Efficient Computation of Parsimonious Temporal Aggregation

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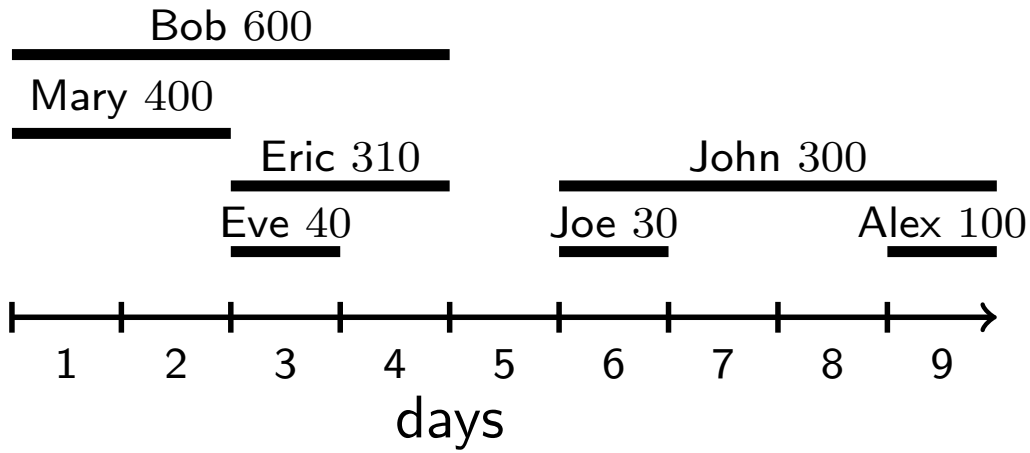
Outline

Instant Temporal Aggregation (ITA)

Patient treatment periods with daily cost

	P	C	T
r_1	Bob	600	[1,4]
r_2	Mary	400	[1,2]
r_3	Eve	40	[3,3]
r_4	Eric	310	[3,4]
r_5	Joe	30	[6,6]
r_6	John	300	[6,9]
r_7	Alex	100	[9,9]



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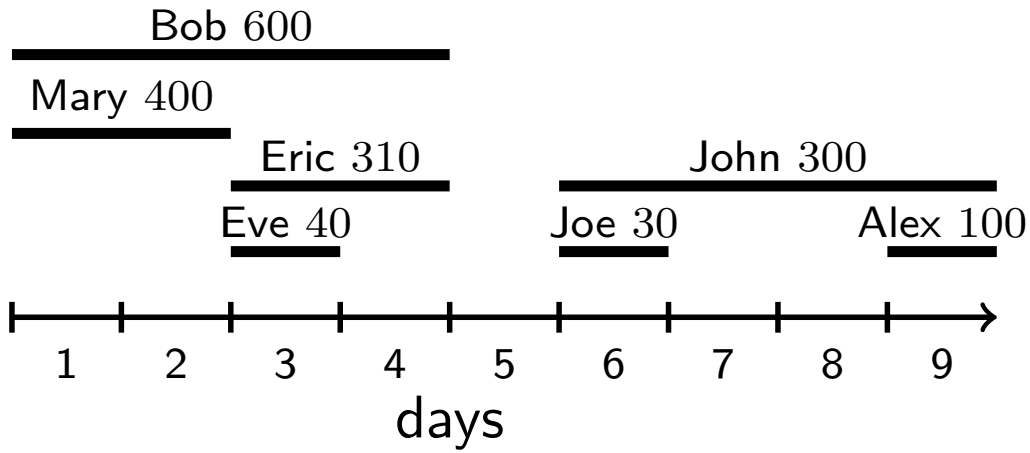
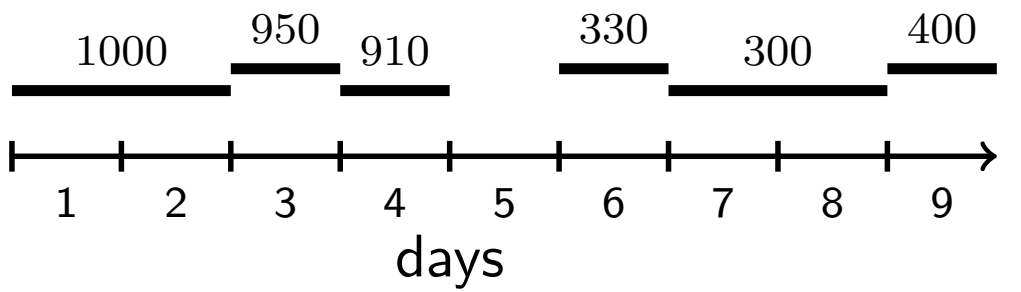


ITA: at each timepoint SUM(C)

	Val	T
s_1	1000	[1,2]
s_2	950	[3,3]
s_3	910	[4,4]
s_4	330	[6,6]
s_5	300	[7,8]
s_6	400	[9,9]

