



# Cutting Edge T-Wise Sampling with ddnnife

Bachelor Thesis by Lars Licha, Supervised by Chico Sundermann, Sebastian Krieter | April 10, FOSD'24, Eindhoven, The Netherlands

# T-Wise Sampling

## Goal:

- Representative list of configurations
- Include all valid feature combinations of size  $t$

## Usage:

- Testing, analyzing, profiling, evaluation, ...

# T-Wise Sampling

## Goal:

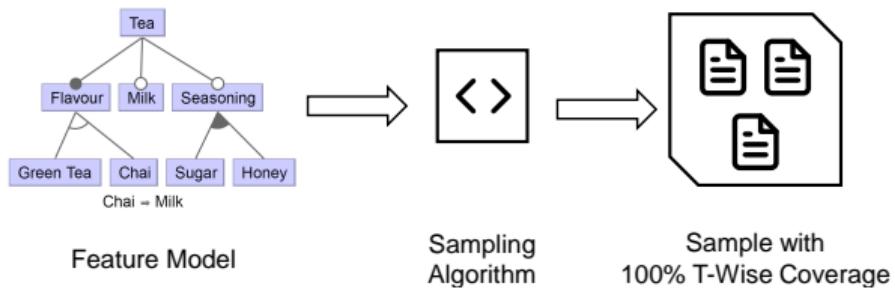
- Representative list of configurations
- Include all valid feature combinations of size  $t$

## Usage:

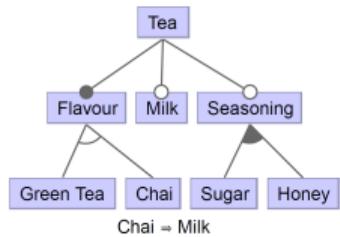
- Testing, analyzing, profiling, evaluation, ...

## Implementation:

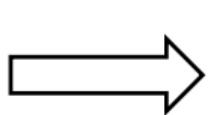
- Typically SAT-based



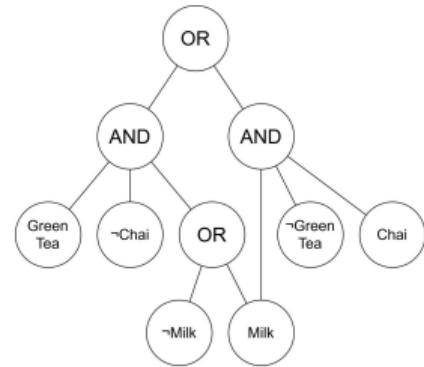
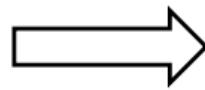
# Knowledge Compilation with d-DNNFs



