

# Visualizing Dynamic Programming On Tree Decompositions

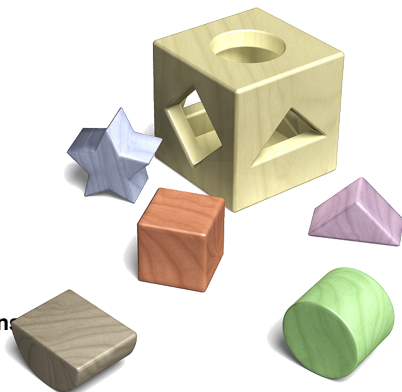
Martin Rübke

Fakultät Informatik

Technische Universität Dresden

Germany

- ▶ **REWORK AFTER CHAPTERS**
- ▶ **WHAT was the motivation**
- ▶ **WHAT could be used otherwise?**
- ▶ **WHO benefits from visualization?**
- ▶ **METHODOLOGY challenges and solutions**
- ▶ **WHAT could be developed next?**



*"Logic is everywhere ..."*

## Motivation

- ▶ DP-on-TD-algorithms can solve Model Counting and various combinatorial problems
- ▶ Implementations of those are competing with modern solvers
- ▶ **But:** those are fairly hard to implement efficiently
- ▶ Practical debug output quickly becomes very large (GB)
- ▶ Finding the cause of the problem is a time consuming challenge

## Background

The algorithms of interest solve problems of:

- ▶ **combinatorics (NP-problems)**
- ▶ **model-counting (#P-problems)**

Recent promising results for Projected Model Counting by Markus Hecher<sup>1</sup>.

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<sup>1</sup>Hecher M., Thier P., Woltran S. (2020) Taming High Treewidth with Abstraction, Nested Dynamic Programming, and Database Technology. In: Pulina L., Seidl M. (eds) Theory and Applications of Satisfiability Testing - SAT 2020. SAT 2020. Lecture Notes in Computer Science, vol 12178. Springer, Cham. [https://doi.org/10.1007/978-3-030-51825-7\\_25](https://doi.org/10.1007/978-3-030-51825-7_25)

# Tree Decompositions

A tree decomposition is a tree obtained from an arbitrary graph s.t.

1. **Each vertex must occur in some bag**
2. **For each edge, there is a bag containing both endpoints**
3. **Connected: Subgraph “restricted” to any vertex must be connected**

Graphic

# Graphs for Boolean Formulas

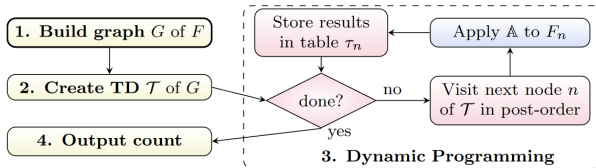
## ► Example set of CNF-clauses:

$\{c_1 = \{v_1, v_3, \neg v_4\}, c_2 = \{\neg v_1, v_6\}, c_3 = \{\neg v_2, \neg v_3, \neg v_4\}, c_4 = \{\neg v_2, v_6\}, c_5 = \{\neg v_3, \neg v_4\}, c_6 = \{\neg v_3, v_5\}, c_7 = \{\neg v_5, \neg v_6\}, c_8 = \{v_5, v_7\}\}$



Figure: The primal (left), incidence (middle) and dual (right) graph

## gpusat2 - Solving on GPU



- Customized tree decompositions
- Adapted memory-management
- Improved precision handling



<sup>1</sup>Images: Markus Zisser. *Solving the #SAT problem on the GPU with dynamic programming and OpenCL*. Technische Universität Wien, 2018.

## Database templates in Python Generating SQL queries

1. Create graph representation
2. Decompose graph
3. Solve sub-problems
4. Combine rows

- ▶ **SAT and #SAT**
- ▶ **#o-Coloring**
- ▶ **Vertex cover**

...

```

- #εTab#:          SELECT 1 AS cnt
- #intrTab#:       SELECT 1 AS val UNION ALL 0
- #localProbFilter#: (l1,1 OR ... OR l1,k1) AND ... AND (ln,1 OR ... OR ln,kn)
- #aggrExp#:       SUM(cnt) AS cnt
- #extProj#:       τ1.cnt * ... * τℓ.cnt AS cnt

```

### (a) Problem #SAT

```

- #εTab#:          SELECT 0 AS card
- #intrTab#:       SELECT 1 AS val UNION ALL 0
- #localProbFilter#: ([a1] OR [v1]) AND ... AND ([an] OR [vn])
- #aggrExp#:       MIN(card) AS card
- #extProj#:       τ1.card + ... + τℓ.card - (Σi=1ℓ |χ(ti) ∩ {a1}| - 1) *
                  τ1. [a1] - ... - (Σi=1ℓ |χ(ti) ∩ {ak}| - 1) * τ1. [ak]

