16-350
Planning Techniques for Robotics

Planning Representations:
Lattice-based Graphs, Explicit vs. Implicit Graphs

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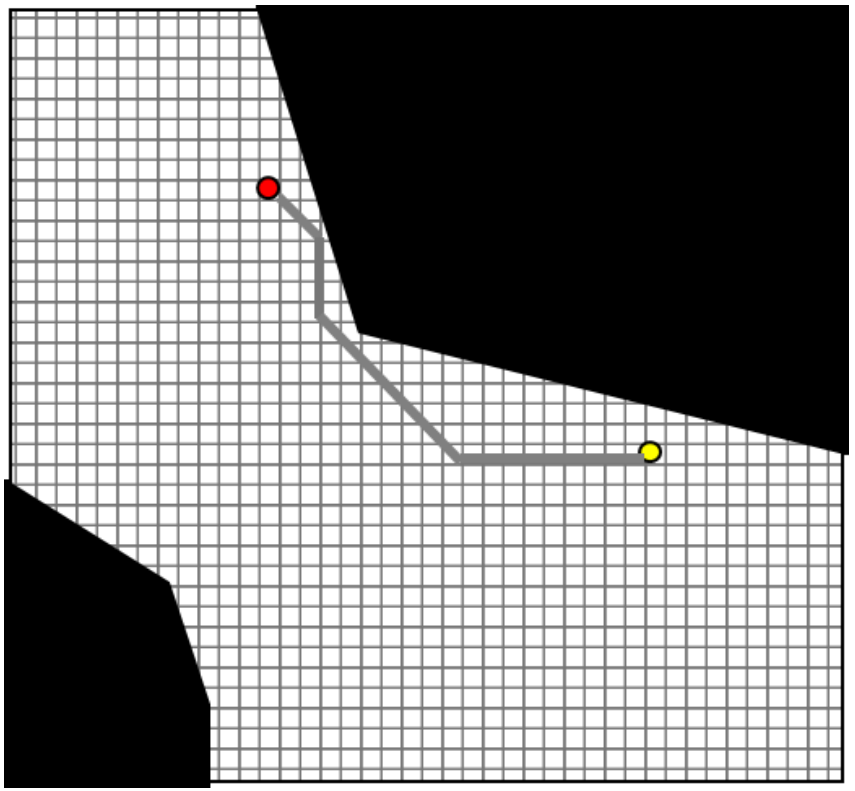
Beyond Planning for Omnidirectional Robots

What's wrong with using Grid-based Graphs when planning for non-omnidirectional robots?



Beyond Planning for Omnidirectional Robots

What's wrong with using Grid-based Graphs when planning for non-omnidirectional robots?

"Can't turn in place"

*e.g., constraints on the minimum turning radius (still **kinematic** planning)*

*e.g., constraints on turning rate (rate of change in wheel orientation) and inertial constraints (**kinodynamic** planning)*

