Driving Like a Human: Imitation Learning for Path Planning using CNNs

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Introduction: Path Planning
Short Review:
Dijkstra's Algorithm
Short Review: Dijkstra‘s Algorithm

Find shortest path from start to goal:
Short Review: Dijkstra‘s Algorithm

Find shortest path from start to goal:

Assign edge costs, node costs, Start = 0
Short Review: Dijkstra‘s Algorithm

Find shortest path from start to goal:

- Assign edge costs, node costs, Start = 0
- Propagate and sum costs
Short Review: Dijkstra’s Algorithm

Find shortest path from start to goal:

- Assign edge costs, node costs, Start = 0
- Propagate and sum costs
- Expand cheapest node
Short Review: Dijkstra‘s Algorithm

Find shortest path from start to goal:

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Short Review: Dijkstra‘s Algorithm

Find shortest path from start to goal:

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- Expand cheapest node
Short Review: Dijkstra’s Algorithm

Find shortest path from start to goal:

- Assign edge costs, node costs, Start = 0
- Propagate and sum costs
- Expand cheapest node
- Re-assign minimum cost
Find shortest path from start to goal:

- Assign edge costs, node costs, Start = 0
- Propagate and sum costs
- Expand cheapest node
- Re-assign minimum cost
Short Review: Dijkstra’s Algorithm

Find shortest path from start to goal:

- Assign edge costs, node costs, Start = 0
- Propagate and sum costs
- Expand cheapest node
- Re-assign minimum cost
- Trace back shortest path
Short Review: Dijkstra’s Algorithm

Find shortest path from start to goal:
Short Review: Dijkstra’s Algorithm

Find shortest path from start to goal:
Short Review: Dijkstra‘s Algorithm

Find shortest path from start to goal:

![Graph showing a grid with a start node, an obstacle, and a goal node.](image-url)
Short Review: Dijkstra‘s Algorithm

Find shortest path from start to goal:
Shortest Path with a CNN
Finding the Shortest Path with a CNN

- Assign edge costs, node costs, Start = 0
Finding the Shortest Path with a CNN

- Assign edge costs, node costs, Start = 0
- Propagate
Finding the Shortest Path with a CNN

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Finding the Shortest Path with a CNN

Finding the Shortest Path with a CNN

Replace

Cost → Non-Zero Padding (!) → Transition Filters → Transition Cost → Cost per Action → Updated Cost

min pool

Argmin of this layer is transition policy
Evaluating the Shortest Path with a CNN

\[
\text{Destination State} \rightarrow \text{Current State} \star \text{Transition Policy} \rightarrow \text{Transition Selection} \rightarrow \text{Flipped Transition Filters} \rightarrow \text{Next State}
\]

\[
\text{argmin}
\]

- Destination State
- Current State
- Transition Policy
- Transition Selection
- Flipped Transition Filters
- Next State
Example:
Simple Path Planning
Example: Path Planning

Find shortest path from start to goal:

![Diagram showing a grid with a start, goal, and obstacle]

- Start
- Goal
- Obstacle
Example: Path Planning

- Nine possible transition filters
- Cost is the traversed distance

\[ +\sqrt{2} \quad +1 \quad +\sqrt{2} \]

\[ +1 \quad +0 \quad +1 \]

\[ +\sqrt{2} \quad +1 \quad +\sqrt{2} \]
Example: Path Planning

- Cost Model
  - Additive layer
  - High cost where obstacle is located
Example: Path Planning

Cost Map

State Transition Map
Finding the Shortest Path with a CNN

- If you use Dijkstra:
  - Graph traversal with known transitions is faster
  - States can be updated selectively
  - Visited nodes will never be touched again

- Why would you do it then?
Driving Like a Human: Imitation Learning
Imitation Learning

Intersection in Karlsruhe

Arial view: Google Maps
Imitation Learning

- Recorded trajectories
- Teach a network to imitate human behavior

Intersection in Karlsruhe

Arial view: Google Maps
Imitation Learning

Replace

Cost → Non-Zero Padding (!) → Transition Filters → Transition Cost → Cost per Action → min pool → Updated Cost
Imitation Learning

Replace

Cost → Non-Zero Padding → Transition Filters → Transition Cost → Cost per Action → Updated Cost

Fill in the whole bunch of CNN techniques
Example II: Imitation Learning

In our case: FC-ResNet operating on the arial view
Imitation Learning

Path driven by human
Imitation Learning

Path driven by human

Cost map from arial image
Imitation Learning

Path driven by human

Cost map after planning
Imitation Learning

Path planned by network

Cost map after planning
Imitation Learning

Path planned by network
Path driven by human

Cost map after planning
Imitation Learning

Path planned by network
Path driven by human
Outlook: Prediction and Cooperation
Outlook: Pedestrian Prediction

Camera image

Semantic map and top view

Teach a network to predict human motion by planning
Outlook: Pedestrian Prediction

Crop of map centered around pedestrian

“Pedestrian Prediction by Planning using Deep Neural Networks”, arXiv:1706.05904
Outlook: Pedestrian Prediction

Predict destination for planning

“Pedestrian Prediction by Planning using Deep Neural Networks”, arXiv:1706.05904
Outlook: Pedestrian Prediction

Predicted with Net

“Pedestrian Prediction by Planning using Deep Neural Networks”, arXiv:1706.05904
Outlook: Cooperative Planning

Teach a network resolve conflicts

Summary
Summary

Planning Net…

… for imitation

… for prediction

… for cooperation
The People

Jannik Quehl
Trajectory Data

Maximilian Naumann
Cooperative Planning

Florian Wirth
Destination Prediction