OOPSMP:
An Object-Oriented Programming System for Motion Planning

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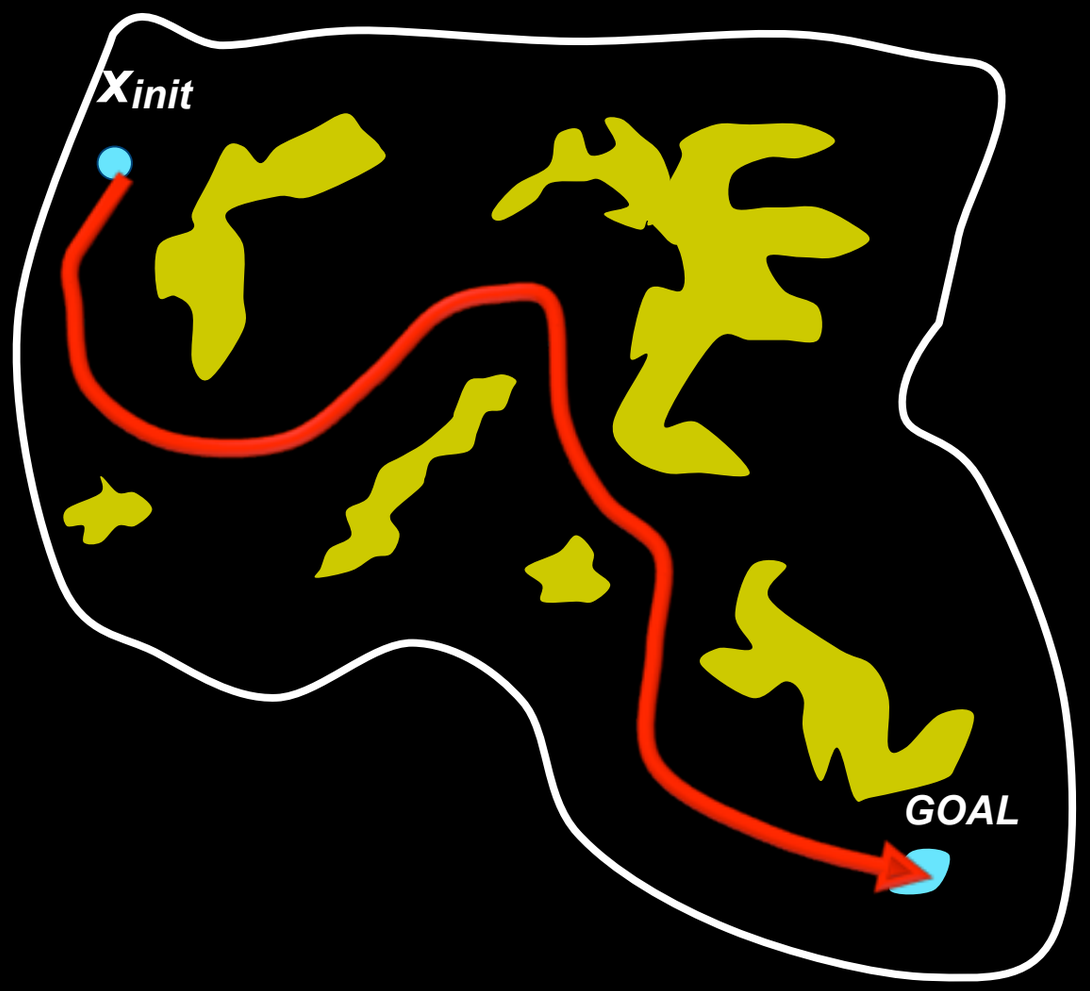
Introduction

