# Revisiting the c2d Knowledge Compiler

**Adnan Darwiche**

**Computer Science Department**

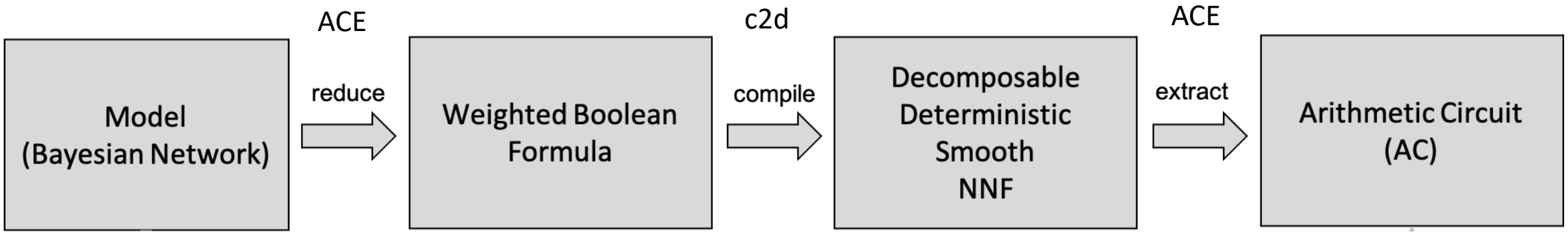
**UCLA**

# The c2d knowledge compiler

reasoning.cs.ucla.edu/c2d

- Compiles CNF into Decision-DNNF (+ other utilities)
- Released a real while back!
- Upcoming release: c2d version 3.0 (significant re-write of code)

- ACE uses various c2d options (some hidden, not in c2d manual).



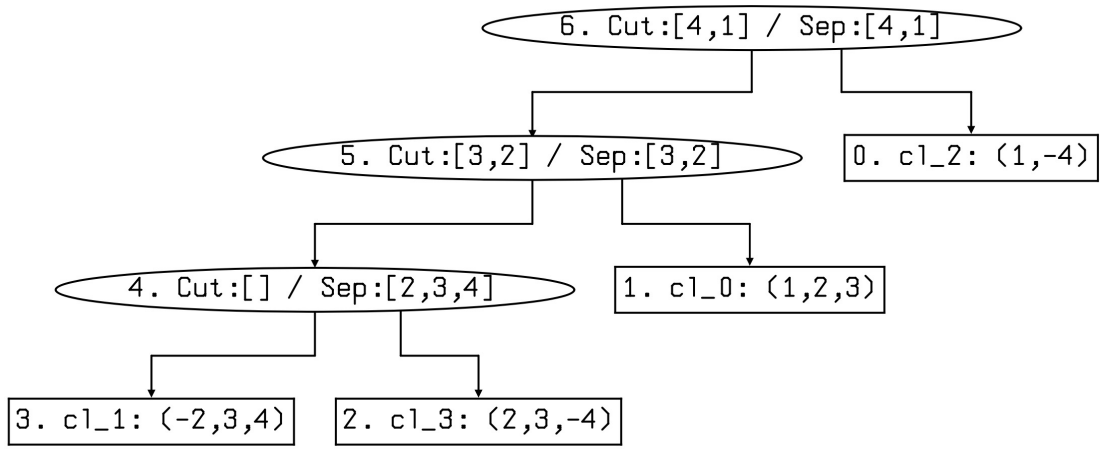

reasoning.cs.ucla.edu/ace

Durgesh Agrawal, Yash Pote, Kuldeep S. Meel:
**Partition Function Estimation: A Quantitative Study.** IJCAI-21

