Explaining Path Plan Optimality: Fast Explanation Methods for Navigation Meshes Using Full and Incremental Inverse Optimization

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Motivation

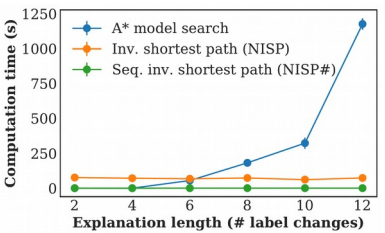
- Path planner output can be hard to understand and/or tune.
- Explanation computation speed important for interactive applications.
- Many planning problems are also MILP, for which fast solvers becoming available.

Contributions

- Fast inverse-shortest-path formulations of explanations for "why is A the shortest path, rather than B?" on NavMeshes
- We show these explanations are more effective at updating mental model of maps than cost-based explanations

Scalability result

Our MILP-based methods faster than A* model search. Our incremental method NISP# consistently 1s.



Navigation Meshes

- Graphs where each node is a walkable polygon, associated with an area-type (e.g. water, grass): $l_{k,i}=1$ if node i has area k.
- Each area-type associated with a cost-of-transport c_k (cost per meter).

Two formulations

- One uses dual vars of SP
- Other enumerates all paths, enforces their cost > desired. Can be made incremental (add more paths until desired becomes optimal)

NISP:

$$\min_{l',\boldsymbol{\pi},\boldsymbol{\lambda}} \quad \|\boldsymbol{l}' - \boldsymbol{l}\|_1$$

$$\text{s.t.} \quad \sum_i A_{ij}\pi_i = \sum_k d_j c_k l'_{k,r(j)} \quad \forall_{j:x'_j=1}$$

$$\sum_i A_{ij}\pi_i + \lambda_j = \sum_k d_j c_k l'_{k,r(j)} \quad \forall_{j:x'_j=0}$$

$$\boldsymbol{\pi} \in \mathbb{R}^{|V|},\ \boldsymbol{\lambda} \in \mathbb{R}^{|E|}$$

$$\lambda_j \geq 0 \quad \forall_{j:x'_j=0}$$

$$\boldsymbol{l}' \in \{0,1\}^{K|V^r|}$$

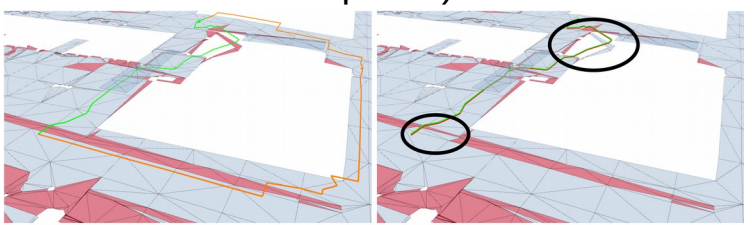
$$\sum_k l'_{k,i} = 1 \quad \forall_i,$$

ContrastiveNISP:

$$\min_{\boldsymbol{l}'} \quad \|\boldsymbol{l}' - \boldsymbol{l}\|_1$$

$$\text{s.t.} \quad G\boldsymbol{l}' \leq 0$$

$$\boldsymbol{l}' \in \{0,1\}^{K|V^r|},$$



(a) Question: "why path A not B?" (why orange path not green?)

(b) Terrain-type explanation: "B would require a change in terrain labels such as this"

Iterations of NISP#

User study

- Baseline path-cost exp: "Path A optimal because cost(A)=4, but cost(B)=5."
- NISP#a: "B would be optimal if terrain labels were X, Y or Z" (all optimal-length explanations)