Online Graph Pruning for Pathfinding on Grid Maps

Daniel Harabor and Alban Grastien, AAAI 2011
Presented by James Walker

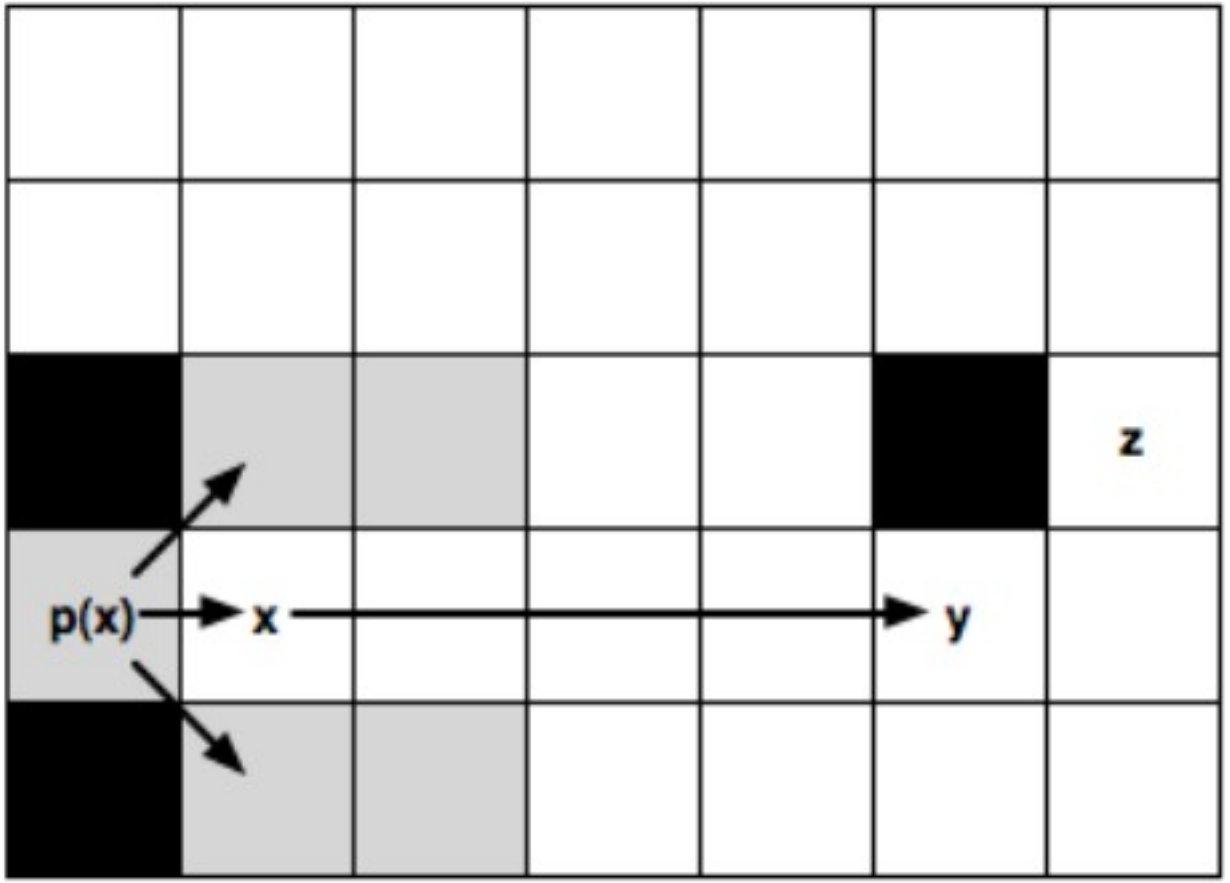
Synopsis

- An algorithm for improving A* performance on uniform-cost grid search spaces
- Works by only expanding nodes called “jump points”
- In benchmarks, improves A* performance dramatically and outperforms other A* optimizations including hierarchical pathfinding

Characteristics

- Search performance dramatically improved
- Guaranteed optimality
- No preprocessing required
- Fairly simple to implement
- Orthogonal to existing techniques (so it can be combined with other optimizations)
- Essentially no drawbacks!!