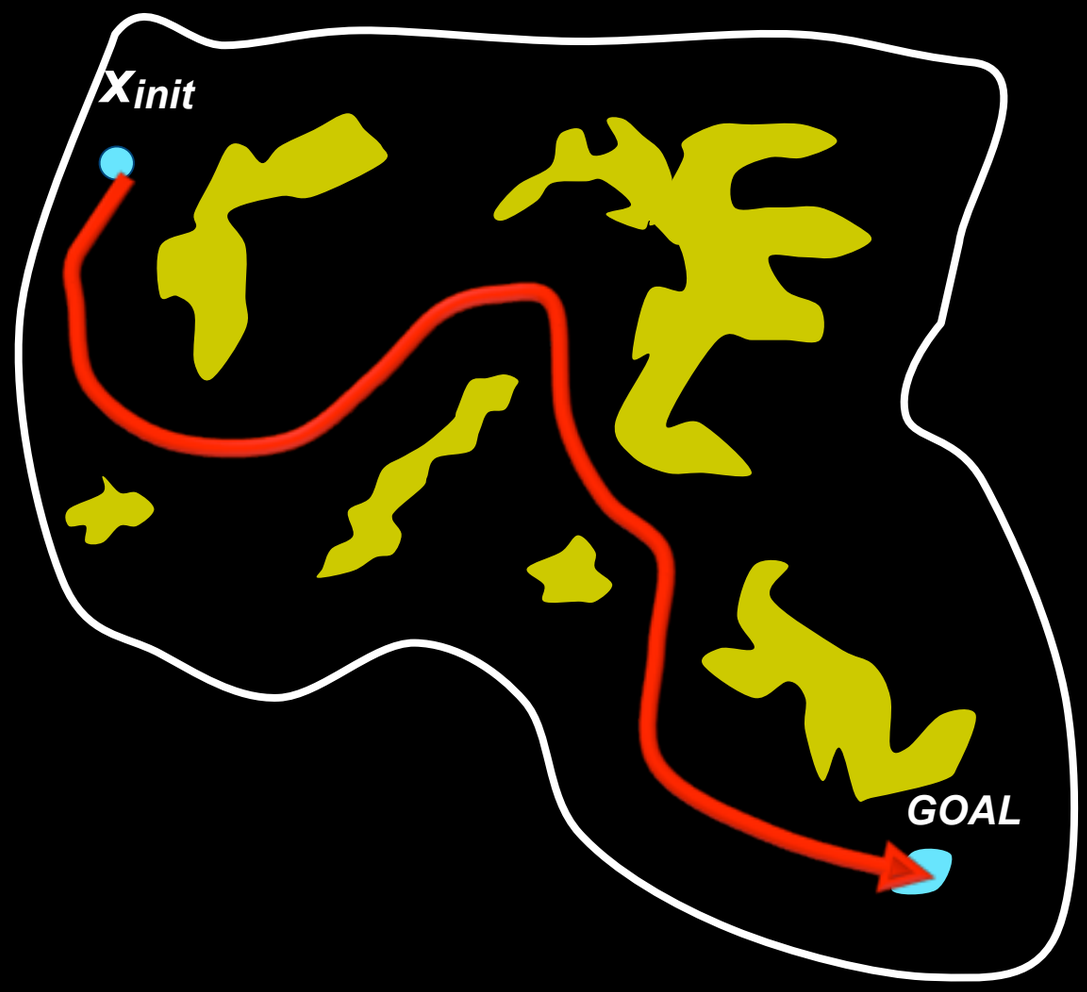
Motion planning: given two configurations of a robot, find a collision-free path that connects them.



Introduction

Motion planning: given two configurations of a robot, find a collision-free path that connects them.

More generally: find paths for one or more robots that satisfy all constraints on geometry, physics, safety, etc.



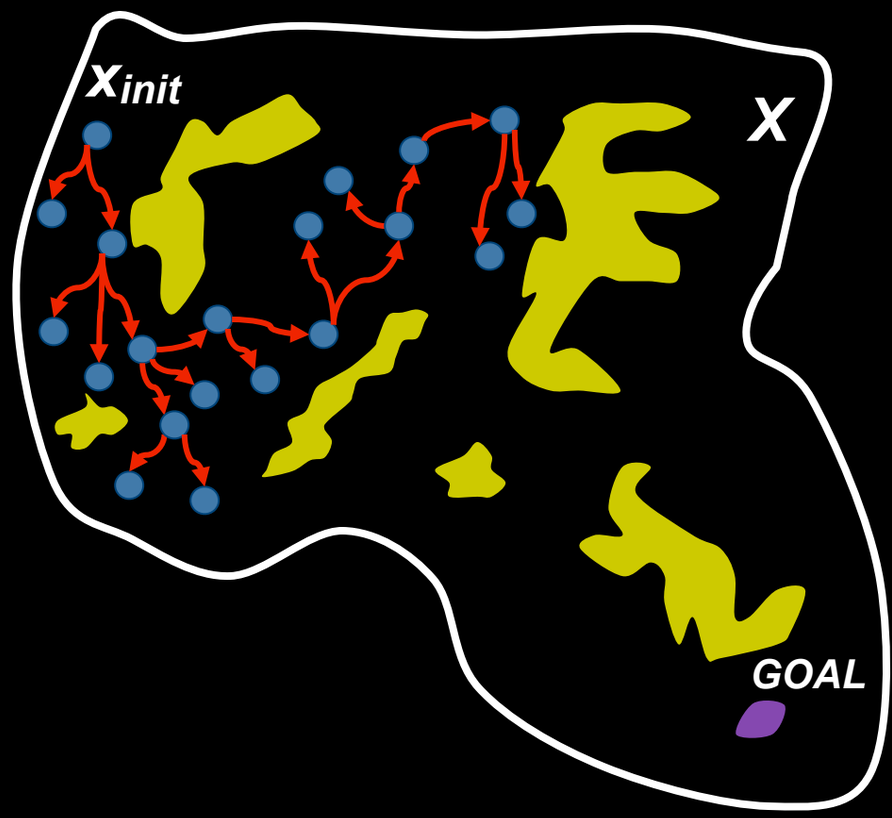
Motion planning problems are hard

PROBLEM	COMPLEXITY
Geometric Constraints:	
Sofa Mover (3DOF)	$O(n^{2+\varepsilon})$ - not implemented [HS96]
Piano Mover (6DOF)	Polynomial – no practical algorithm [SS83]
n Disks in the Plane	NP-Hard [SS83]
n Link Chain in 3D	PSPACE-Complete [HSS87]
Generalized Mover	PSPACE-Complete [Canny88]
Dynamics Constraints:	
Point with Newtonian Dynamics	NP-Hard [DXCR93]
Polygon Dubin's Car (Linear)	Decidable [CPK08]
Nonlinear	Unknown, probably undecidable
Discrete Transitions and Dynamics Constraints:	
Hybrid Systems	Undecidable [Alur et. al 95]

