Bounded Suboptimal Path Planning with Compressed Path Databases

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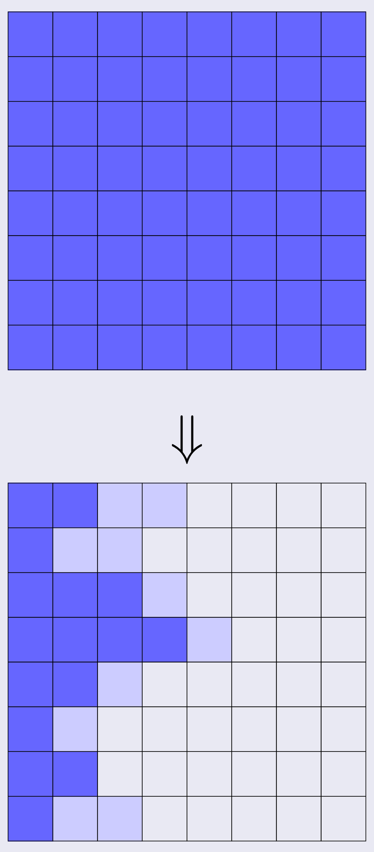
Introduction



Compress First move matrix by:
RLE, h-symbol

What are CPDs?

- Precompute all-pair first moves: $O(n^2)$
- **Compress:** $\ll O(n^2)$
- Search-free path extraction

Motivation of this work:

- Existing approaches have achieved good compression and hard to improve.
- Trade-off between space and suboptimality.

Idea

- For each node, only store first-move data for a subset of grid nodes C, called *centroid*
  - First-move matrix: $N \times N \rightarrow N \times |C|$
- Each node i belongs to a centroid $C(i)$
- Centroid path (*cp* for short)

$$cp(s,t) = shortestPath(s, C(t)) + +shortestPath(C(t), t)$$

- Bounded suboptimal: $|t, C(t)| \leq \delta$

Contribution

- Order-of-magnitude reductions in pre-processing
- Several factors improvement in database size
- Faster look-up
- Suboptimality cost per path is substantially smaller than the guaranteed upper bound

Result

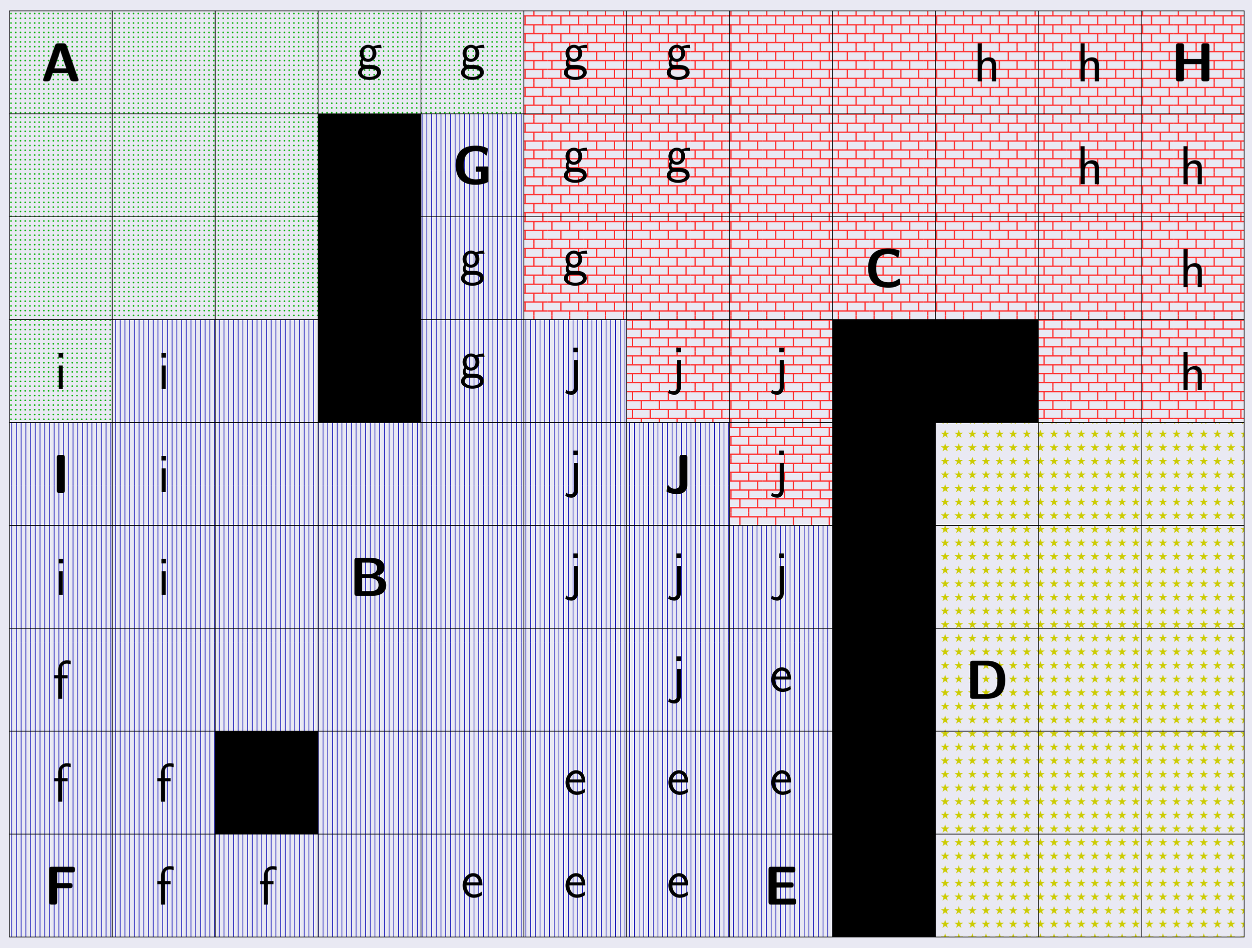
Size reduction ratio: $\frac{|fwd_0|}{|rev_\delta|}$ or $\frac{|fwd_0|}{|fwd_\delta|}$

