Shortest Path Speed-up Through Binary Image Downsampling

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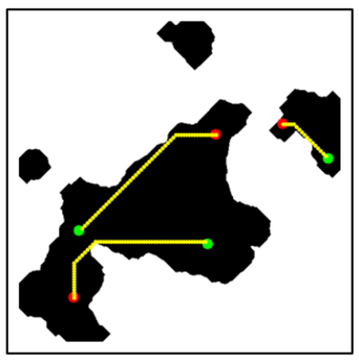
Summary

We propose a novel approach to achieve huge speed-ups for shortest path computations on 2D binary images at the cost of slight inaccuracies.



How?

"Arc flag"-based techniques are SOTAs for shortest path computation speed-ups. However, they required an expensive preprocessing step, which become a performance bottleneck. We propose to tackle the bottleneck by solving the shortest path problems in downsampled versions of the binary images and later convert the computed paths back.

Why this is important?

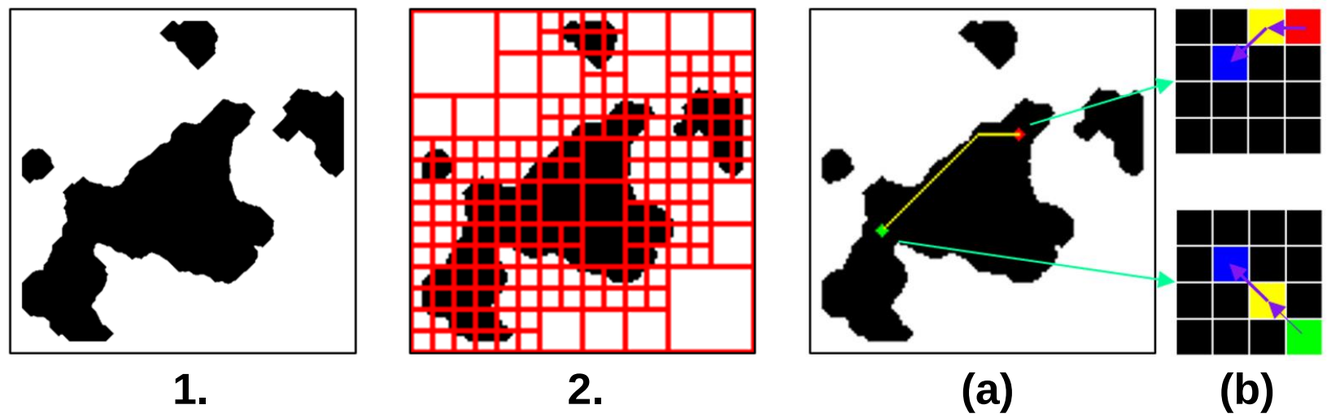
2D geographical maps in games and movies are often encoded as binary images Point-to-point shortest path computations (e.g. Dijkstra) in such maps are computationally expensive as even small binary images are akin to large 2D graphs of many vertices (each pixel is one) and edges (each pair of adjacent pixels is one).

Testing results

Our method dramatically reduced the times of the preprocessing step and run-time queries. Memory usages are also reduced. Accuracy is only slightly impacted. By using topology-preserving downsampling, no false-positive or negative-positive cases happen.

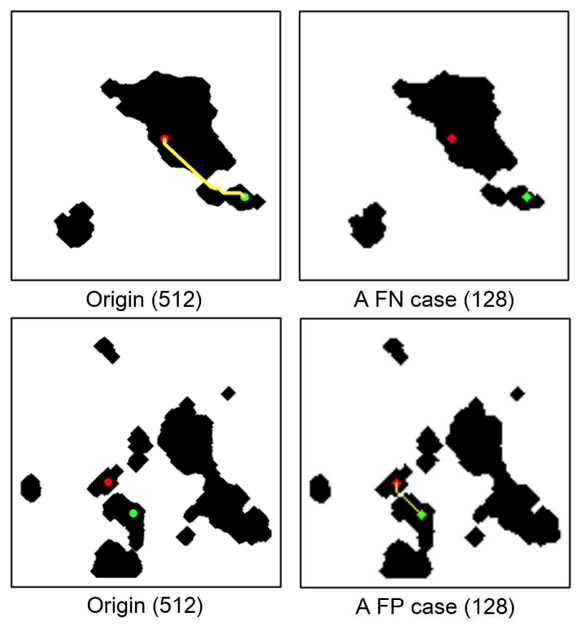
Method pipeline

1. Compute a downsampled version of the binary map.
2. Preprocessing: compute the graph partition and arc-flags on the downsampled image.
3. Run-time:
(a) compute shortest paths in the downsampled image.
(b) Path conversion: map each path pixel to center of corresponding block in original image. Then compute shortest paths within source and target blocks to connect actual pixels to block centers.



Key: *topology-preserving* downsampling

If the downsampled image has different topologies, critical "false positive" cases (i.e., two disconnected vertices incorrectly become connected) and "false negative" cases (the vice versa) can happen. Chen et al. (ECCV2024) offers a reliable and fast topology-preserving solution.



References

Chia-Chia Chen and Chi-Han Peng. Topology-Preserving Downsampling of Binary Images. The 18th European Conference on Computer Vision (ECCV) 2024.

	Geographical Map Dataset, 512x512, 100 images, 200 random source-target pairs per image. Best in red, second-best in blue.							
Method	↓Pre. Time (s) Avg./Max/Min	↓SP Time (ms)	↓Search Range	↓#Search Nodes	↓Memory Cost (mil)	↓Dist. Error	↓#FP	↓#FN
Original	39.04/144.14/1.00	413.72	7785.45	15703.4	14.92	0	0	0
Bicubic	13.96/45.68/0.21	32.42	511.92	1019.42	0.83	3.31	120	3
Voting	8.23/24.47/0.19	27.05	498.08	993.48	0.79	1.00	14	0
Ours	4.07/15.83/0.17	34.02	517.28	1024.47	0.83	0.22	0	0

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