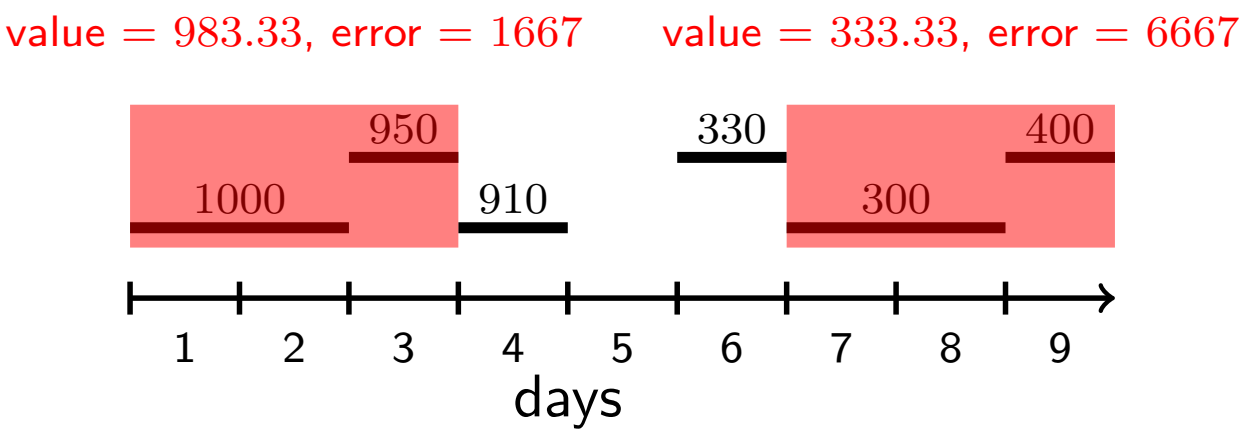


Parsimonious Temporal Aggregation (PTA)

Input: ITA result
Output: merged tuples to size c with minimum error

Rules:

- Merge only adjacent tuples
- Merged values are weighted mean
- Error is Squared Sum Error
- Result is of size c



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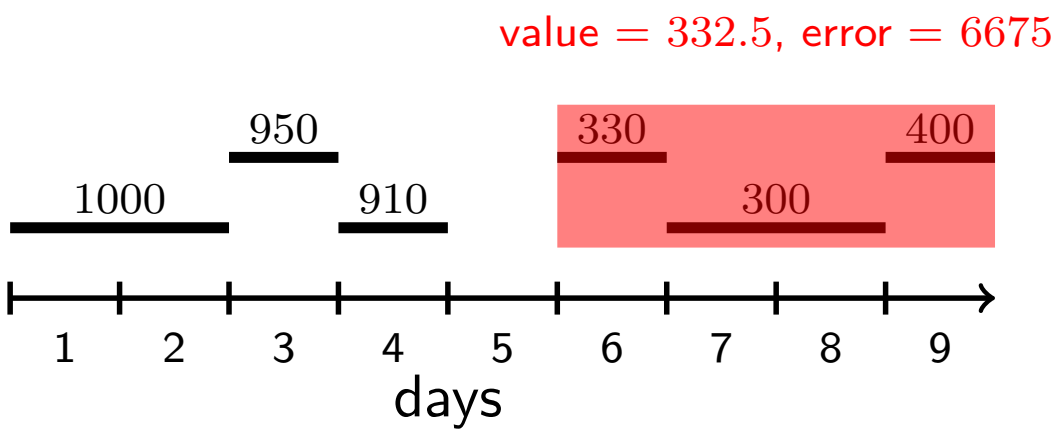
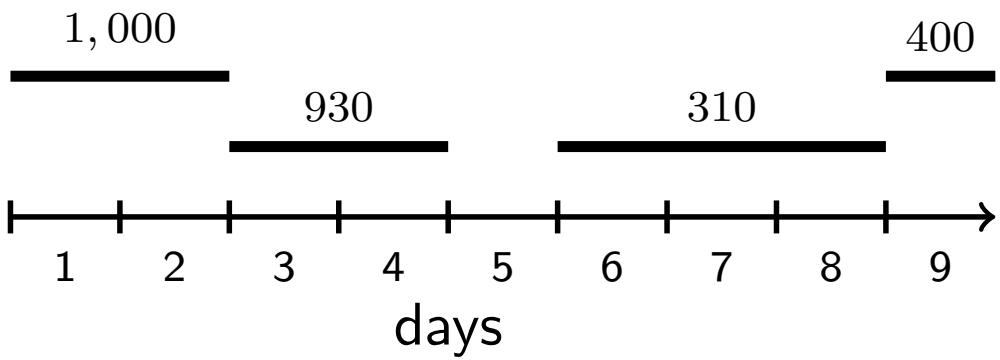


PTA Optimal Solution

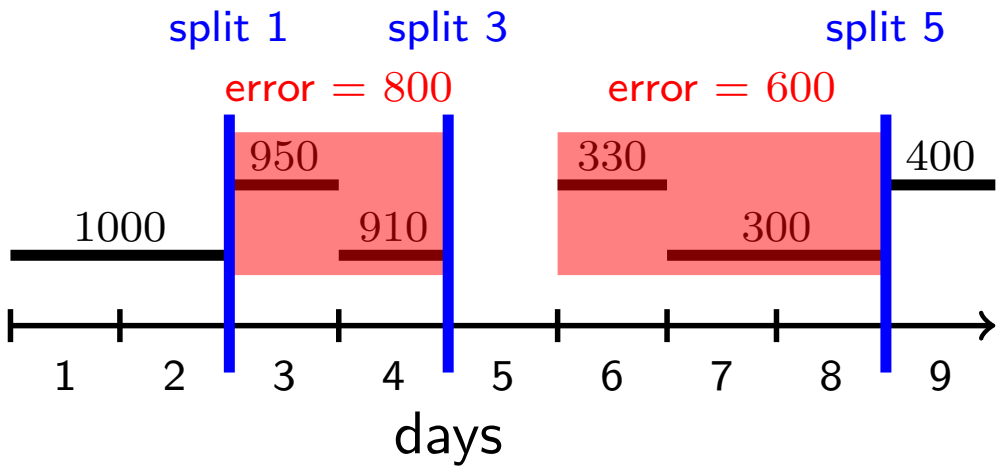
Result of ITA for SUM(C) (size $n = 6$)

Result PTA ($c = 4$) total error 1,400 (optimal solution)