Exact, Approximate, and Probabilistically Complete Algorithms

Method	Advantage	Disadvantage
exact	theoretically insightful	impractical
cell decomposition	easy	does not scale
control-based	online, very robust	requires good trajectory
potential fields	online, easy	slow or fail
sampling-based	fast and effective	cannot recognize impossible query

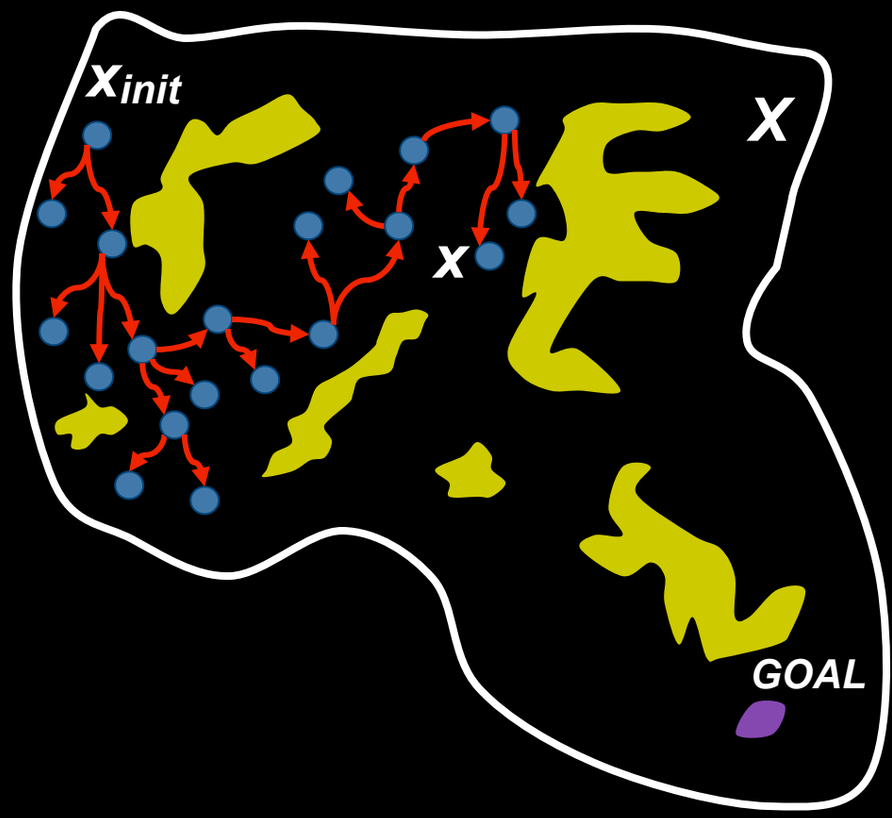
Sampling-based algorithms



Sampling-based algorithms

Compute a trajectory from an initial state to a goal region

Trajectory should satisfy all state constraints (e.g., no collisions) and dynamics constraints



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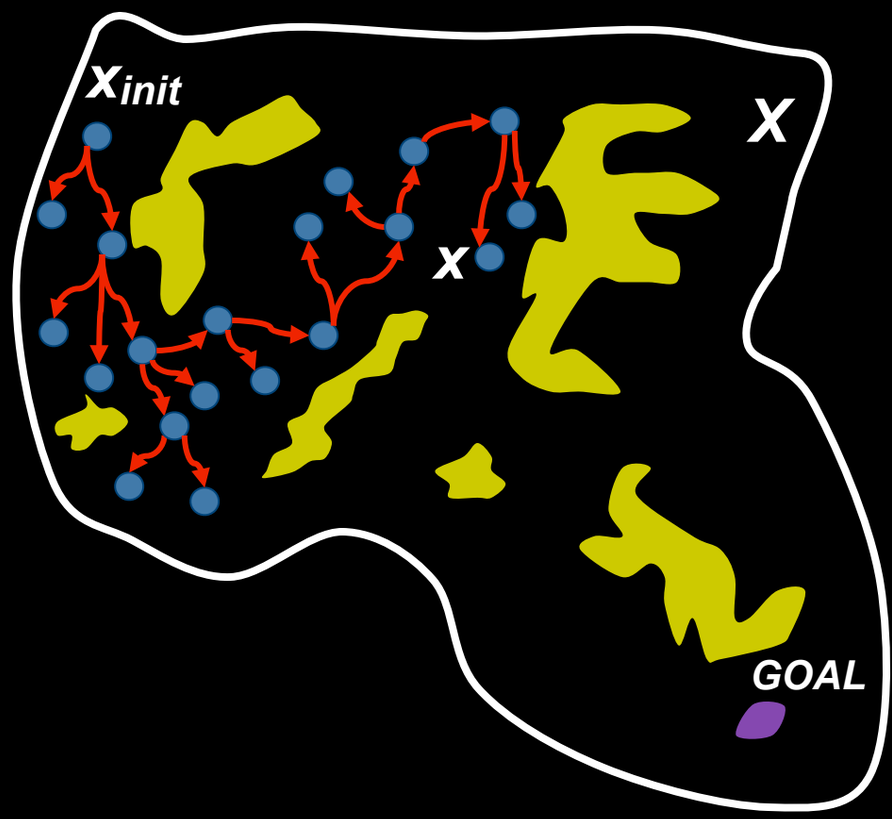
Basic tree-search framework