Example



When moving in a straight line toward y, x dominates all shaded nodes so there's no need to expand them.

Example Cont.

- Repeat until another jump node is encountered
- If blocked by obstacles, conclude that searching in this direction is fruitless and generate nothing

Pruning Rules

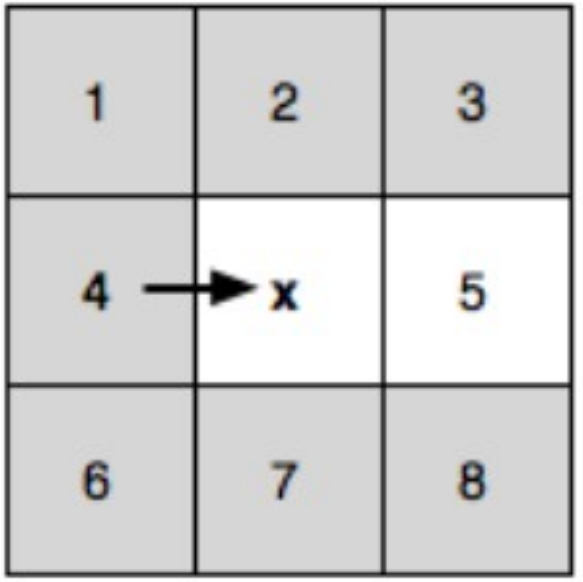
- Goal: For the current node, identify which of its neighbors don't need to be expanded to reach the goal optimally.
- 2 cases: straight move & diagonal move

Straight move pruning

- Prune any node n ε neighors(x) which satisfies the following dominance constraint:

  len(<p(x), …, n> \ x) <= len(<p(x), x, n>)

- Example: Prune all neighbors except 5

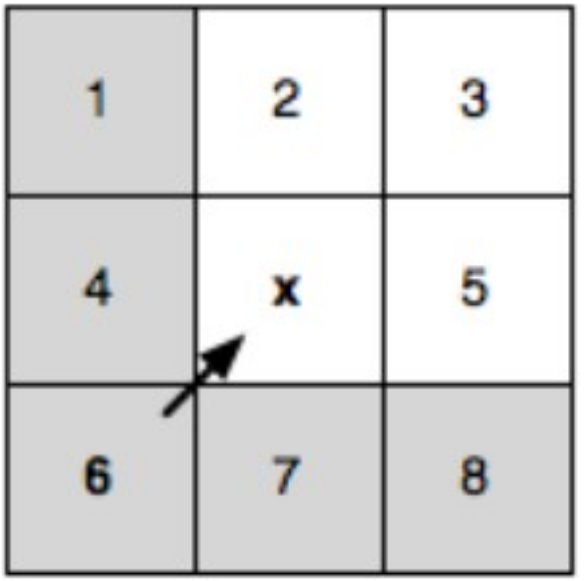


Diagonal move pruning

- Almost identical to previous case, except strict dominance is required:

  len(<p(x), …, n> \ x) < len(<p(x), x, n>)

- Example: Prune all neighbors except 2,3,5

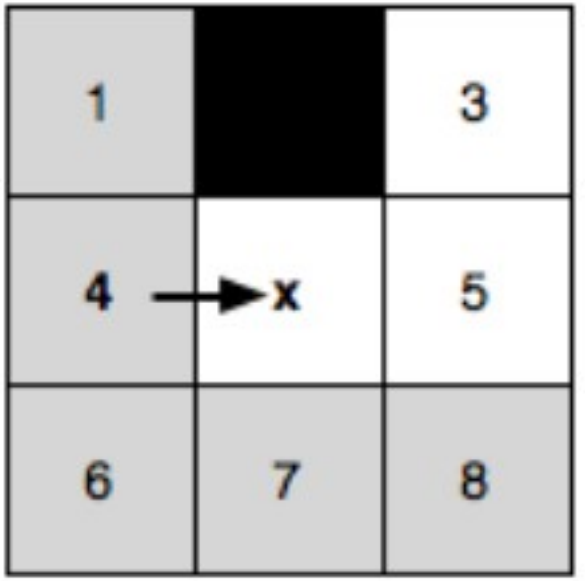


Forced evaluation

- Sometimes an obstacle can force us to evaluate a node we would otherwise prune:

  len(<p(x), x, n>) < len(<p(x), …, n> \ x)

- Example: Evaluation of 3 is forced.