Feature Model



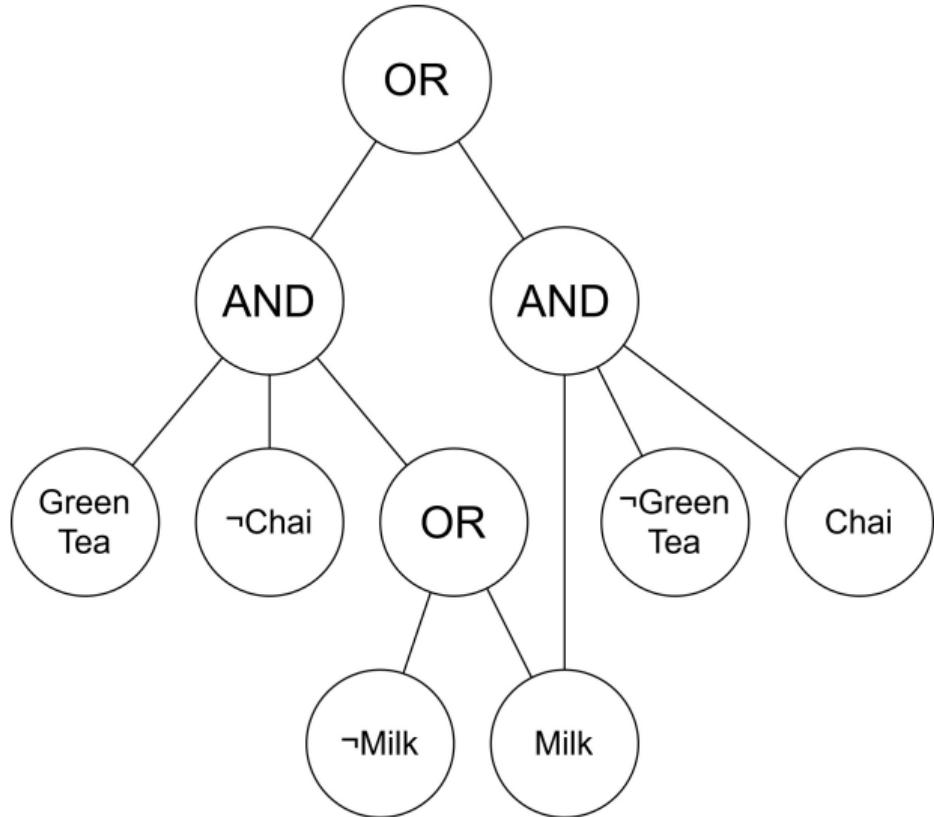
Knowledge  
Compiler



d-DNNF

# Knowledge Compilation with d-DNNFs

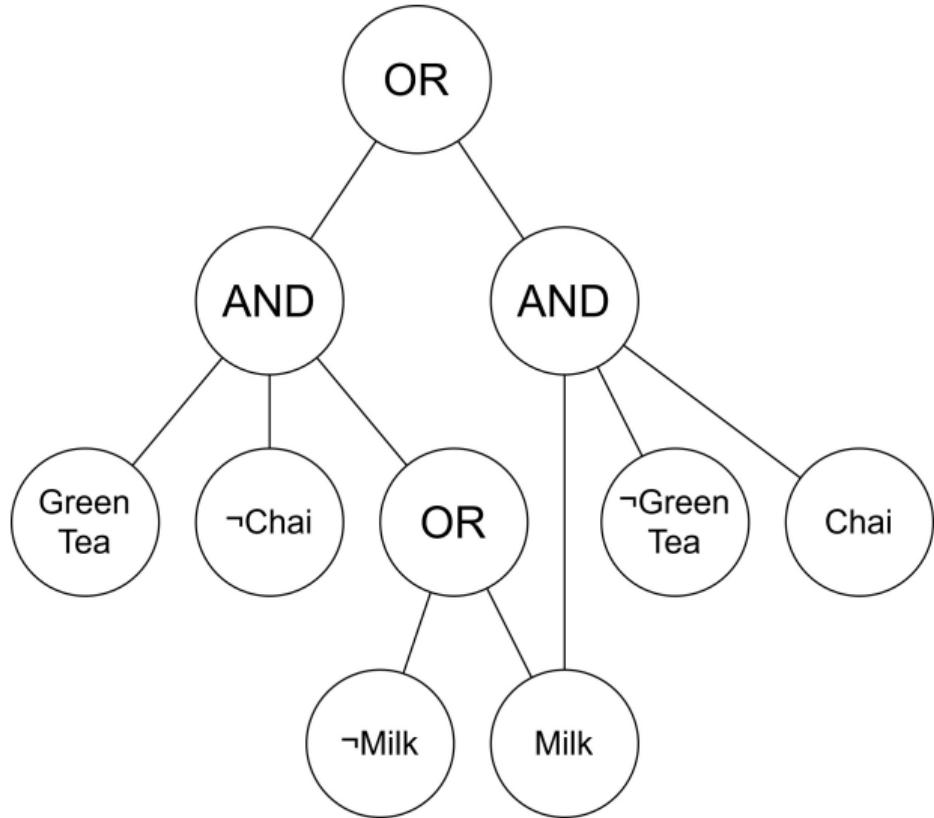
deterministic Decomposable Negation  
Normal Form



# Knowledge Compilation with d-DNNFs

deterministic Decomposable Negation Normal Form

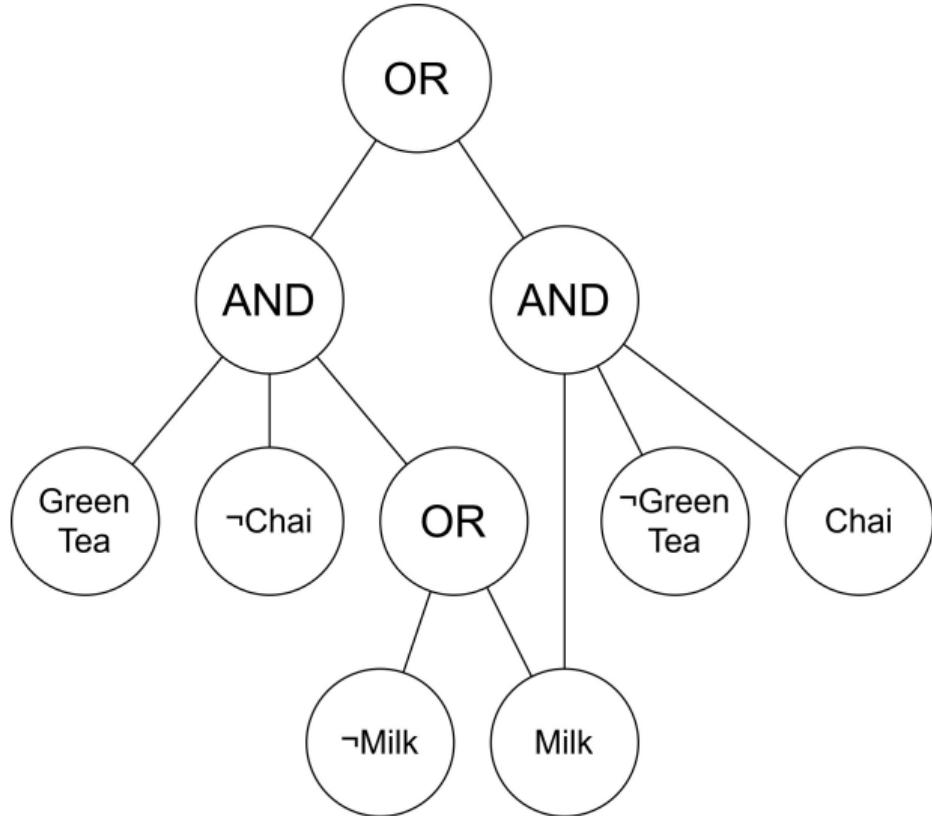
- Leaf nodes are literals
- AND children share no variables
- OR children share no valid assignments



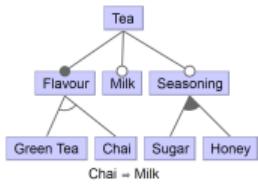
# Knowledge Compilation with d-DNNFs

deterministic Decomposable Negation Normal Form

- Leaf nodes are literals
  - AND children share no variables
  - OR children share no valid assignments
- ⇒ SAT and #SAT can be computed efficiently