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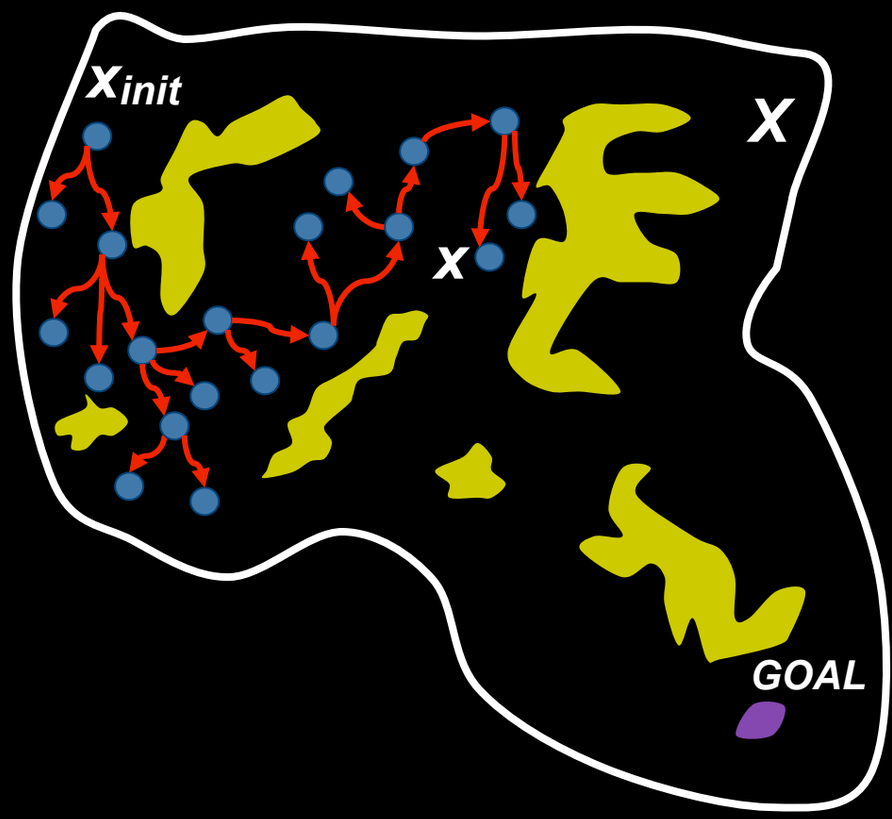

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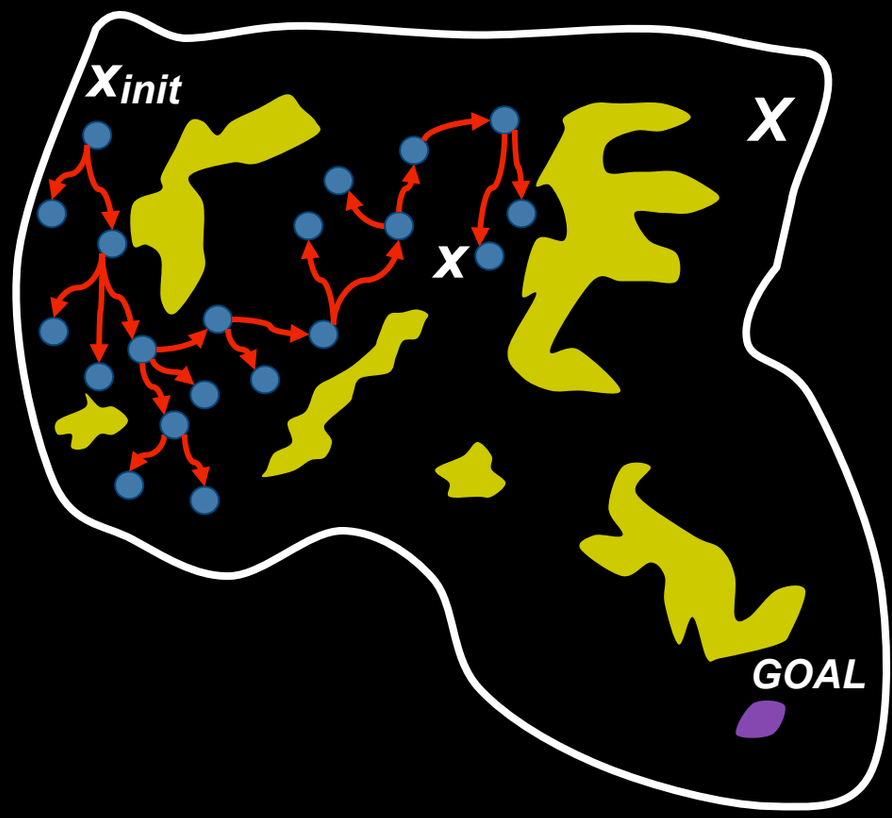