Jump Point Formal Definition

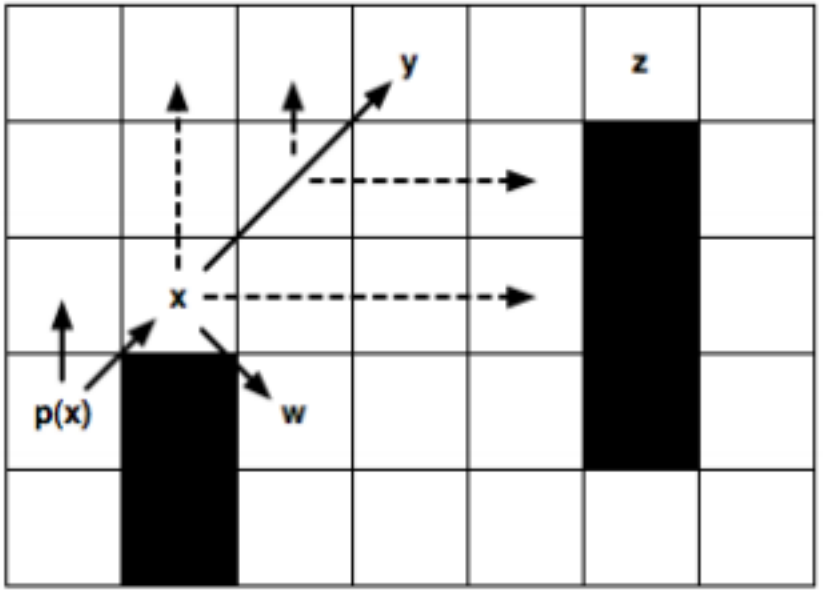
- Node y is a jump point from x, heading in direction d, if y minimizes the value k such that $y = x + kd$ and one of the following conditions holds:

  1. y is the goal

  2. y has at least one neighbor with forced evaluation

  3. d is a diagonal move and there exists a node $z = y + k_i d_i$ which lies $k_i \varepsilon N$ steps in direction $d \varepsilon \{d_1, d_2\}$ s.t. z is a jump point from y by condition 1 or 2.

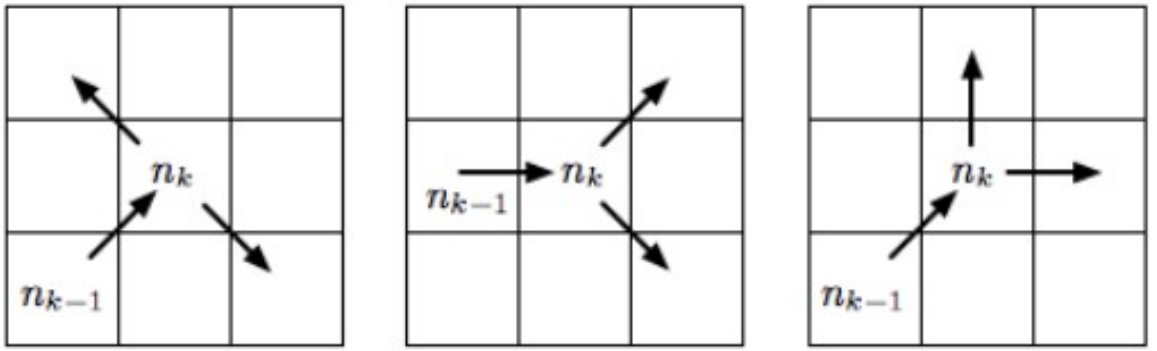
Condition 3 Example



- Intuitively, it's simple: If you're on a diagonal and you turn to a non-diagonal to the next jump point, you yourself are a jump point.