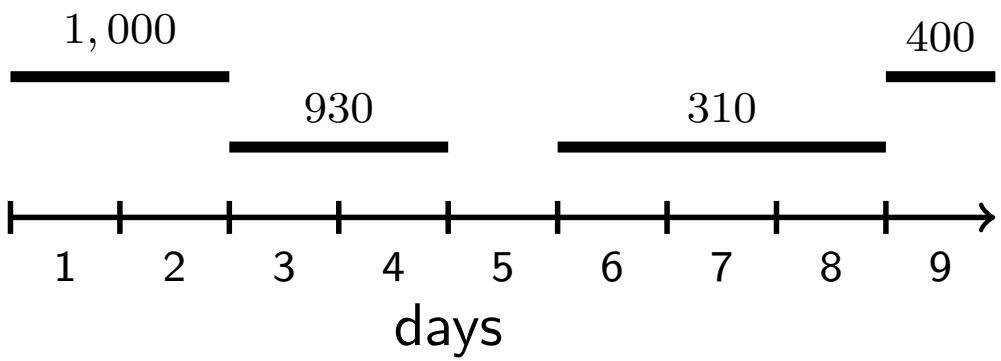


Split Points / Split Path

- PTA computes a split path (sequence of split points)
- Tuples between split points are merged



Split Path: [1, 3, 5]



PTA Existing Algorithm

Dynamic Programming Algorithm

Error Matrix $\mathbf{E}$

	i=1	2	3	4	5	6
k=1	0	1667	5700	∞	∞	∞
2	-	0	800	5700	6300	12375
3	-	-	0	800	1400	6300
4	-	-	-	0	600	1400

$\mathbf{E}_{i,k}$ minimum error in reducing the first i tuples to size k

only the last two rows are used

Split Point Matrix $\mathbf{J}$

	i=1	2	3	4	5	6
k=1	0	0	0	0	0	0
2	0	1	1	3	3	3
3	0	0	2	3	3	5
4	0	0	0	3	3	5

$\mathbf{J}_{i,k}$ optimum split point when reducing the first i tuples to size k

whole matrix

Problem and Contribution

Problem

- Runtime and space requirements of existing algorithm not scalable

Contribution

- **Diagonal Pruning**: Reduces the computational complexity by avoiding unnecessary computations
- **Split Point Graph**: Reduces the space complexity
- Result remains **optimal**

Diagonal Pruning

Lemma (Diagonal Pruning)

For the computation of the error matrix $\mathbf{E}$ *and split point matrix* $\mathbf{J}$ *there exists an upper bound for variable* i*.*

	i=1	2	3	4	5	6
k=1	0	0	0	0	0	0
2	-	1	1	3	3	3
3	-	-	2	3	3	5
4	-	-	-	3	3	5

- Red cells can be avoided, reduces runtime
- allows to eliminate parts of the matrices, reduces memory

Introduction

Diagonal Pruning

Split Point Graph

Experimental Evaluation

Split Point Graph

Challenge

Substitution of Split Point Matrix $\mathbf{J}$ by alternative structure to reduce memory consumption

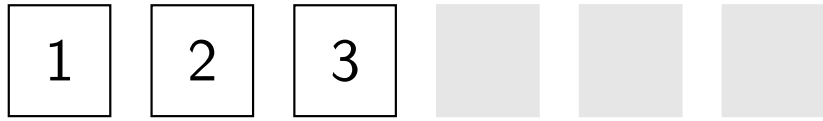
Idea

unnecessary nodes are not stored

Split Point Graph

- Only necessary nodes are inserted
- Nodes are removed when they become obsolete (Path Pruning)

Graph Evolution

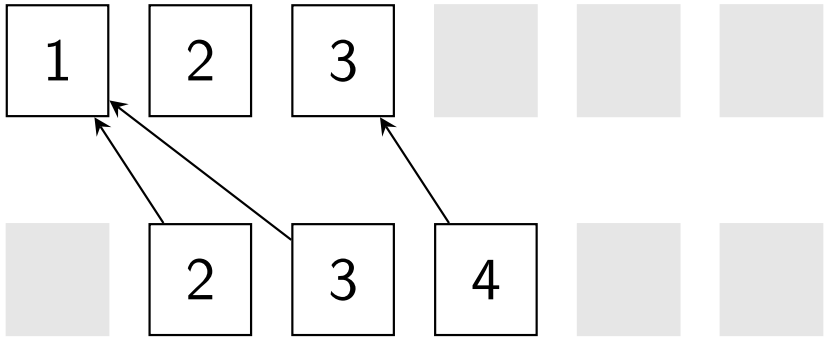


diagonal pruned node

active path pruned nodes

path pruned nodes

Graph Evolution



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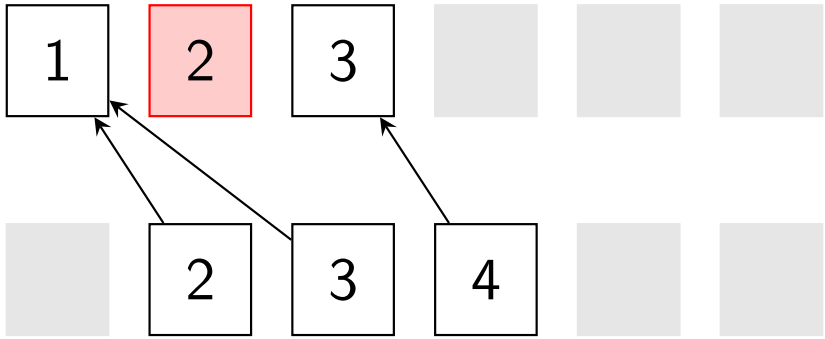