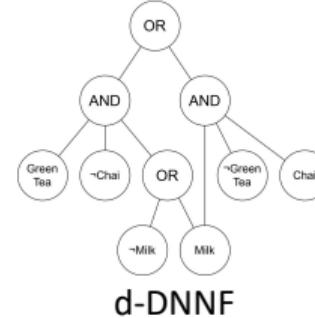
# T-Wise Sampling with d-DNNF



Feature Model

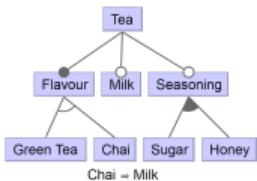


Knowledge  
Compiler

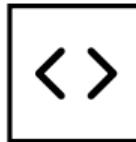


d-DNNF

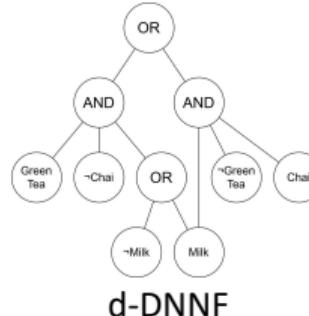
# T-Wise Sampling with d-DNNF



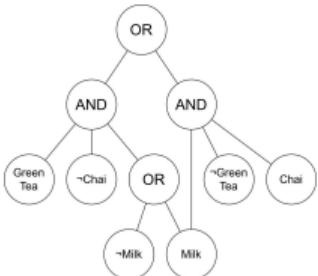
Feature Model



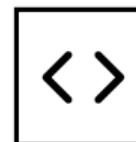
Knowledge  
Compiler



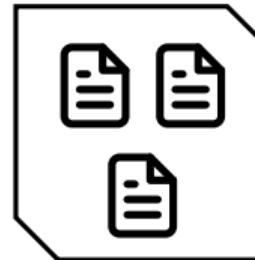
d-DNNF



d-DNNF



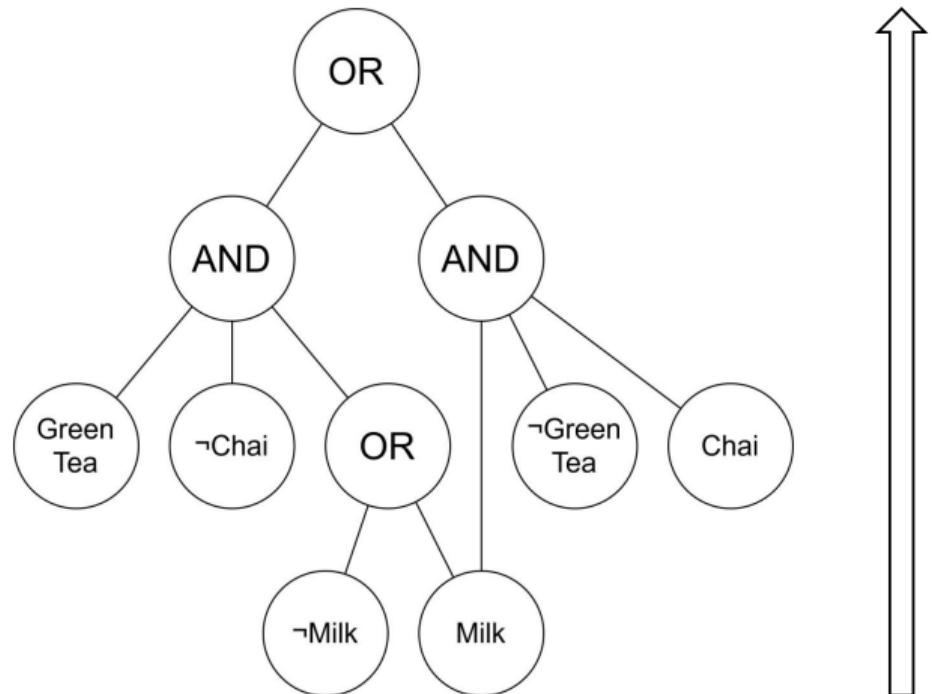
Sampling  
Algorithm



Sample with  
100% T-Wise Coverage

# General Idea

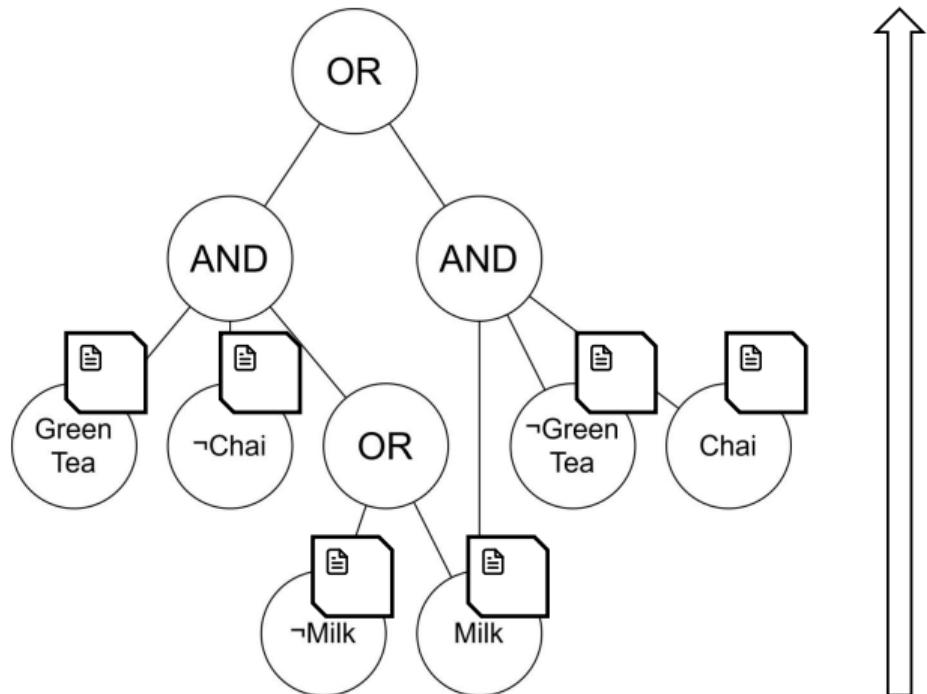