| Method Name | Problem Classes | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Relation-al (354) | Prome-das (65) | BN (60) | Ising (52) | Segment (50) | ObjDetect (35) | Protein (29) | Misc (27) | Total (672) |
| Ace | 354 | 65 | 60 | 51 | 50 | 0 | 16 | 15 | 611 |
| Fractional Belief Propagation (FBP) | 293 | 65 | 58 | 41 | 48 | 32 | 29 | 9 | 575 |
| Loopy Belief Propagation (BP) | 292 | 65 | 58 | 41 | 46 | 32 | 29 | 10 | 573 |
| Generalized Belief Propagation (GBP) | 281 | 65 | 36 | 47 | 40 | 34 | 29 | 9 | 541 |
| Edge Deletion Belief Propagation (EDBP) | 245 | 42 | 56 | 50 | 49 | 35 | 28 | 23 | 528 |
| GANAK | 353 | 58 | 53 | 4 | 0 | 0 | 7 | 14 | 489 |
| Double Loop Generalised BP (HAK) | 199 | 65 | 58 | 43 | 43 | 35 | 29 | 14 | 486 |
| Tree Expectation Propagation (TREEEP) | 101 | 65 | 58 | 50 | 48 | 35 | 29 | 15 | 401 |
| SampleSearch | 89 | 56 | 33 | 52 | 37 | 35 | 29 | 25 | 356 |
| Bucket Elimination (BE) | 98 | 32 | 15 | 52 | 50 | 35 | 29 | 22 | 333 |
| Conditioned Belief Propagation (CBP) | 109 | 32 | 21 | 41 | 50 | 35 | 29 | 8 | 325 |
| Join Tree (JT) | 98 | 32 | 15 | 52 | 50 | 19 | 26 | 21 | 313 |
| Dynamic Importance Sampling (DIS) | 24 | 65 | 25 | 52 | 50 | 35 | 29 | 27 | 307 |
| Weighted Mini Bucket Elimination (WMB) | 68 | 13 | 17 | 50 | 50 | 20 | 28 | 12 | 258 |
| miniC2D | 187 | 1 | 30 | 31 | 0 | 0 | 0 | 1 | 250 |
| WeightCount | 93 | 0 | 27 | 0 | 0 | 0 | 0 | 0 | 120 |
| WISH | 0 | 0 | 0 | 9 | 0 | 0 | 0 | 0 | 9 |
| FocusedFlatSAT | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 6 |