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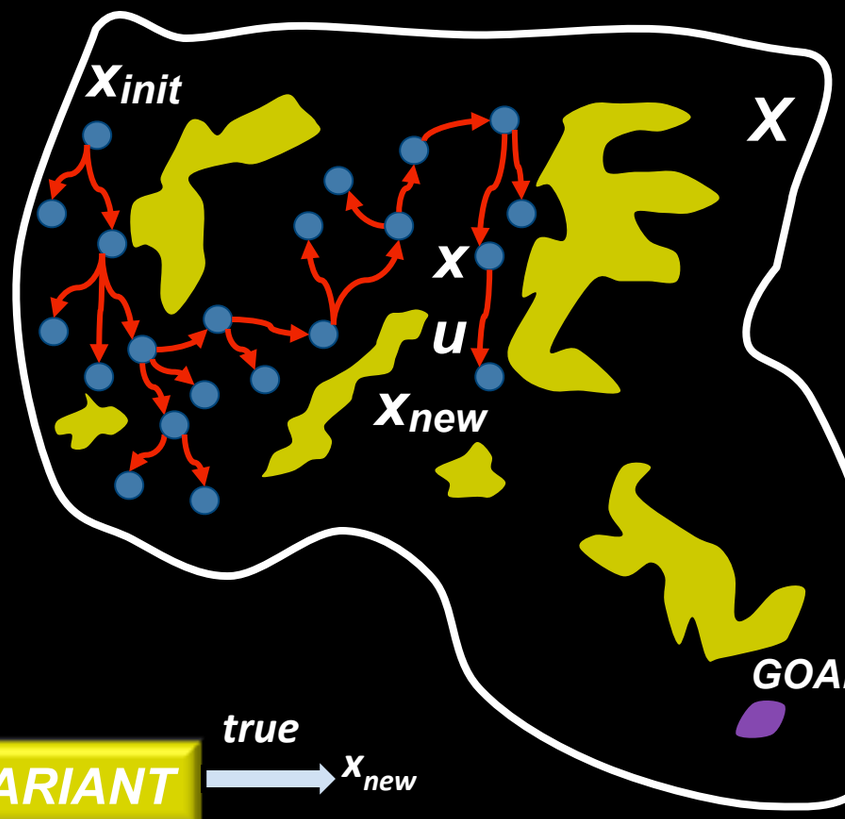