Beyond Planning for Omnidirectional Robots

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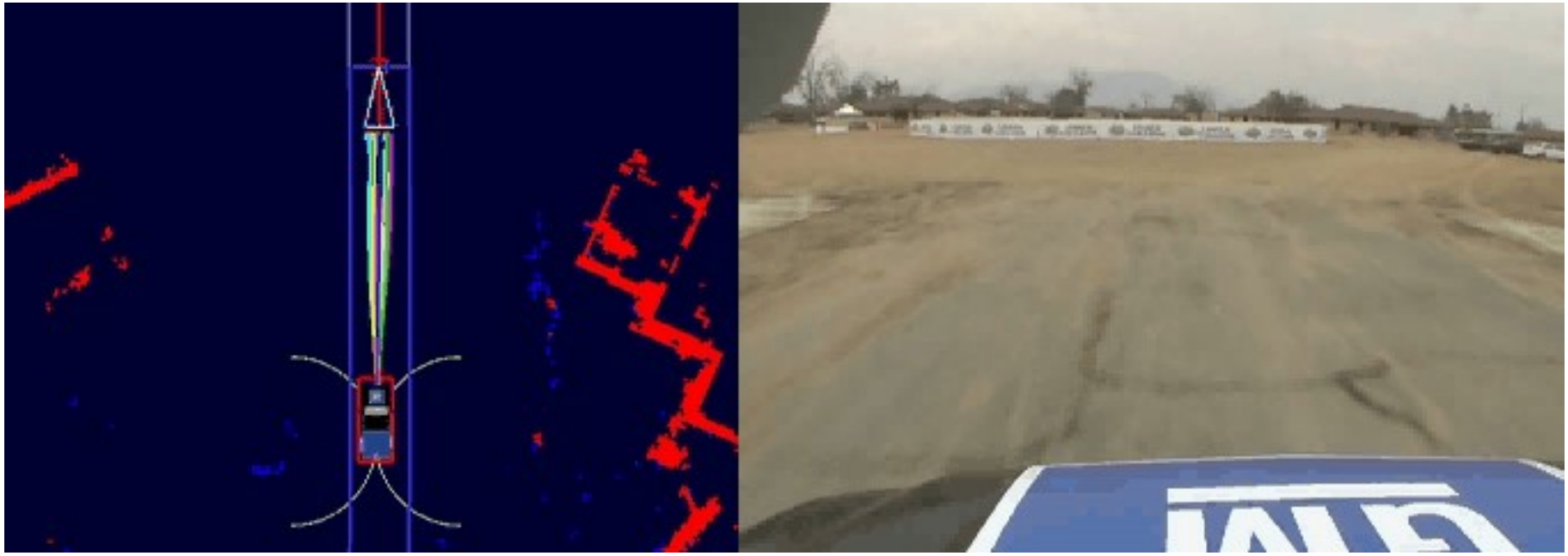
***Kinodynamic planning**:*
Planning representation includes $\{X, \dot{X}\}$, where X-configuration and $\dot{X}$-derivative of X (dynamics of X)

Beyond Planning for Omnidirectional Robots

(x,y,Θ,v) planning
with Anytime D (Anytime Incremental A*) on Lattice Graphs*



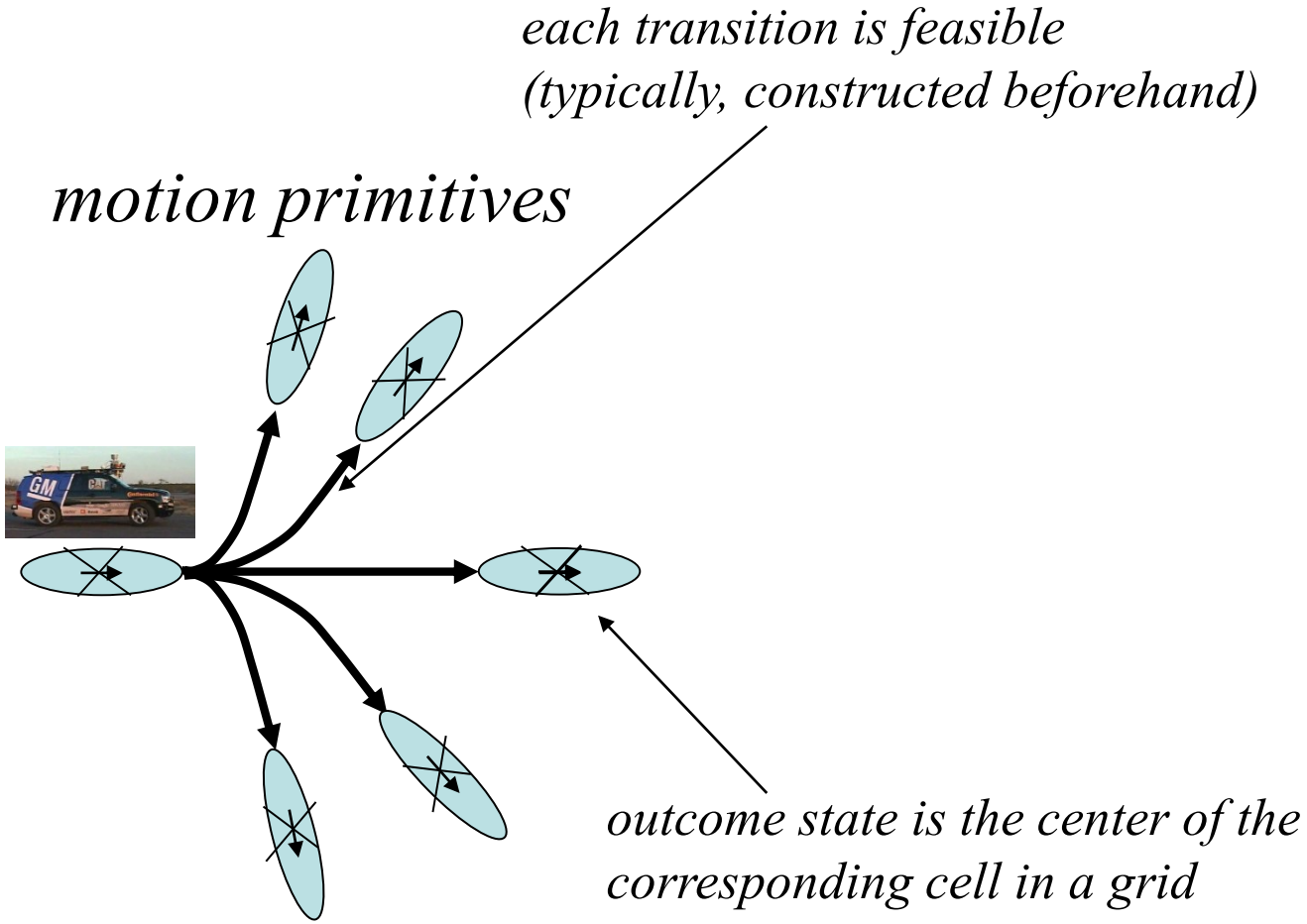
Beyond Planning for Omnidirectional Robots