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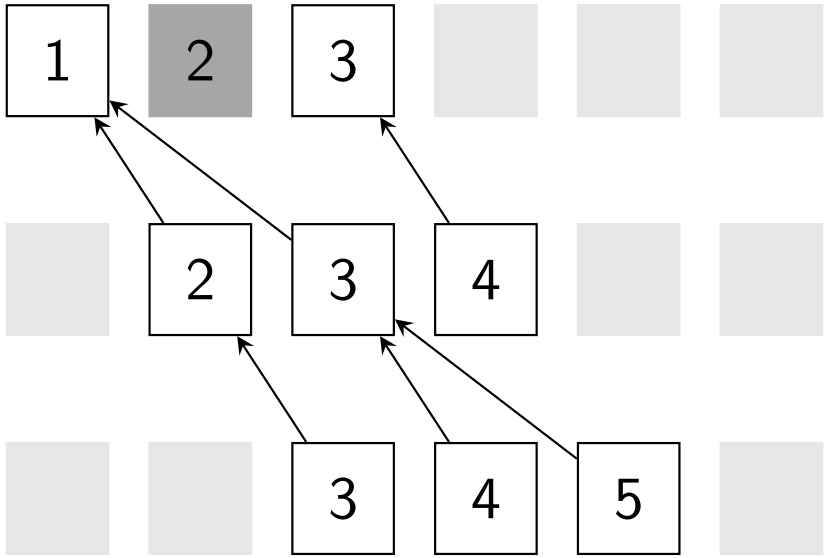

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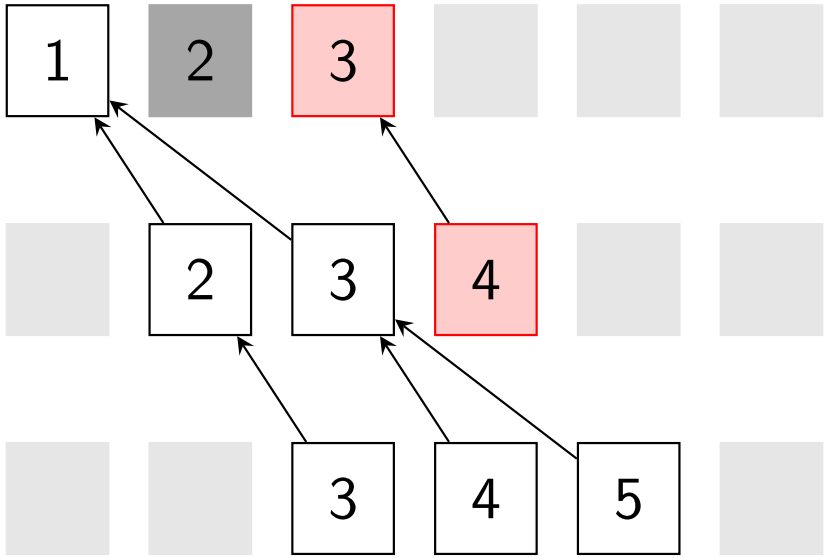

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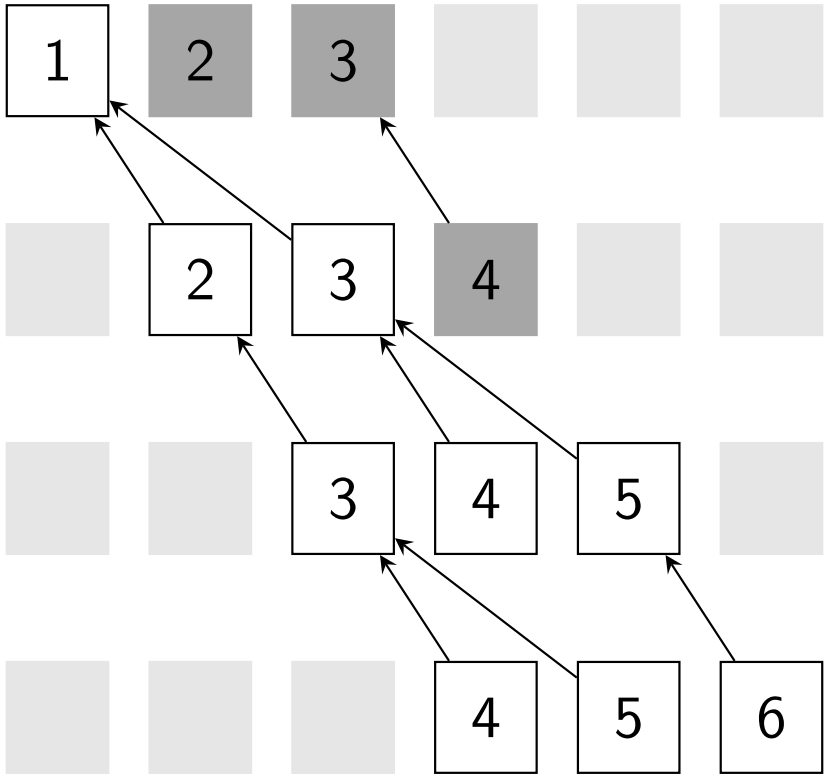