Use bottom-up approach



# General Idea

Use bottom-up approach

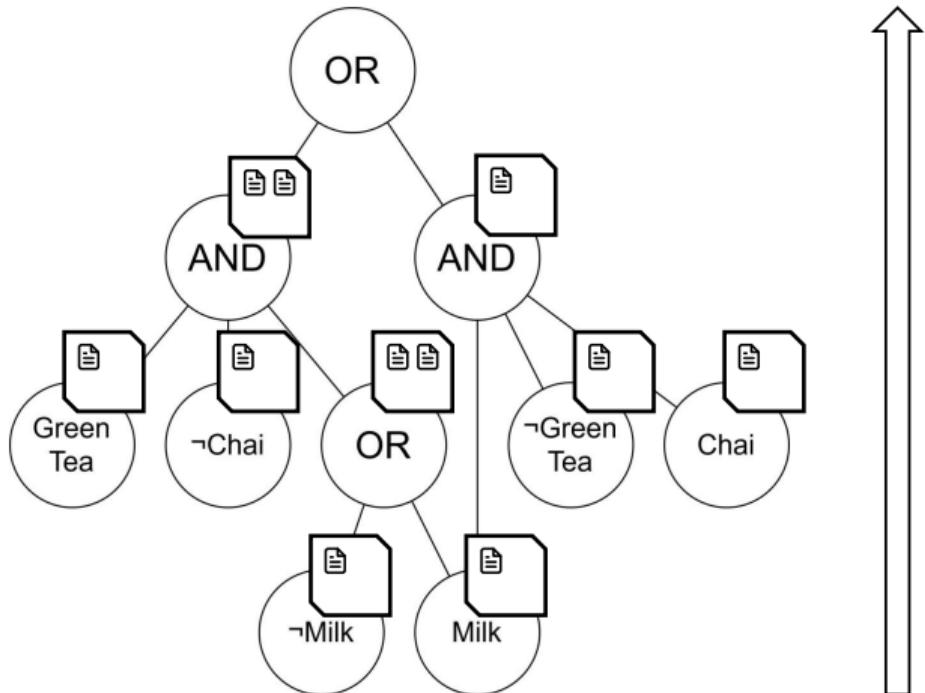
1. Create partial samples at leaf nodes



# General Idea

Use bottom-up approach

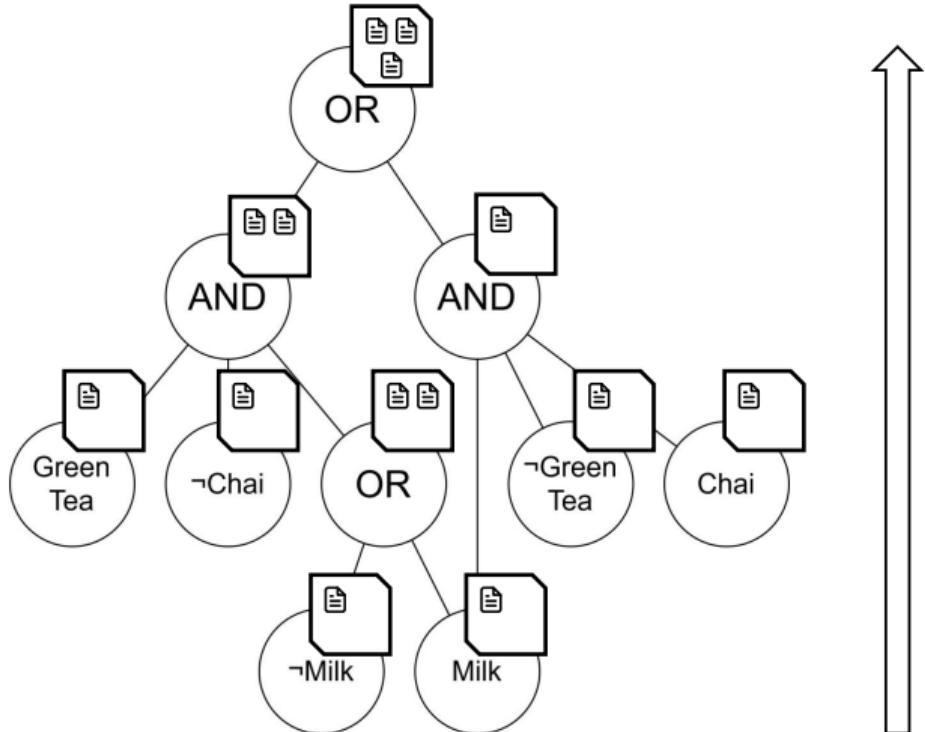
1. Create partial samples at leaf nodes
2. Merge partial samples at parent nodes
3. Extend partial sample for each parent node



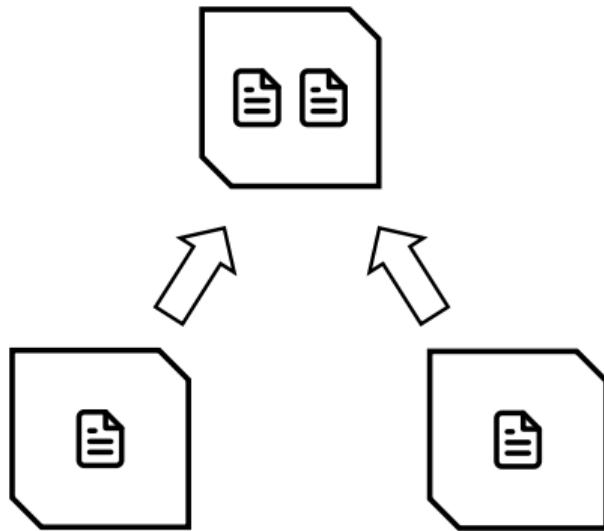
# General Idea

Use bottom-up approach

1. Create partial samples at leaf nodes
2. Merge partial samples at parent nodes
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4. Repeat 2–3 until root node yields complete t-wise sample