δ	type	mean	min	25%	50%	75%	max
2	rev	0.33	0.01	0.12	0.20	0.35	1.57
	fwd	0.97	0.85	0.93	0.98	1.01	1.19
4	rev	0.82	0.02	0.45	0.72	1.05	2.34
	fwd	1.13	0.85	1.02	1.12	1.24	1.68
8	rev	1.54	0.04	1.13	1.56	1.99	3.45
	fwd	1.34	0.86	1.08	1.27	1.56	2.90
16	rev	2.59	0.09	1.87	2.48	3.12	7.39
	fwd	1.60	0.86	1.14	1.36	1.86	4.90
32	rev	3.81	0.21	2.39	3.18	4.16	17.88
	fwd	1.84	0.87	1.19	1.42	2.10	7.20
64	rev	4.93	0.44	2.70	3.64	5.12	32.43
	fwd	2.08	0.87	1.24	1.50	2.21	9.65

Speed up ratio: $\frac{Time(fwd_0)}{Time(rev_\delta)} or \frac{Time(fwd_0)}{Time(fwd_\delta)}$

	mean	min	25%	50%	75%	max
rev_{16}	1.839	0.061	1.311	1.747	2.162	235.606
rev_{32}	1.738	0.031	1.194	1.666	2.091	229.882
rev_{64}	1.580	0.008	0.998	1.490	1.953	207.992
fwd_{16}	1.209	0.013	1.038	1.125	1.312	175.824
fwd_{32}	1.233	0.033	1.041	1.144	1.355	163.937
fwd_{64}	1.230	0.012	1.013	1.139	1.389	184.361

Method: Compute Centroids



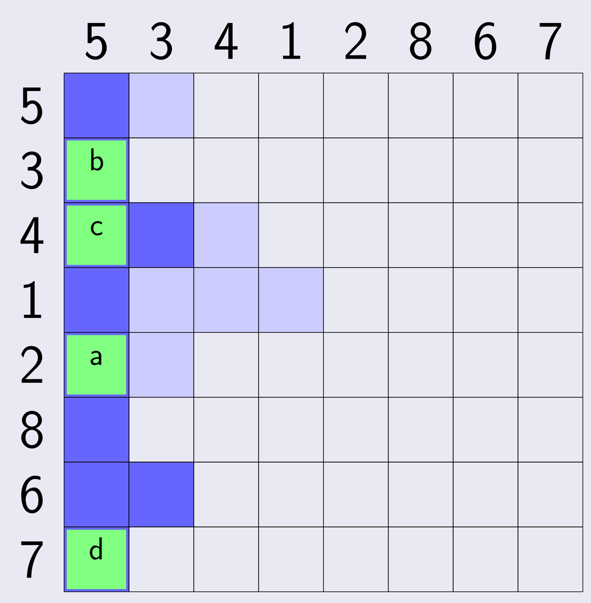
- let $\delta = 3$
- S1: generate seed-centroids by a heuristic function such that $d(c_i, c_j) \leq 2\delta$
- S2: generate centroids on "borders"
- $\delta \leq d(c_i, c_j) \leq 2\delta$
- $|C_i| \geq \frac{\delta}{2}$
- thus $i \leq \frac{2V}{\delta}$