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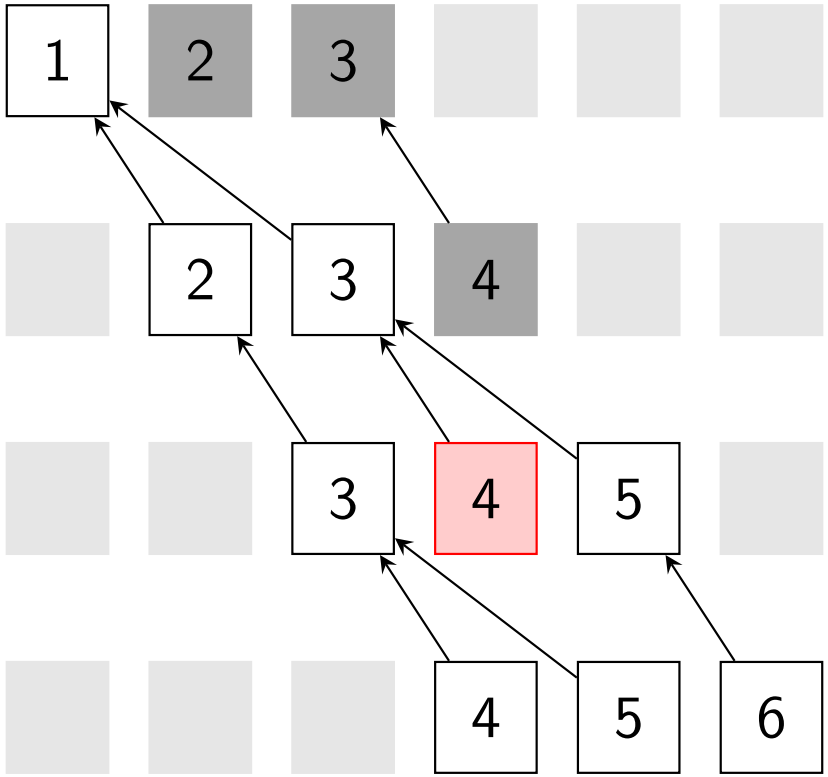

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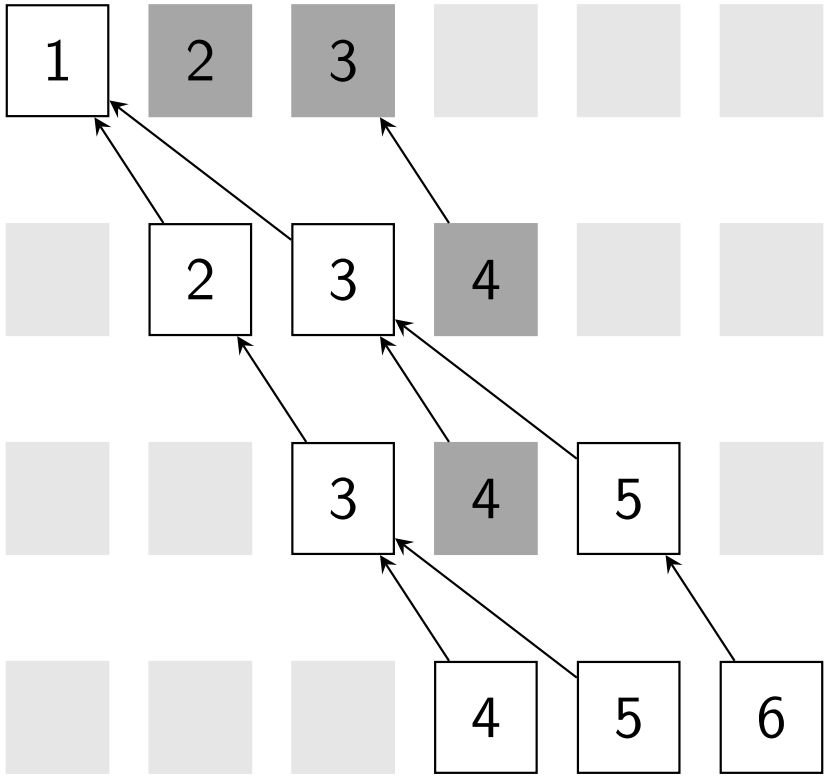