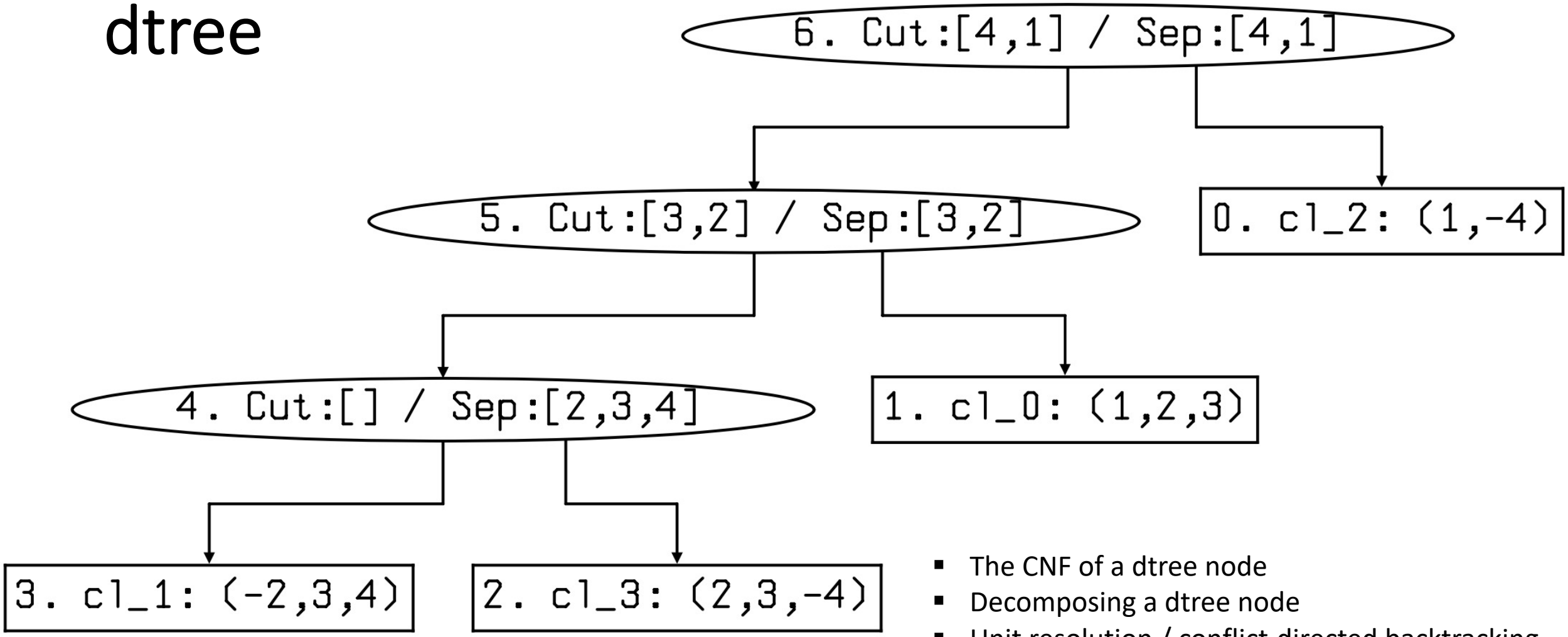
# Decomposition Strategy

- **dtree:** decomposition tree
- Has width (corresponds to treewidth)
- Two methods: minfill (fast), hypergraph partitioning (slow)
- Released version: 32-bit/hmetis
- Upcoming version 3.0: 64-bit/PaToH, new heuristic that chooses between previous two methods