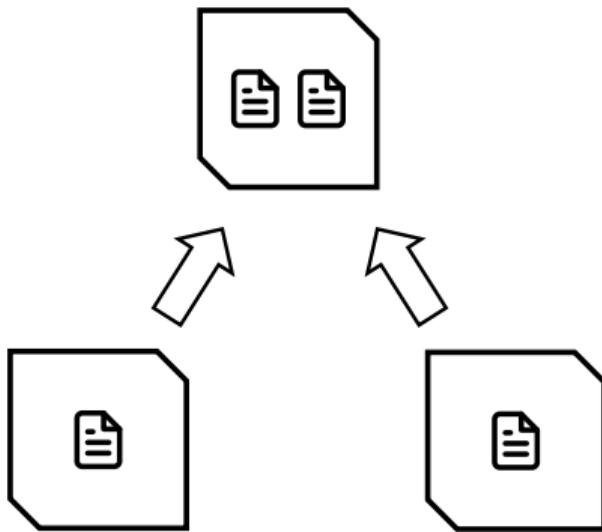
# Merging Samples at OR Nodes



**Merge:**

1. Build union of samples of children

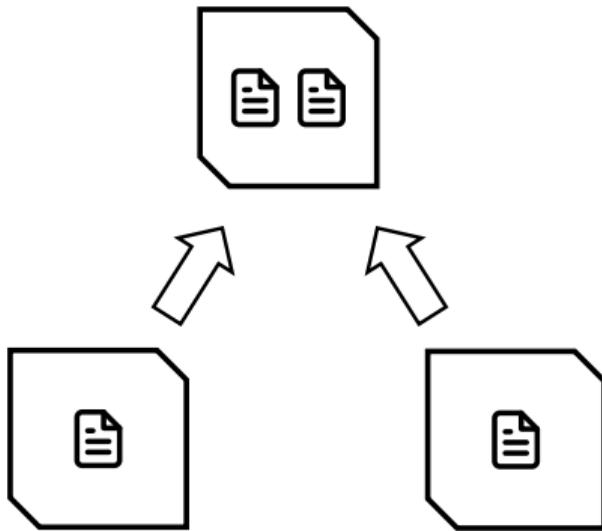
# Merging Samples at OR Nodes



## Merge:

1. Build union of samples of children
2. Remove redundant configurations
  - Uses greedy approach
  - Sort configurations with a heuristic
  - Add configurations to union sample one by one, ignoring configurations that cover no new tuples

# Merging Samples at OR Nodes



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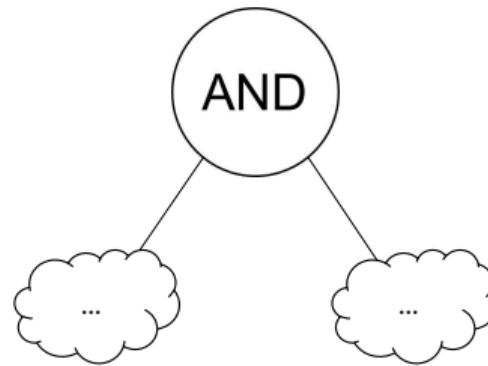
## Possible optimizations:

- Better utilization of OR-node property possible?
- Use non-local optimization (Consider nodes higher up in the d-DNNF graph)?

# Merging Samples at AND Node

Merge:

1. Combine configurations in partial samples

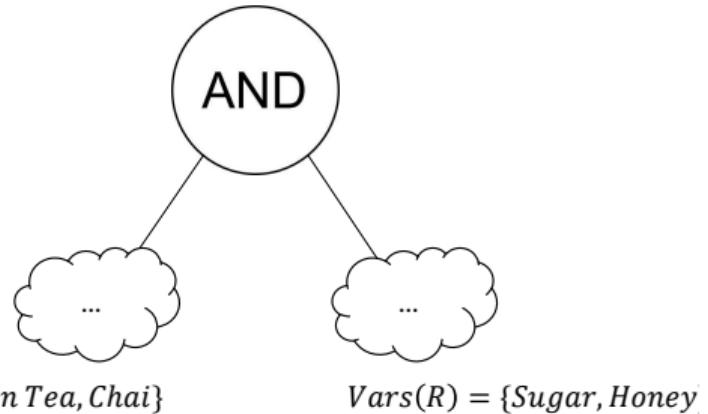


# Merging Samples at AND Node

Merge:

1. Combine configurations in partial samples

$$Vars(AND) = \{Green\ Tea, Chai, Sugar, Honey\}$$

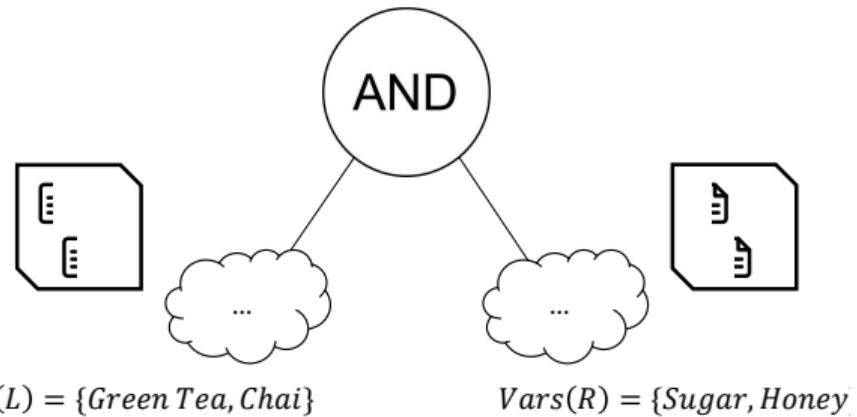


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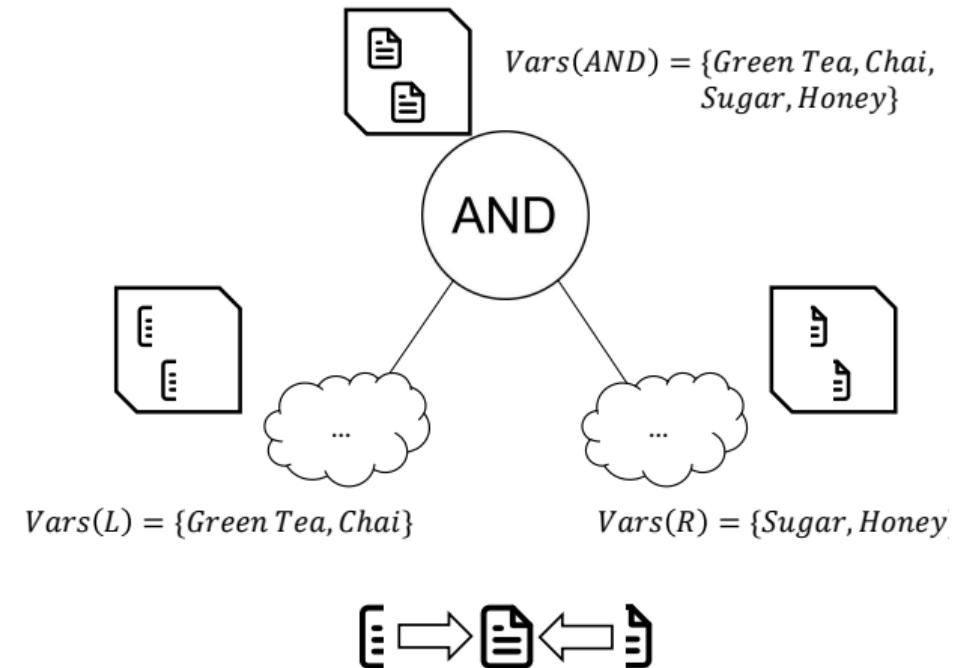
$$Vars(AND) = \{Green\ Tea, Chai, Sugar, Honey\}$$



# Merging Samples at AND Node

Merge:

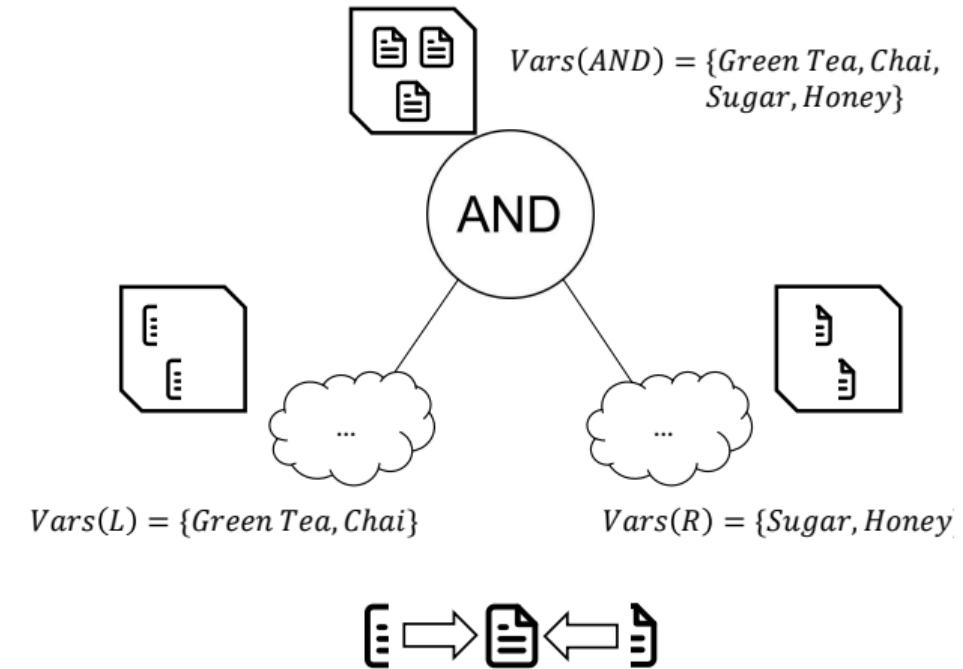
1. Combine configurations in partial samples



# Merging Samples at AND Node

Merge:

1. Combine configurations in partial samples
2. Create new configurations for missing tuples



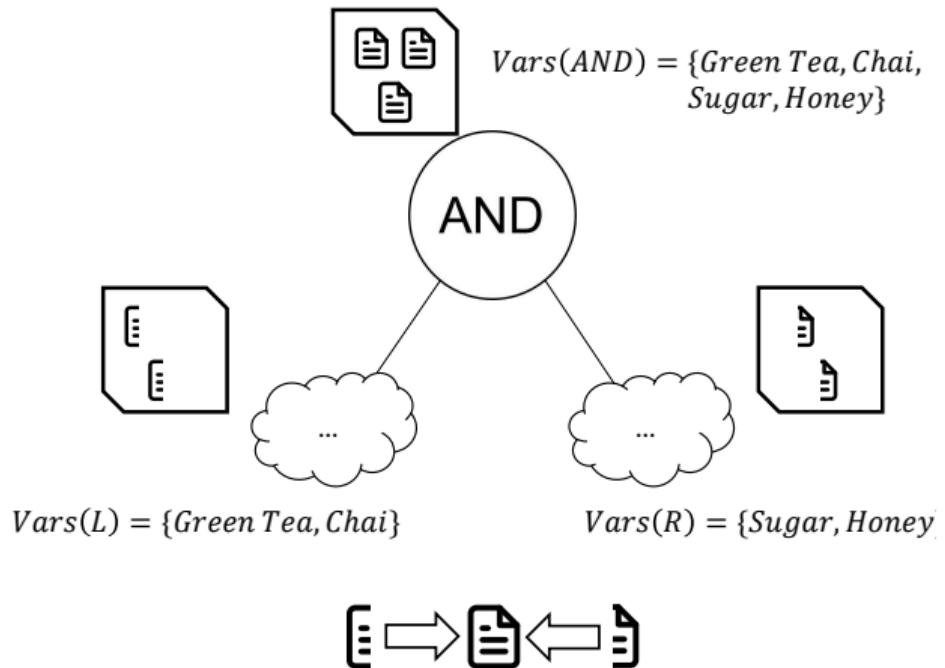
# Merging Samples at AND Node

Merge:

1. Combine configurations in partial samples
2. Create new configurations for missing tuples

Possible optimizations:

- Better matching strategy?
- Better strategy for finding new tuples?