diagonal pruned node

active path pruned nodes

path pruned nodes

Total number of nodes: 24

Not computed nodes: 12

Path pruned nodes: 4

Experimental Configuration

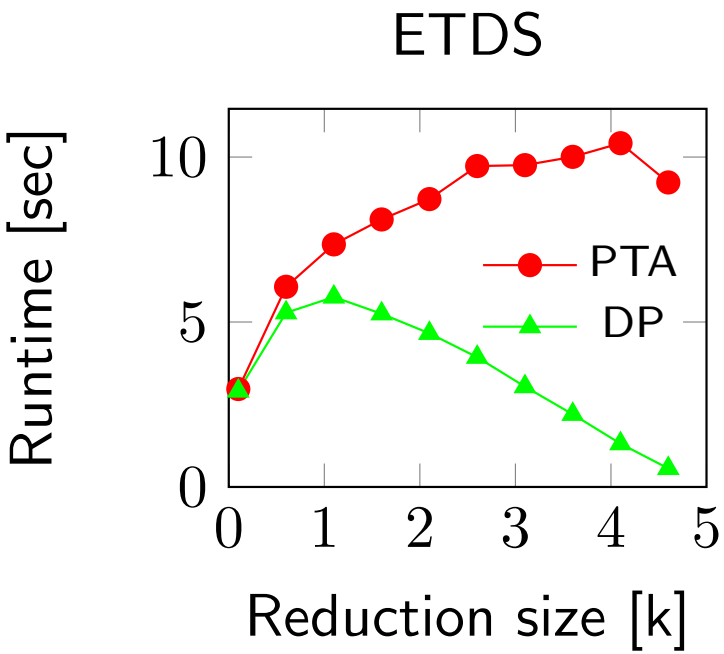
Synthetic Datasets

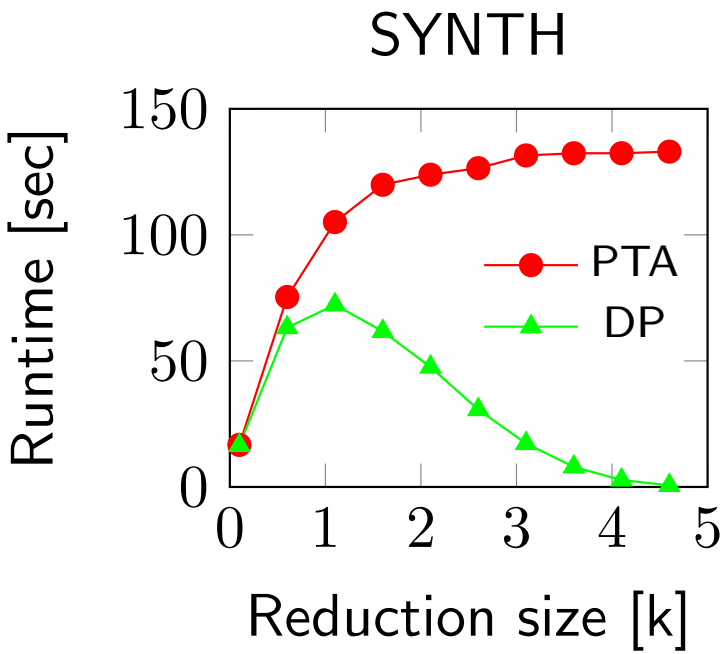
- SYNTH: random distributed values
- ETDS: evolution of employees in a company

Algorithm Comparisons

- PTA: original Algorithm
- DP: PTA with diagonal pruning
- SGP: Split point graph with diagonal and path pruning

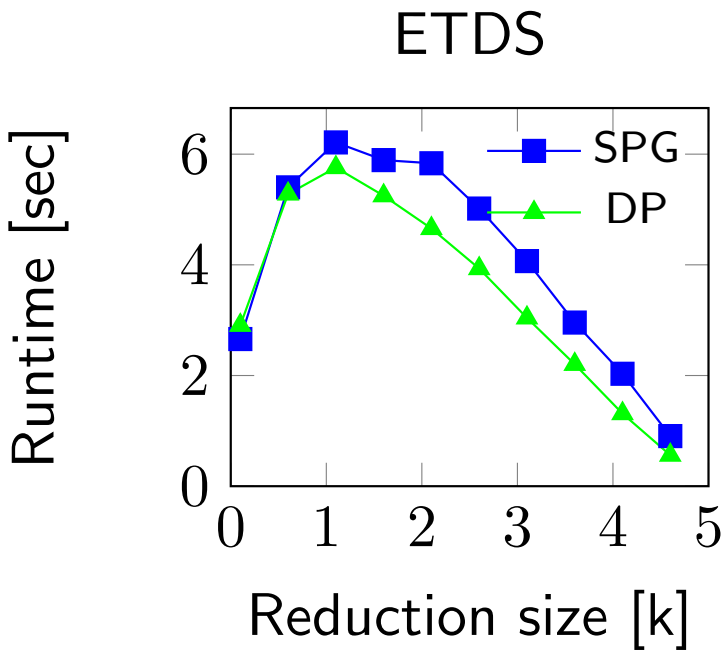
Runtime: PTA vs Diagonal Pruning

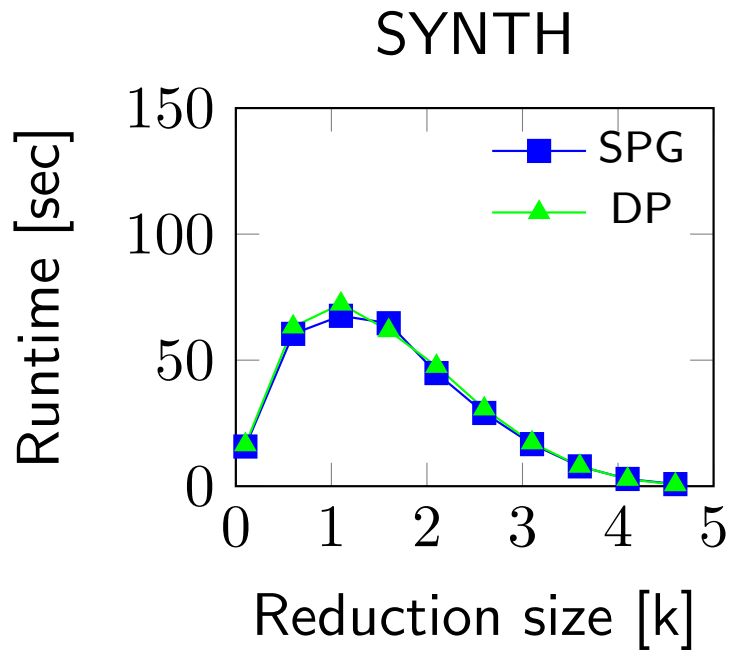




Diagonal pruning substantially reduces runtime

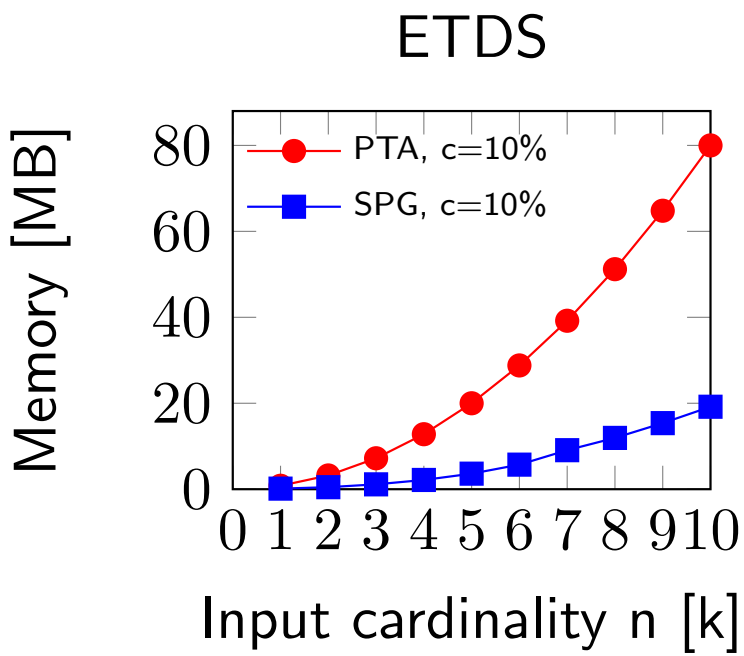
Runtime: Split Point Graph vs PTA with Diagonal Pruning