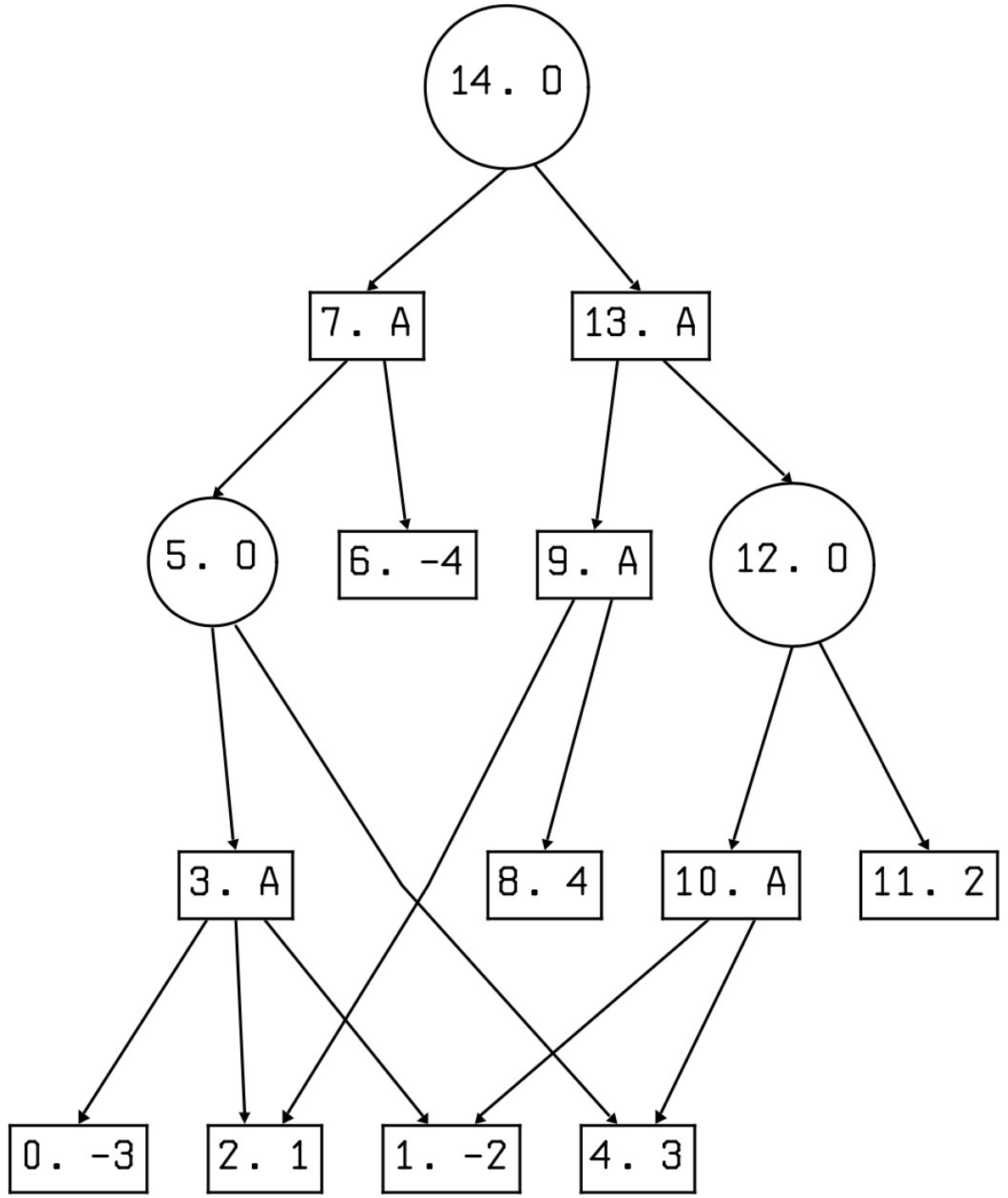

Adnan Darwiche:
**Modeling and Reasoning with Bayesian Networks.** Cambridge University Press 2009,

# dtree




- The CNF of a dtree node
- Decomposing a dtree node
- Unit resolution / conflict-directed backtracking
- Formula caching

# Decision-DNNF



# Formula Caching

- Var is relevant in (sub)dtree iff appears in unsubsumed clause of dtree
- If var is relevant, capture its state: true, false, free
- Need two bits for each var in CNF of (sub)dtree
- Cache key is a bit vector (two bits per var)

- Less complete than D4 caching scheme, but appears more space/time efficient (now experimenting with D4 caching scheme)
- Cache only before starting to decompose the CNF of a dtree node

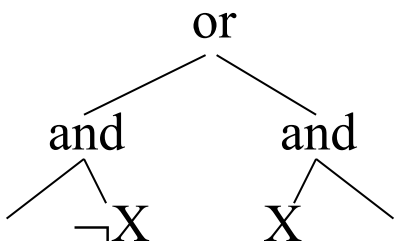
# Model Counting (on Decision-DNNF)

- Exact model counting (MC) using long integers (gmp)
- Exact weighted model counting (WMC) using rationals (gmp)
- Requires smoothing Decision-DNNF which can be a space bottleneck
- Exact model counting using rationals (no smoothing needed):
  - Each literal has weight ½
  - Multiply weighted model count by number of variable instantiations

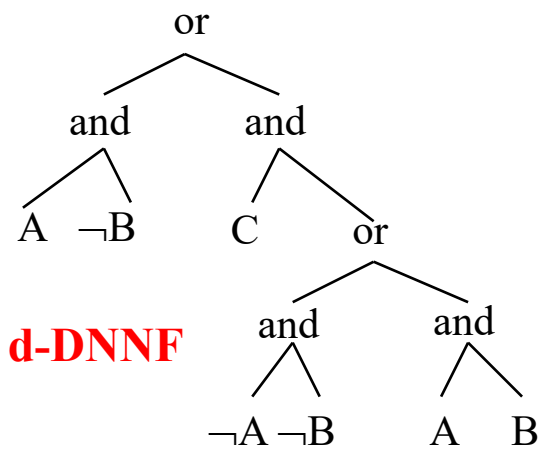
# New Feature in c2d v3.0?

Oztok & Darwiche, arXiv 2017

- Decomposability with general determinism

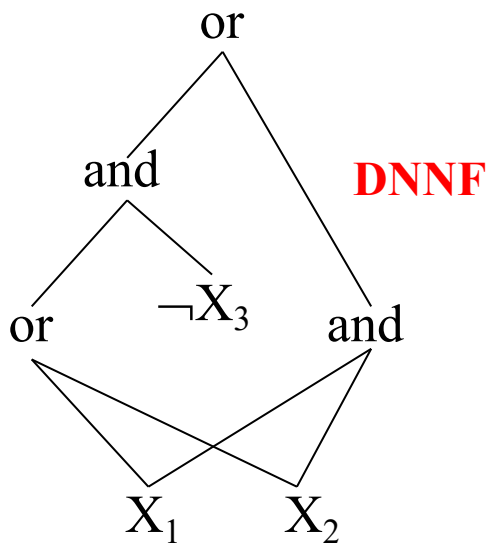



**Decision-DNNF**




**d-DNNF**

- Decomposability without determinism




**DNNF**

- Perhaps infrastructure that opens path for exploring heuristics for auxiliary variables

# Thank You

YouTube Channel


Branching on Formulas

A Perspective from Knowledge Compilation