Method: Reverse CPD

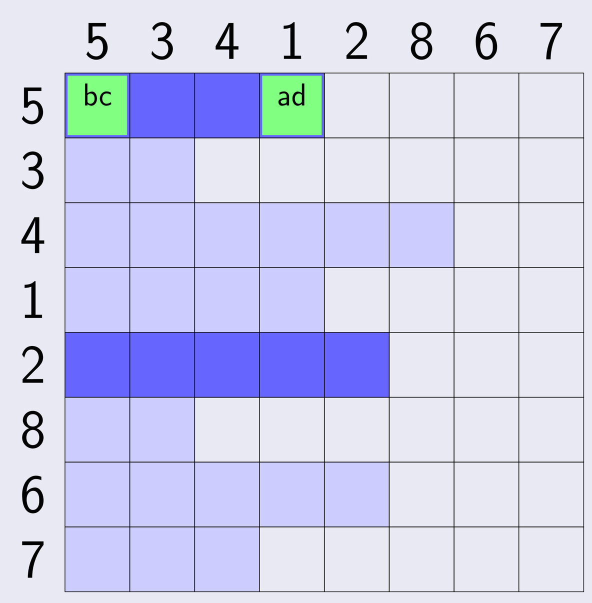
Advantages of reverse-CPD:

- get more space reduction from the centroids idea
  - forward-CPD throws non-centroids columns - may get same number of entries after compression
  - reverse-CPD throws non-centroids rows - always reduce the size
- faster path extraction
  - forward-CPD look-up in multiple row
  - reverse-CPD look-up in target row - less cache missing - single look-up may faster
  - and one look-up may extract multiple continuous moves - needs less number of look-up

Forward: 16, 10 (with centroids)

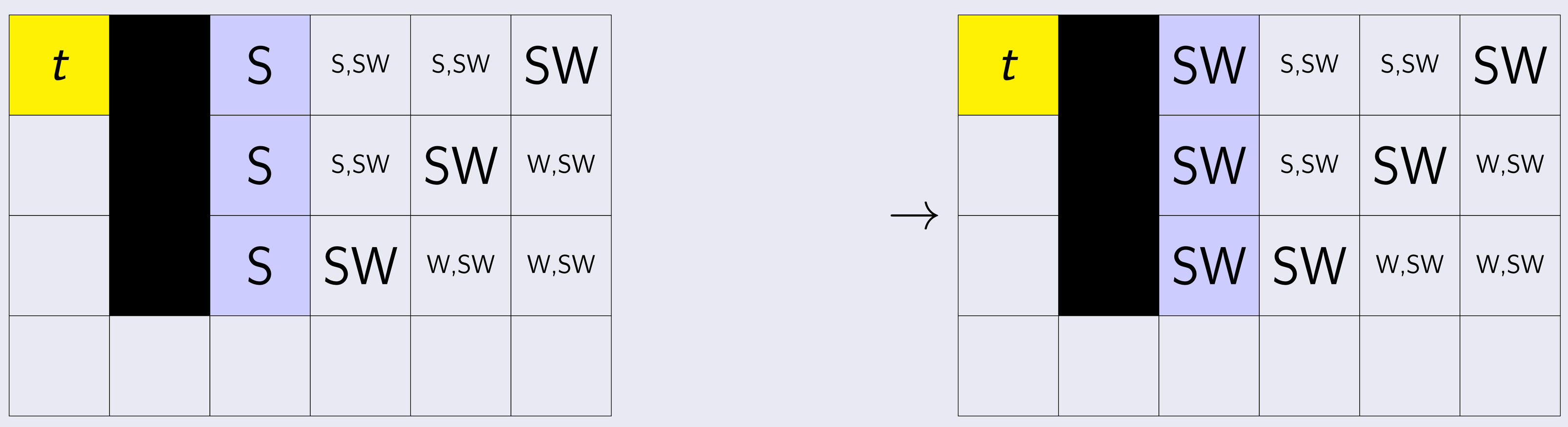


Reverse runs: 31, 9 (with centroids)



- $C = \{2, 5\}$
- Path: (2, 3, 4, 7, 5)

Method: Encode 'illegal' move



- Encoding S to SW allows us to compress the rectangle region to SW.
- When look-up column-3 symbols, we know SW is illegal, thus we can decode it to a valid move S.