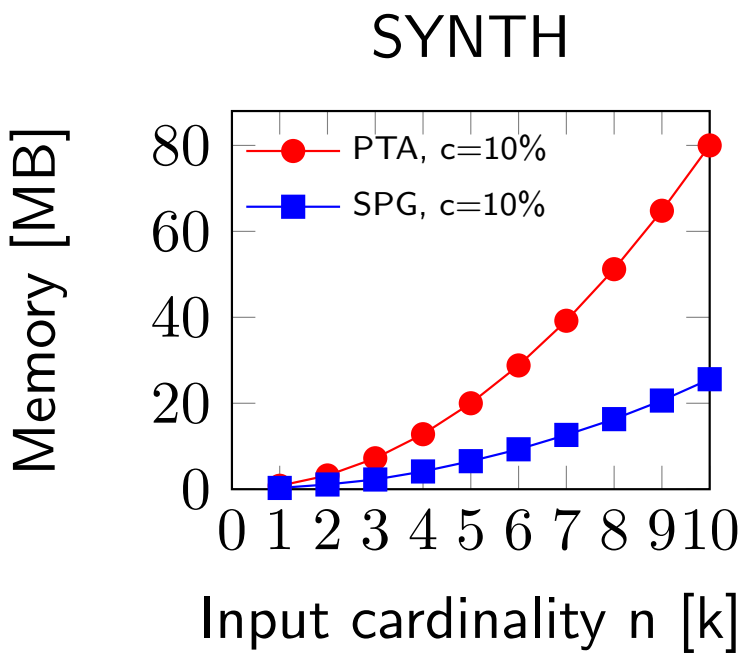




The overhead of the dynamic graph structure and path pruning is very small

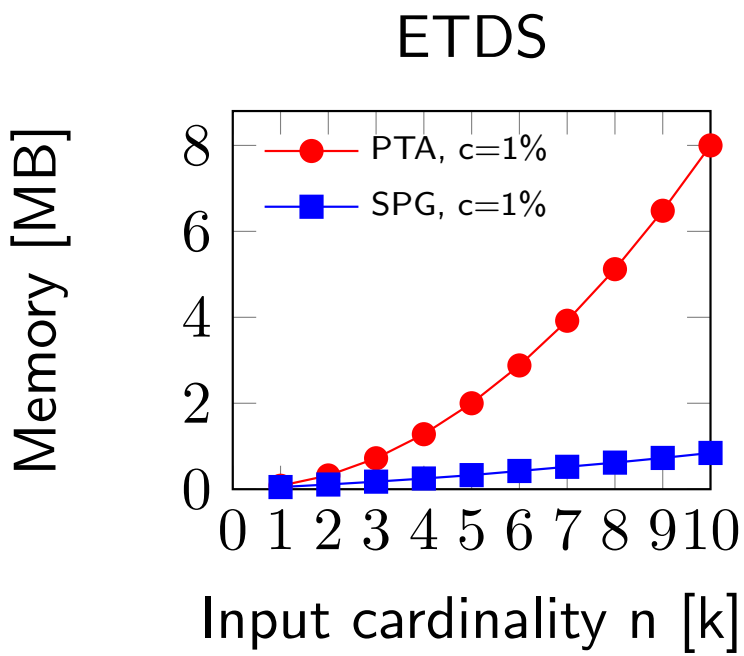
Space Efficiency: PTA vs SPG (compression to 10%)

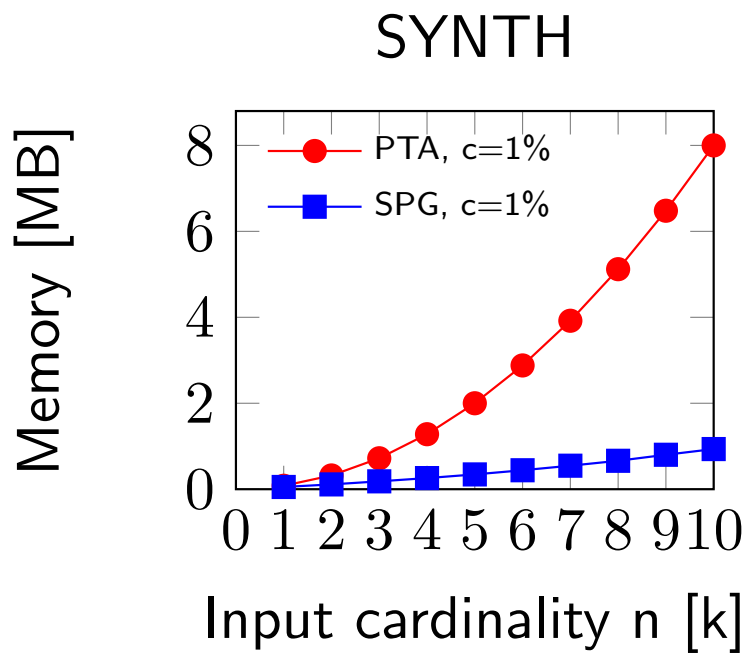




Graph Implementation with Diagonal Pruning and Path Pruning substantially reduces space consumption