(x,y,Θ) planning with ARA-based algorithm on Lattice Graphs*

Joint work with V. Kumar (Upenn), I. Kaminer (NPS) and V. Dobrokhodov (NPS) [thakur et al., '13]

Lattice Graphs

- Graph *{V, E}* where
  - *V*: centers of the grid-cells
  - *E*: motion primitives that connect centers of cells via short-term **feasible** motions



Lattice Graphs

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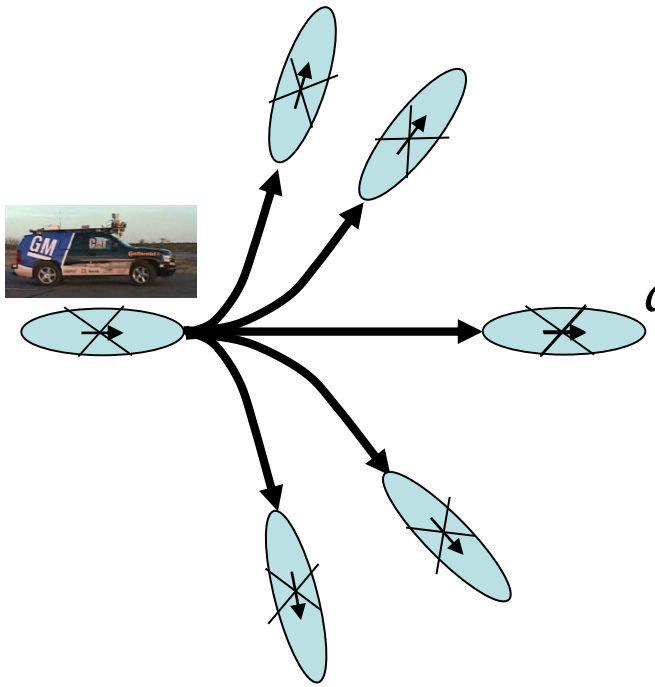
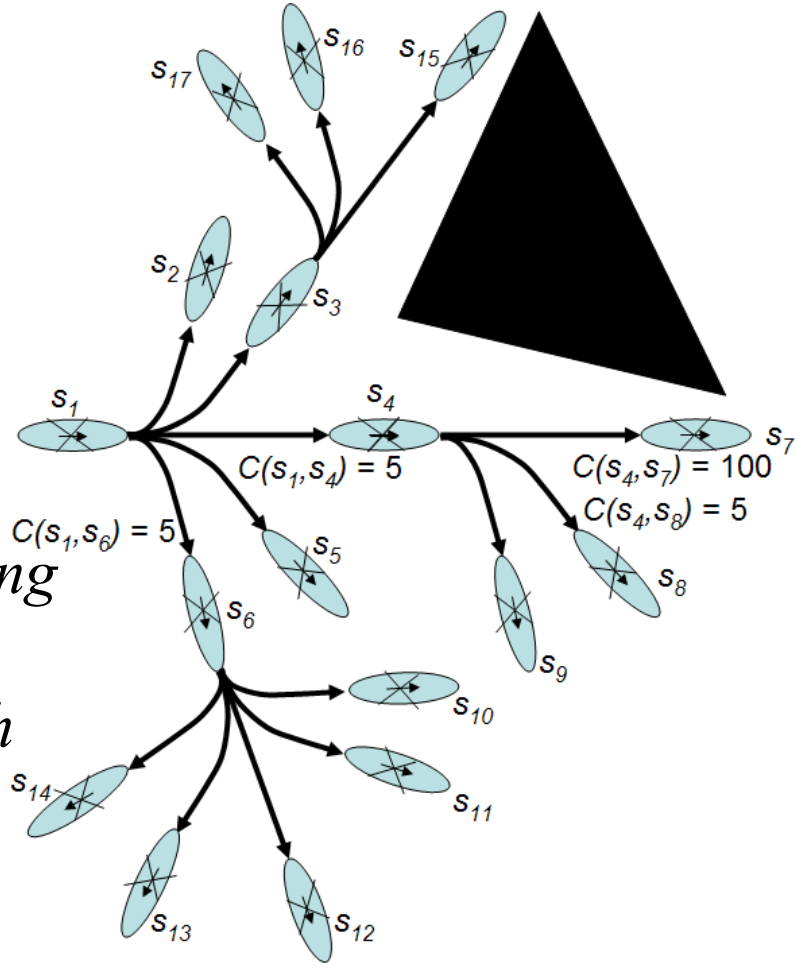
motion primitives