# Comparison to SAT-Based Sampling

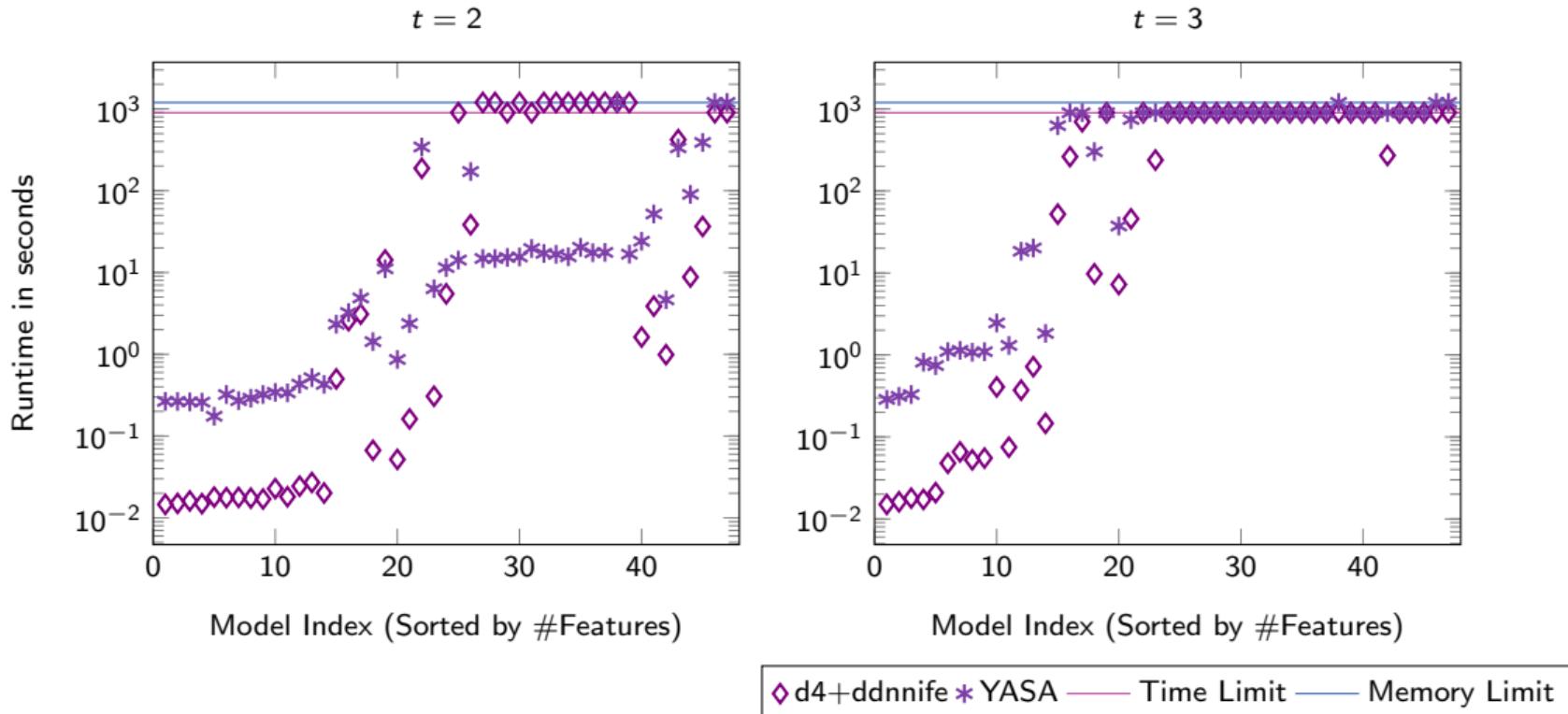
Sampling with  $t \in \{2, 3\}$ , comparing