```

### (b) Problem MinVC

## Diff. debug information and problem types

Display user-defined strings where applicable  
Different ?????? Grafik bag, Grafik solution

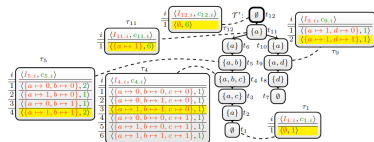
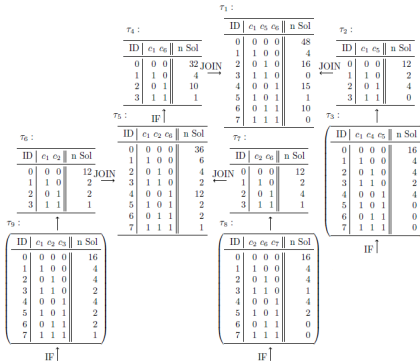


## Challenge2

## Challenge3

## Visualization

### Manually for one run

dpdb????<sup>2</sup>

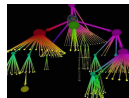
<sup>2</sup>"Solving #SAT on the GPU with Dynamic Programming and OpenCL",  
Diploma Markus Zisser 2018 Technische Universität Wien, p.33



© Gephi.org - a tool for data analysts and scientists keen to explore and understand graphs.<sup>3</sup>



LaBRI  
université  
BORDEAUX



Tulip - Better Visualization Through Research.<sup>4</sup>



<sup>5</sup> Vis.js



Sigma.js



vasturiano/3d-force-graph<sup>6</sup>

=<sub>2</sub> Related Work Schluss / Wiss Arbeiten -<sub>2</sub> Nicht speziell Angeschaut / Format aus Solvern extrahiert - kann trotzdem sehr generisch sein (dpdb speziell)

<sup>3</sup><https://gephi.org/>

<sup>4</sup><https://tulip.labri.fr/TulipDrupal/>

<sup>5</sup><https://neo4j.com/developer/tools-graph-visualization/>

## Outlook

for relevant problems the static graph visualization will become to complicated.

<https://data-science-blog.com/blog/2015/07/20/3d-visualisierung-von-graphen/>

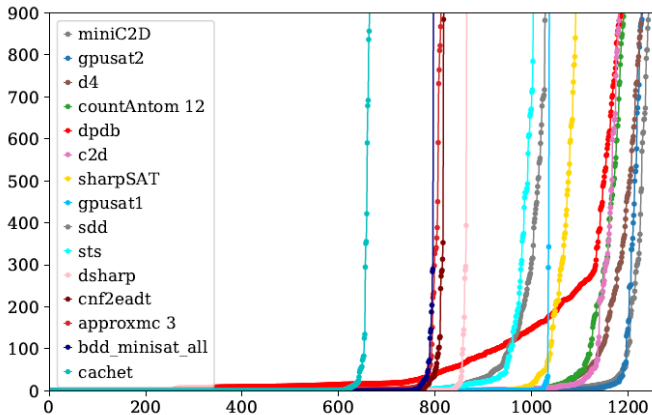
=¿ Automatische Methoden werden häufig schwerer als gedacht.

Für tiefere Debugging Tasks müsste evtl auch der Ansatz erneuert werden

=¿ Was wären weitere Fragestellungen was man ansehen möchte

## Benchmark

Performance of all three programs on #SAT instances:



## Visualization

## Manually for dpdb

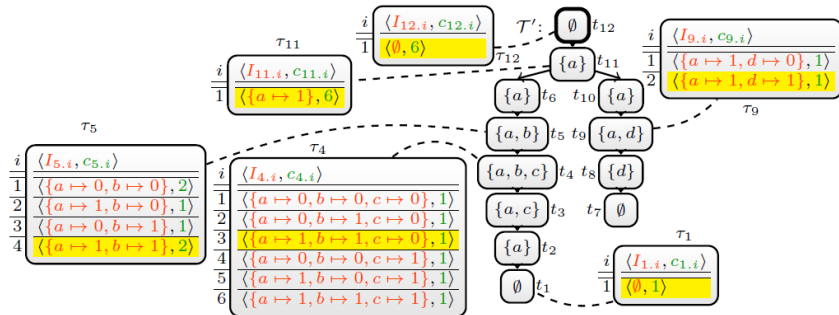


Figure: Handcrafted #SAT example-run from dpdb<sup>7</sup>

<sup>7</sup>"Exploiting Database Management Systems and Treewidth for Counting", Fichte, Hecher, Thier, Woltran

## Bibliography