Proof of Optimality

- For each optimal length path in a grid map there exists an equivalent length path which can be found by only expanding jump point nodes.
- Turning points:



- Note that straight-to-straight turning points are trivially suboptimal.

Proof of Optimality Cont.

- **Diagonal-first path:** A path π is diagonal-first if it contains no straight-to-diagonal turning point <n_k-1, n_k, n_k+1> which could be replaced by a diagonal-to-straight turning point <n_k-1, n'_k, n_k+1> s.t. that the length of π remains unchanged.

- **Lemma 1:** Each turning point along an optimal diagonal-first path π' is also a jump point (see paper for proof of lemma).

Proof of Optimality Cont.

- Let π be an arbitrary optimal path and π' a diagonal-first symmetric equivalent. Every turning point in π' is expanded optimally when searching with jump point pruning.
- Divide π' into segments π'_i, where all moves in each π'_i are in the same direction. Every node at beginning and end of π'_i is a turning point.

Proof of Optimality Cont.

- Because each π'_i consists of single-direction moves (straight or diagonal), jump points will travel from the start to end nodes of π'_i w/o necessarily expanding all intermediate nodes; this part is guaranteed to be optimal by the pruning rules.
- **Invoke Lemma 1.** Each start and end node of π'_i is a turning point, thus also a jump point, and is expanded.

Proof of Optimality Concluded

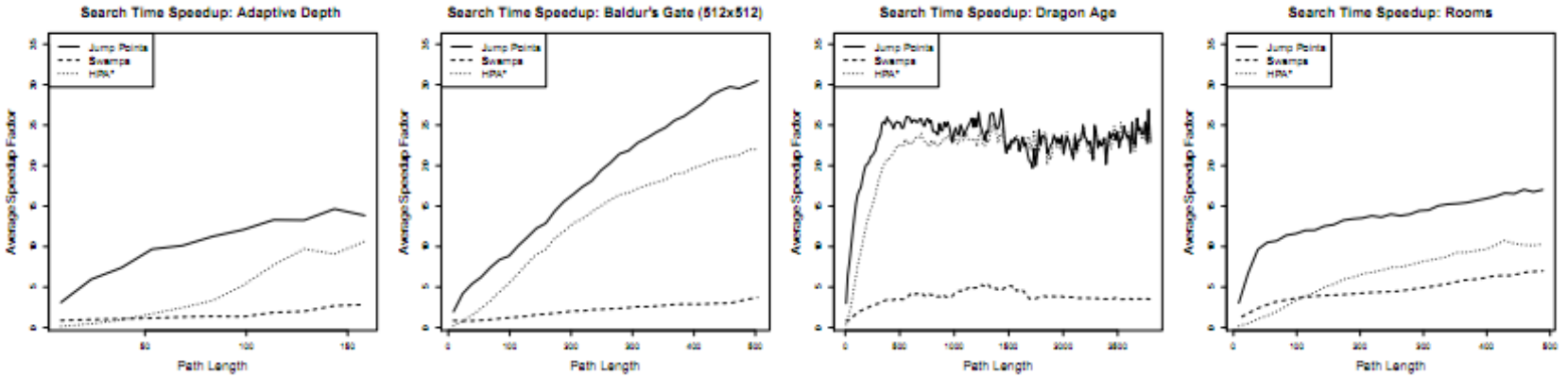
- Because all endpoint nodes of each segment π'_i are expanded optimally, and all straight-line paths between endpoints are optimal, the entire path is optimal.

Experimental Results

Nodes Expanded

	A. Depth	B. Gate	D.Age	Rooms
Jump Points	**20.37**	**215.36**	**35.95**	**13.41**
Swamps	1.89	2.44	2.99	4.70
HPA*	4.14	9.37	9.63	5.11

Computation Time



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Thank you.
Any questions?