replicate it during planning

to generate lattice graph



Lattice Graphs

- Graph *{V, E}* where
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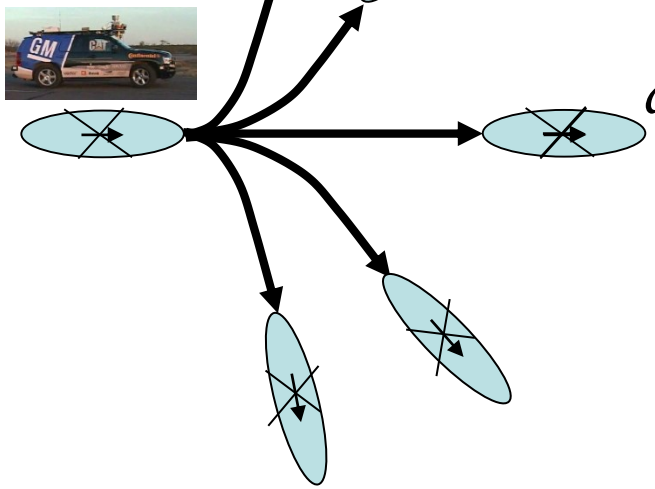
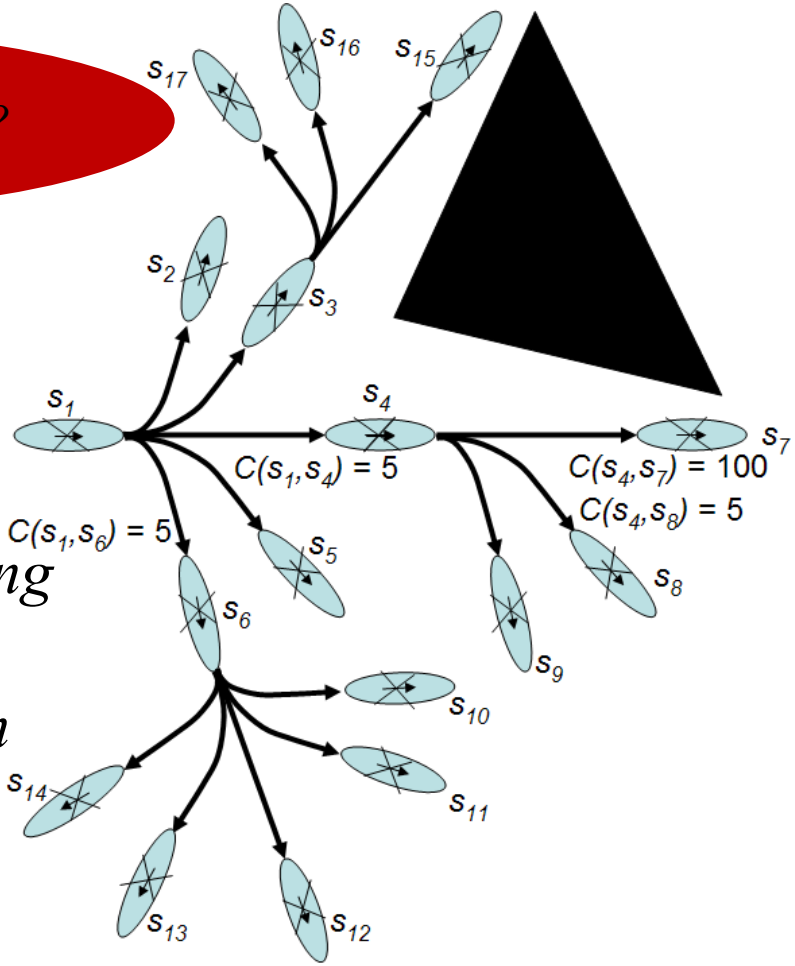
How do edgecosts get assigned?

motion primitives



replicate it during planning → to generate lattice graph



Lattice Graphs

- **Board example** for (x,y,Θ) planning for a unicycle model (minimum turning radius)

Planning as Graph Search Problem

1. Construct a graph representing the planning problem

2. Search the graph for a (hopefully, close-to-optimal) path

The two steps above are often interleaved

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Interleaving Search and Graph Construction

Graph Search using an **Explicit Graph** (allocated prior to the search itself):

1. *Create the graph G = {V, E} in-memory*

2. *Search the graph*

Using Explicit Graphs
is typical for low-D (i.e., 2D) problems in Robotics
(with the exception of PRMs, covered in a later lecture)

Interleaving Search and Graph Construction

Graph Search using an **Implicit Graph** (allocated as needed by the search):

1. *Instantiate Start state*

2. *Start searching with the Start state using functions*

   a) *Succs = GetSuccessors (State s, Action)*
   b) *ComputeEdgeCost (State s, Action a, State s')*

   and allocating memory for the generated states

Using Implicit Graphs is critical for most (>2D) problems in Robotics

Interleaving Search and Graph Construction

- **Board example** for deciding whether to use an Explicit graph or Implicit graph

- Planning for (x,y,Θ,v) for
  - 20 by 20 m environment discretized into 25 cm cells with 8 heading Θ values and 2 velocity v values for a point robot

Is it feasible to use Explicit Graph (memory and pre-computation time reqs)?

Interleaving Search and Graph Construction

- **Board example** for deciding whether to use an Explicit graph or Implicit graph

- Planning for (x,y,Θ,v) for
  - 200 by 200 m environment discretized into 25 cm cells with 16 heading Θ values and 2 velocity v values for a real vehicle

Is it feasible to use Explicit Graph (memory and pre-computation time reqs)?

What You Should Know…

- What are Lattice graphs and how they get constructed
- Explicit vs. Implicit graphs and pros/cons of each