Visualizing Dynamic Programming On Tree Decompositions

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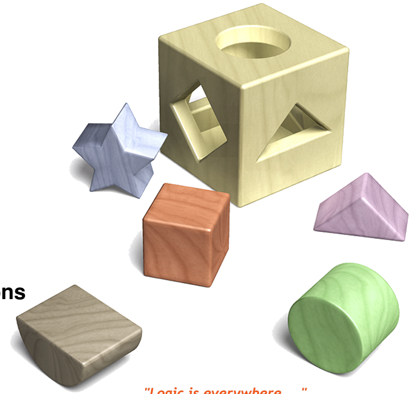
- WHAT **was the motivation**
- WHAT **could be used otherwise?**
- WHO **benefits from visualization?**
- METHODOLOGY **challenges and solutions**
- WHAT **could be developed next?**



"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 soon gets very large**
- **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 a colleague Markus Hecher.

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**

Graphs for Boolean Formulas

- **Example set of CNF-clauses:**

{c1 = {v1, v3, ¬v4}, c2 = {¬v1, v6}, c3 = {¬v2, ¬v3, ¬v4}, c4 = {¬v2, v6}, c5 = {¬v3, ¬v4}, c6 = {¬v3, v5}, c7 = {¬v5, ¬v6}, c8 = {v5, v7}}

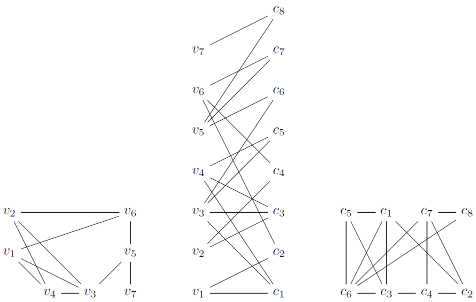


Figure: The primal (left), incidence (middle) and dual (right) graph

gpusat2 - Improving Upon Previous Ideas

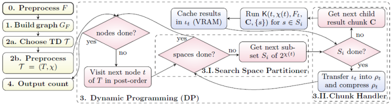


Figure 1: Architecture of our DP-based solver for parallel execution. Yellow colored boxes indicate tasks that are required as initial step for the DP-run or to finally read the model count from the computed results. The parts framed by a dashed box illustrate the DP-part. Boxes colored in red indicate computations that run on the CPU. Boxes colored in blue indicate computations that are executed on the GPU (with waiting CPU).

- **only primal graph (simpler solving DP)**
- **customized tree decompositions**
- **adapted memory-management**
- **improved precision handling**

dpdb

Using databases for intermediate results

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

Generator SQL Qs =¿ Datenbank Templating in Python

- **SAT**
- **#SAT**
- **Vertex cover**

– #εTab#: `SELECT 1 AS cnt`
– #intrTab#: `SELECT 1 AS val UNION ALL 0`
– #localProbFilter#: $(l_{1,1}$ `OR` … `OR` $l_{1,k_1})$ `AND` … `AND` $(l_{n,1}$ `OR` … `OR` $l_{n,k_n})$
– #aggrExp#: `SUM(cnt) AS cnt`
– #extProj#: τ_1`.cnt *` … `*` τ_ℓ`.cnt AS cnt`

(a) Problem #SAT

– #εTab#: `SELECT 1 AS cnt`
– #intrTab#: `SELECT 1 AS val UNION ALL` … `UNION ALL` o
– #localProbFilter#: `NOT` $([\![u_1]\!] = [\![v_1]\!])$ `AND` … `AND NOT` $([\![u_n]\!] = [\![v_n]\!])$
– #aggrExp#: `SUM(cnt) AS cnt`
– #extProj#: τ_1`.cnt *` … `*` τ_ℓ`.cnt AS cnt`

(b) Problem #o-Col

– #εTab#: `SELECT 0 AS card`
– #intrTab#: `SELECT 1 AS val UNION ALL 0`
– #localProbFilter#: $([\![u_1]\!]$ `OR` $[\![v_1]\!])$ `AND` … `AND` $([\![u_n]\!]$ `OR` $[\![v_n]\!])$
– #aggrExp#: `MIN(card) AS card`
– #extProj#: τ_1`.card +` … `+` τ_ℓ`.card -` $(\Sigma_{i=1}^{\ell}|\chi(t_i) \cap \{a_1\}|$ `- 1) *` $\tau_1.[\![a_1]\!]$ `-` … `-` $(\Sigma_{i=1}^{\ell}|\chi(t_i) \cap \{a_k\}|$ `- 1) *` $\tau_1.[\![a_k]\!]$

(c) Problem MinVC

github: `https://github.com/hmarkus/dp_on_dbs`

Challenge1

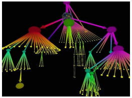
Generisches Datenformat /Strings Visu
Arbeits Space groß
=¿ Anwendungen

Challenge2

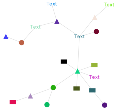
=¿ Wie robust ist die Datenverarbeitung in der Visu =¿ Was Gedanken bei der Visu waren

Challenge3

© Gephi.org - a tool for data analysts and scientists keen to explore and understand graphs.[1]