Space Efficiency: PTA vs SPG (compression to 1%)





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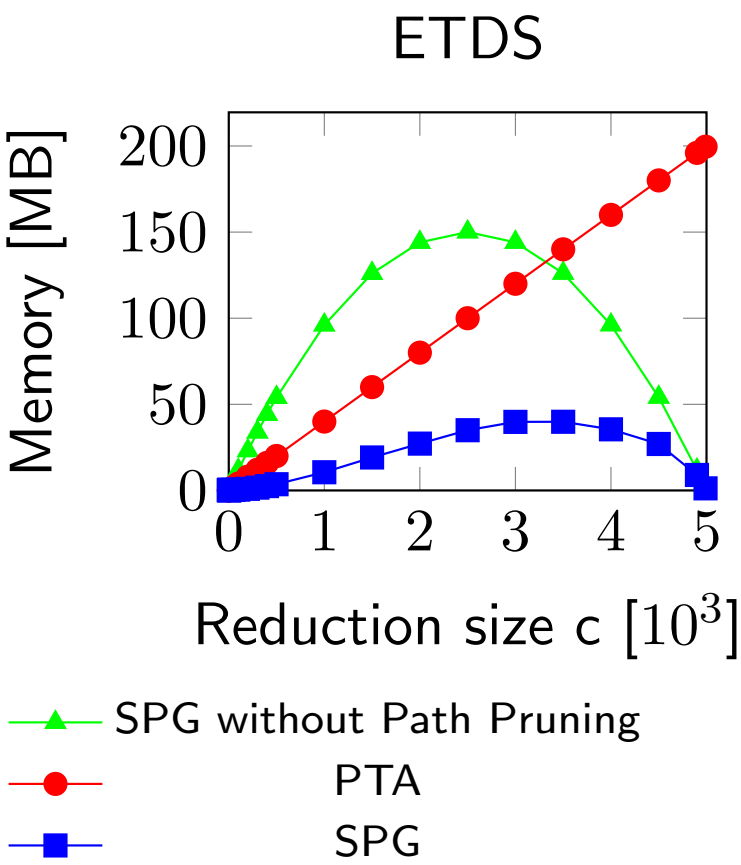
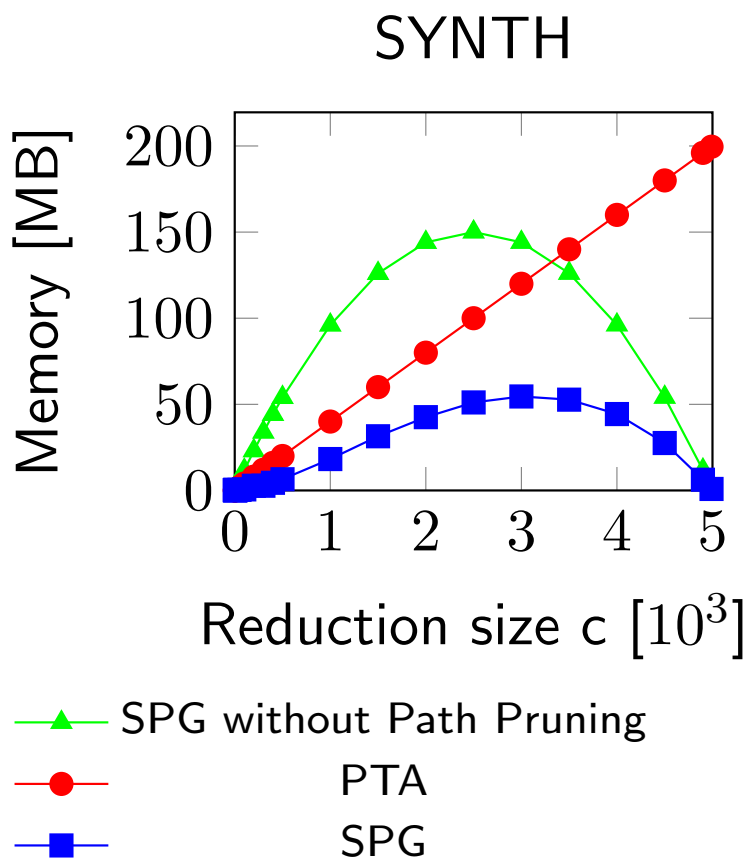
Space Efficiency: Effect of Path Pruning





Path Pruning has a huge pruning effect. It prunes about 2/3 of the graph

Related Work

- Tuma, P.: Implementing Historical Aggregates in TempIS. Ph.D. thesis, Wayne State University, Detroit, Michigan (1992)
- Kline, N., Snodgrass, R.T.: Computing temporal aggregates. In: ICDE. pp. 222-231 (1995)
- Moon, B., Vega Lopez, I.F., Immanuel, V.: Efficient algorithms for large-scale temporal aggregation. IEEE Trans. Knowl. Data Eng. 15(3), 744-759 (2003)
- Tao, Y., Papadias, D., Faloutsos, C.: Approximate temporal aggregation. In: ICDE. pp. 190-201 (2004)
- Gordevičius, J., Gamper, J., Böhlen, M.H.: Parsimonious temporal aggregation. VLDB J. 21(3), 309-332 (2012)

Conclusion

- **Diagonal Pruning** reduces the **runtime** of the computation by reducing the search space of the DP scheme adopted by PTA
- **Split Point Graph** in combination with Path Pruning reduces **memory consumption**
- Experiments showed that the two optimizations reduce memory requirements to one third of the original PTA implementation

Future Work

- Generalization of split point graph for some classes of DP problems
- Computation of PTA queries while the ITA result is computed avoiding two step computation