- d4 + ddnnife
- YASA

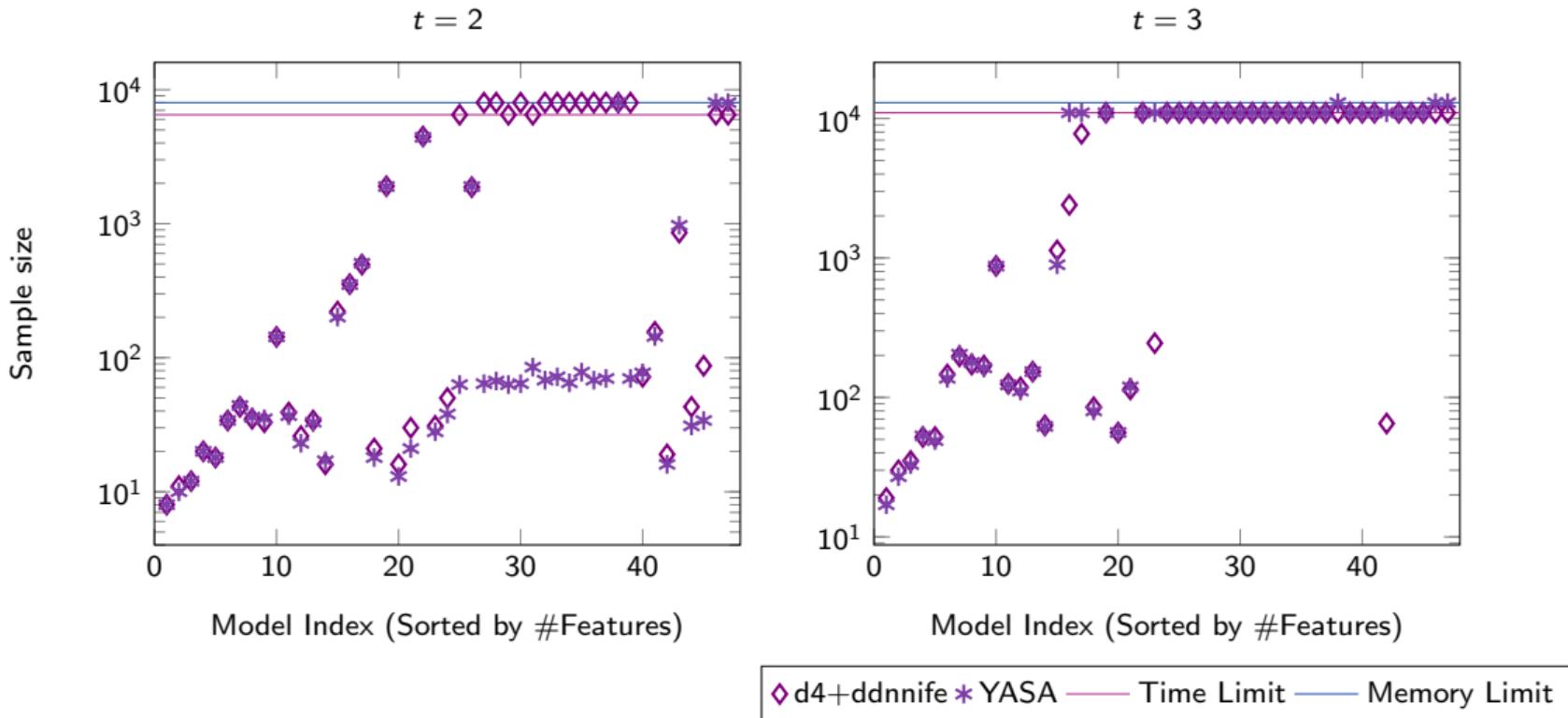
Using 47 different FMs, including

- Automotive01
- Automotive02
- BerkeleyDB
- FinancialServices
- 6 KConfig Systems
- 3 Models from CDL
- 34 Models from Smarch evaluation

# Comparison to SAT-Based Sampling (Sampling Time)

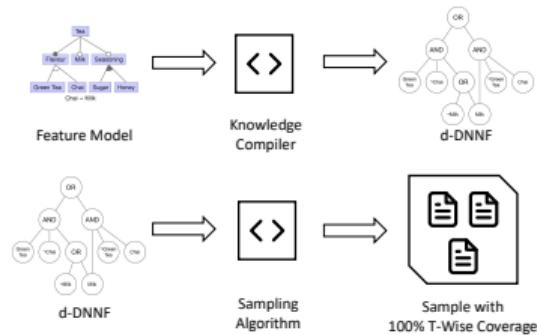


## Comparison to SAT-Based Sampling (Sample Size)

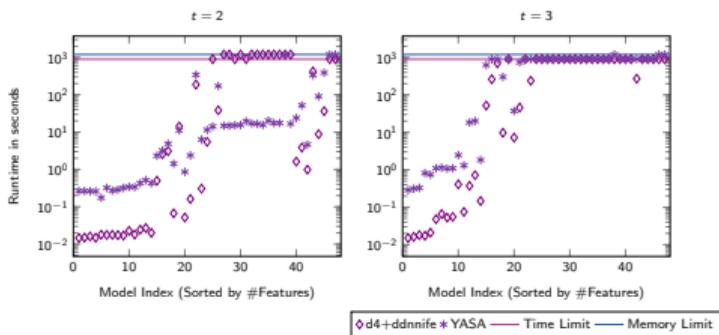


# Conclusion

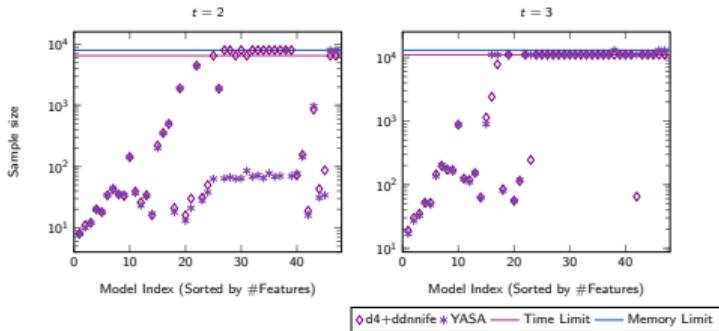
## T-Wise Sampling with d-DNNF



## Comparison to SAT-Based Sampling (Sampling Time)



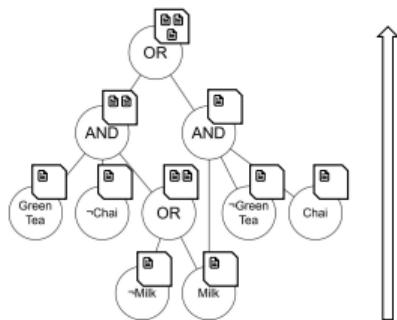
## Comparison to SAT-Based Sampling (Sample Size)



## General Idea

Use bottom-up approach

1. Create partial samples at leaf nodes
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## 1<sup>st</sup> ReVolution Workshop @ SPLC 2024

- Paper submission: **June 04**
- Paper notification: **June 28**
- Final Version: **July 10**

- Short ( $\leq 4$ ) and Full Papers ( $\leq 8$  pages)
- Position Paper
- Industrial Challenges and Lessons Learned
- Informal Tool Demos



**Sebastian Krieter**



**Sandra Greiner**



**Wesley Assuncao**



**Roberto Herrejon**



#re\_volution24