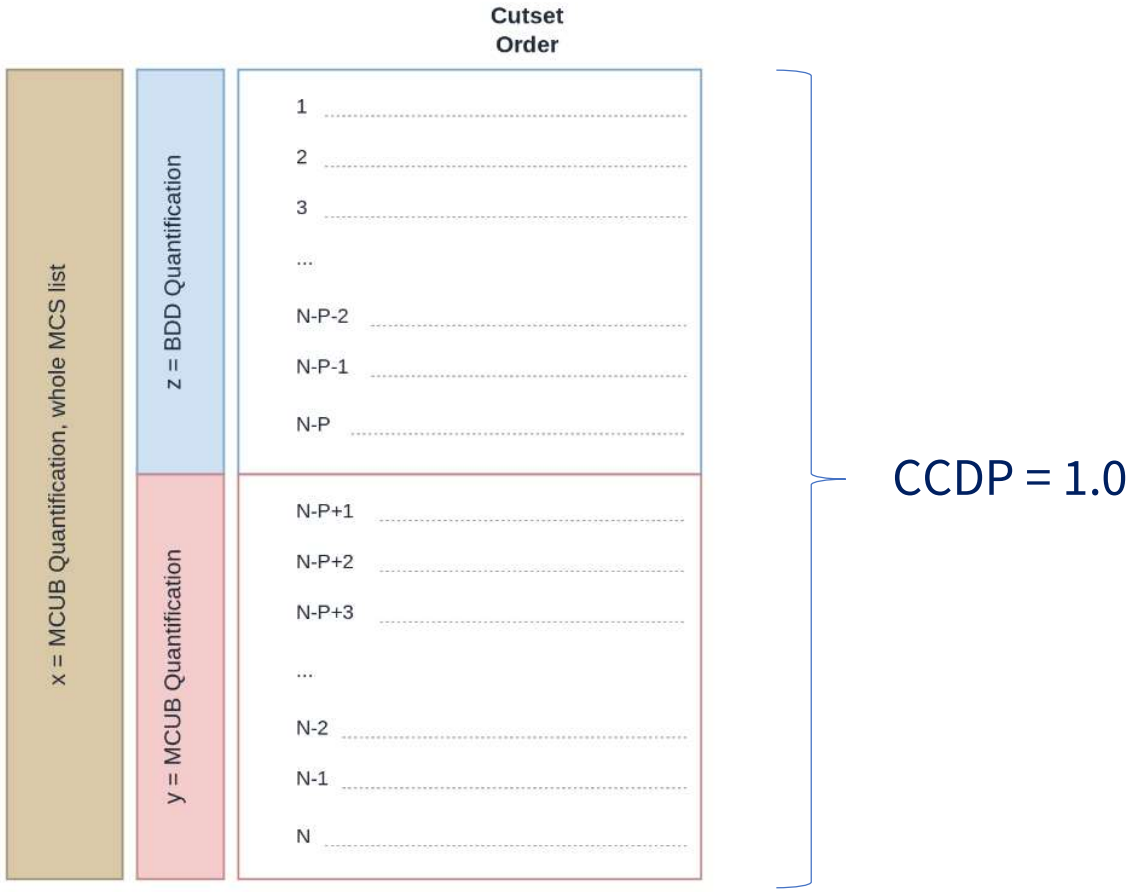
MCS BDD – Difficult Cases



CCDP = 1.0

Seismic analyses

- MCS BDD
  - MUX
  - High values
  - MCS Limit used

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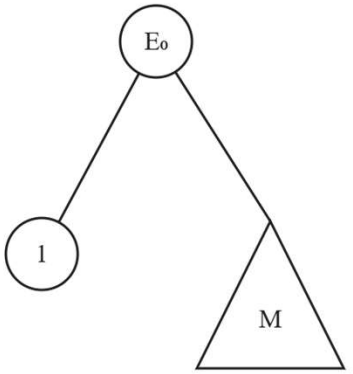
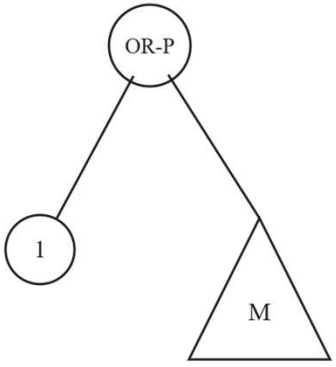
The improved approach

Basis for the improved algorithm

Case where there is no MUX present

- First, we notice that if the MCS below the MCS limit is only MCS represented by the probability of one event E0 – it should be added to the BDD as a new node (M is denoting the representation of the BDD)
  - This will lead to the same approximation as if BDD and MCUB parts are added and then the intersection subtracted.
- Then we observe, what if we create an OR-module of all MCSs below the MCS limit (P is denoting the part below the MCS limit) – this can be added as a node to the BDD in a similar way
  - This will again lead to the same approximation as if BDD and MCUB parts are added and then the intersection subtracted.
- In fact – the event or module can be treated like any other event and be inserted into the BDD structure (Note that M is actually a BDD structure)





Basis for the improved algorithm

Including MUX

- Now, we observe that if we create different OR-modules – such that these are combined considering the other existing MUX events in the MCS (OR_A, OR_B etc)
  - Then such events can be inserted into the BDD structure in relevant places considering the other MUX events
- By this, the addition of the BDD and MCUB parts of the MCS list can consider the intersection of the overlapping parts – also when MUX is present

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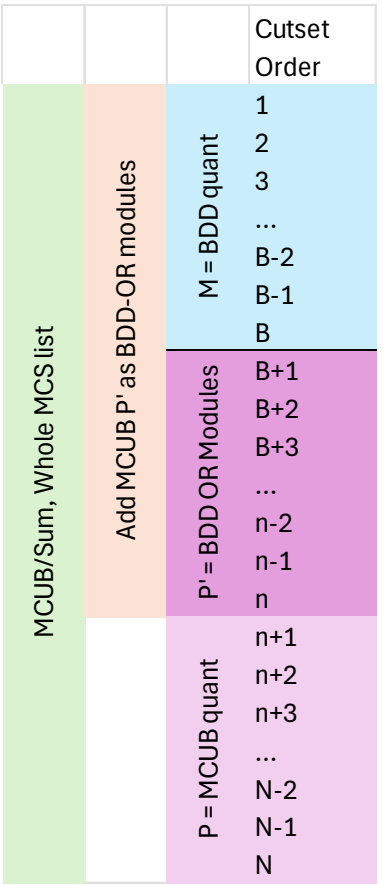
Conclusion

Conclusion

- We have introduced a potential accuracy issue in corner case scenarios – mostly relating to seismic risk in last intervals
- The solution is to modularize the part treated by MCUB into different OR modules and integrate them directly into the BDD structure
- MCS BDD approach is superior to MCUB cases, also in the corner case scenario



Thank you

Please contact:

sales@riskspectrum.com

ola.Backstrom@riskspectrum.com, pavel.krcal@riskspectrum.com