Tulip - Better Visualization Through Research. [2]



[3] Vis.js Sigma.js vasturiano/3d-force-graph [4]

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

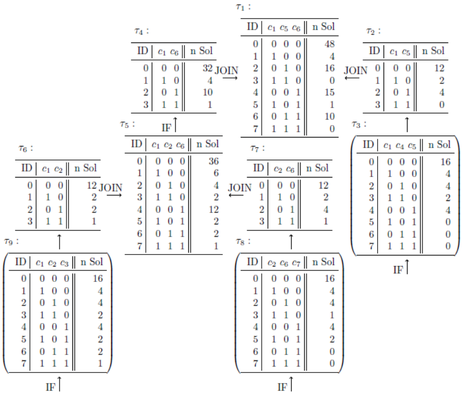
[1] https://gephi.org/

[2] https://tulip.labri.fr/TulipDrupal/

[3] https://neo4j.com/developer/tools-graph-visualization/

Visualization

Manually for gpusat



τ_1:

ID	c_1	c_5	c_6	n Sol
0	0	0	0	48
1	1	0	0	4
2	0	1	0	16
3	1	1	0	0
4	0	0	1	15
5	1	0	1	1
6	0	1	1	10
7	1	1	1	0

τ_4:

ID	c_1	c_6	n Sol
0	0	0	32
1	1	0	4
2	0	1	10
3	1	1	1

τ_2:

ID	c_1	c_5	n Sol
0	0	0	12
1	1	0	2
2	0	1	4
3	1	1	0

τ_5:

ID	c_1	c_2	c_6	n Sol
0	0	0	0	36
1	1	0	0	6
2	0	1	0	4
3	1	1	0	2
4	0	0	1	12
5	1	0	1	2
6	0	1	1	2
7	1	1	1	1

τ_3:

ID	c_1	c_4	c_5	n Sol
0	0	0	0	16
1	1	0	0	4
2	0	1	0	4
3	1	1	0	2
4	0	0	1	4
5	1	0	1	0
6	0	1	1	0
7	1	1	1	0

τ_6:

ID	c_1	c_2	n Sol
0	0	0	12
1	1	0	2
2	0	1	2
3	1	1	1

τ_7:

ID	c_2	c_6	n Sol
0	0	0	12
1	1	0	2
2	0	1	4
3	1	1	1

τ_9:

ID	c_1	c_2	c_3	n Sol
0	0	0	0	16
1	1	0	0	4
2	0	1	0	4
3	1	1	0	2
4	0	0	1	4
5	1	0	1	2
6	0	1	1	2
7	1	1	1	1

τ_8:

ID	c_2	c_6	c_7	n Sol
0	0	0	0	16
1	1	0	0	4
2	0	1	0	4
3	1	1	0	1
4	0	0	1	4
5	1	0	1	2
6	0	1	1	0
7	1	1	1	0

Figure: Handcrafted #SAT example-run from Markus Zisser[5]

=¿ Dynamic programming Grafiken / Verlaufsschema Kurz erklären -¿ Beweise dazu sind aufwändig und recht speziell /

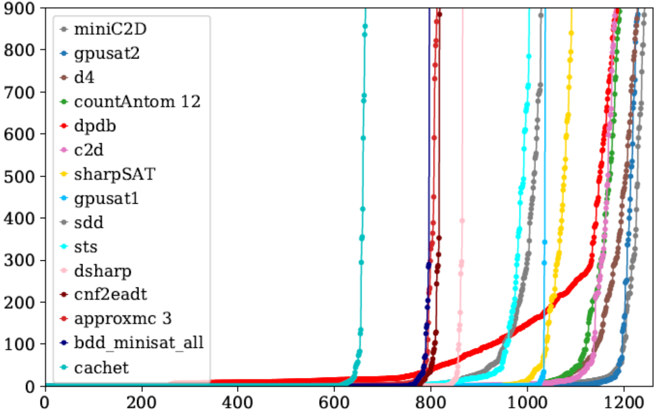
[5] "Solving #SAT on the GPU with Dynamic Programming and OpenCL",

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

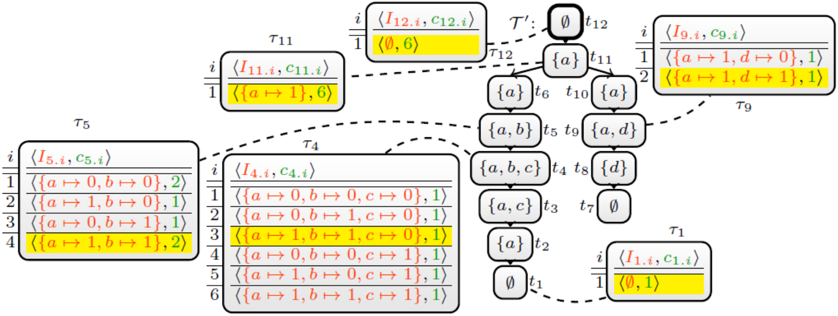


Figure: Handcrafted #SAT example-run from dpdb[6]

[6] "Exploiting Database Management Systems and Treewidth for Counting", Fichte, Hecher, Thier, Woltran

Bibliography