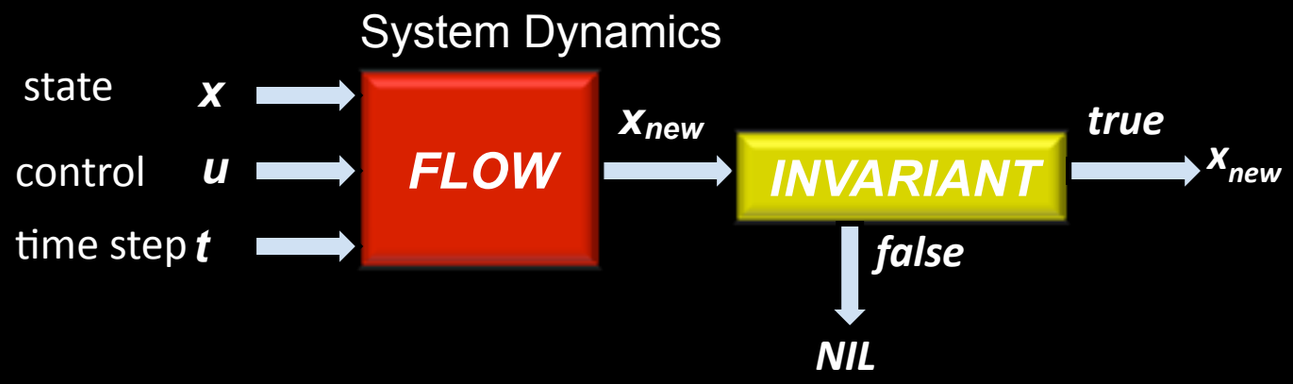

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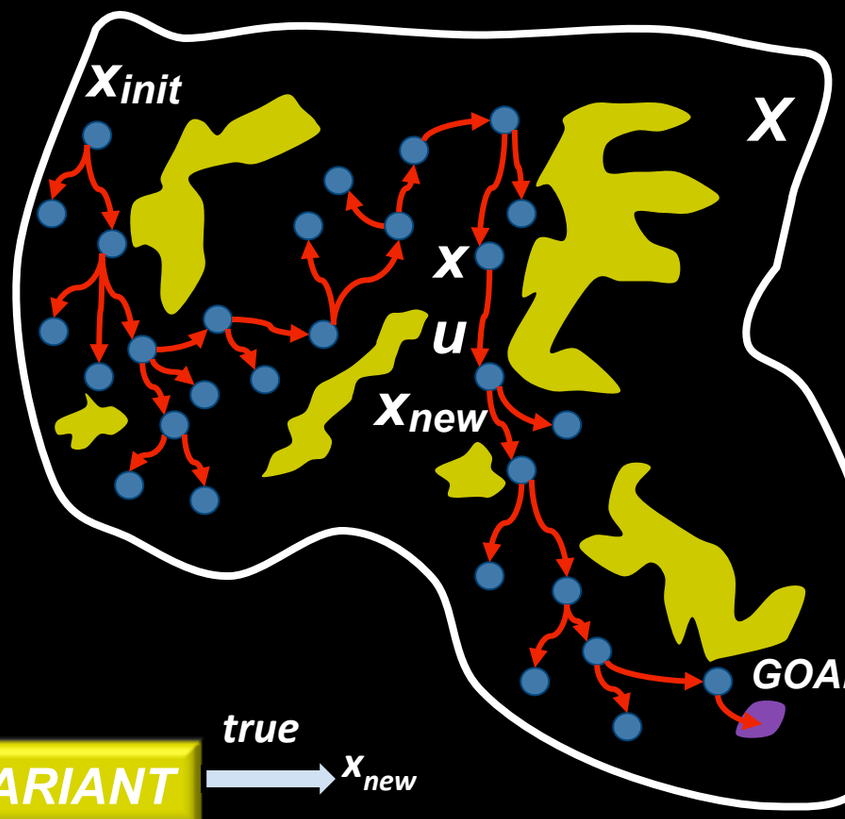
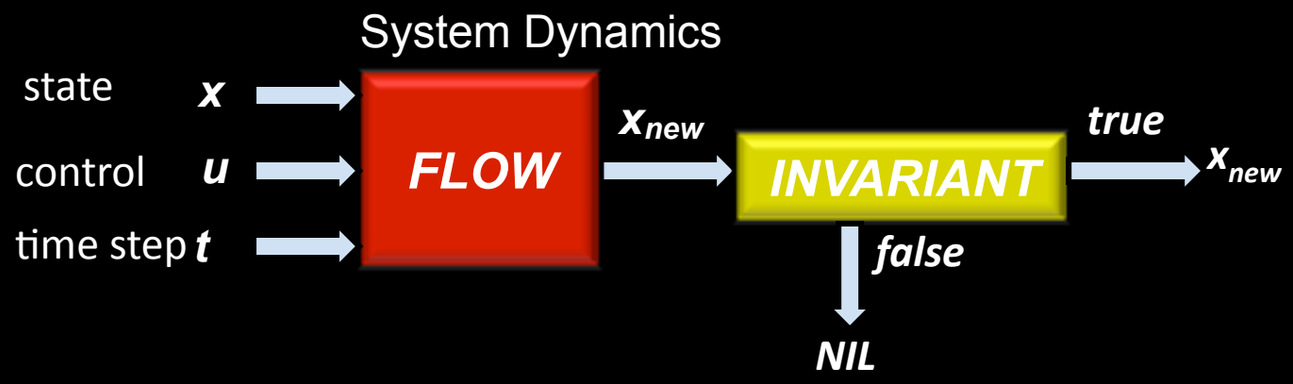
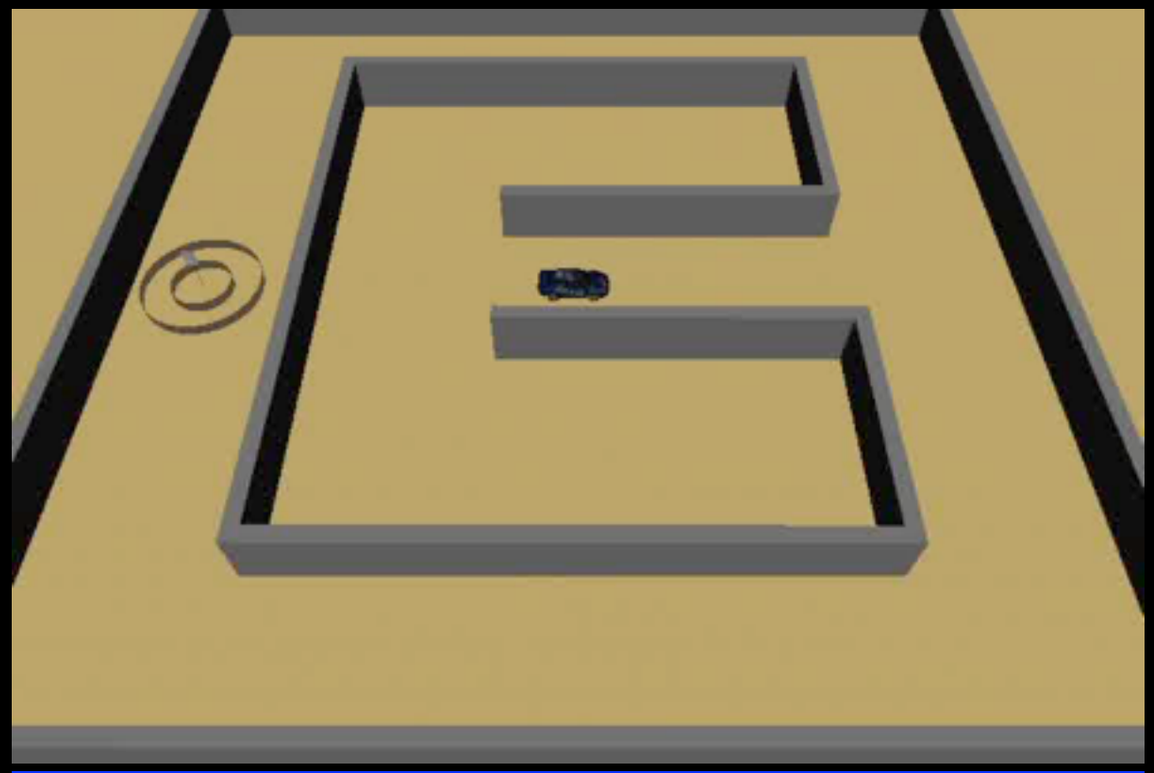
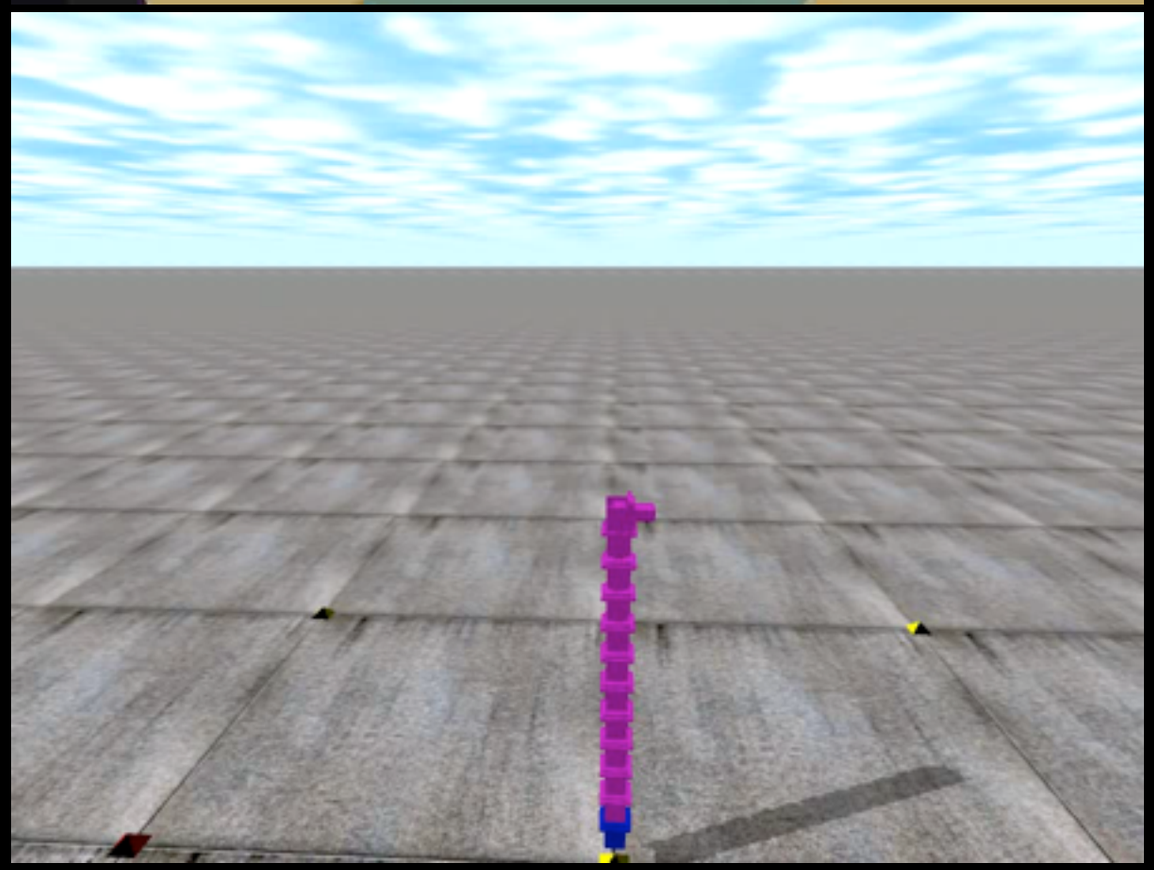
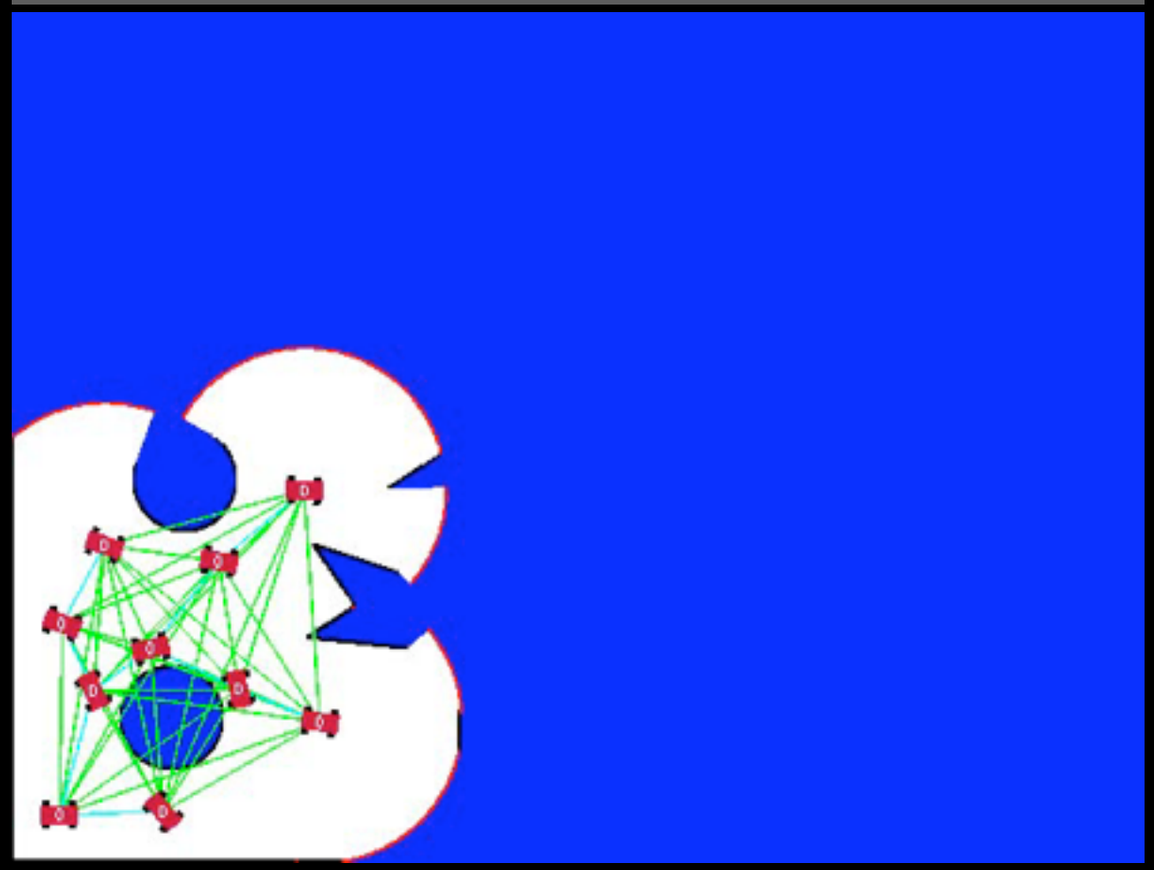




Examples







Outline

- Motivation
- Main features of OOPSMP
- Visual walk-through of using OOPSMP
- OOPSMP plug & play
- Concluding remarks

Motivation

The need for motion planning software

- Teaching tool:
  - Play with different algorithms
  - Quickly create interesting motion planning problems
  - Minimal programming overhead

The need for motion planning software

- Research tool:
  - Easily compare new algorithms with “standard” algorithms
  - Run algorithms on benchmark problems
  - Reuse common data structures

Existing motion planning software

- **Motion Strategies Library**, LaValle et al.
- **Motion Planning Kit**, Schwarzer, Saha, Latombe
- **KineoWorks**, Laumond et al.
- **OpenRAVE**, Diankov & Kuffner

OOPSMP:

Object-Oriented Programming System for Motion Planning

OOPSMP:

Object-Oriented Programming System for Motion Planning

- contains several motion planning algorithms
- is easily extensible with new algorithms
- has an easy to use graphical front-end
- runs on a variety of platforms
- already used in several classes and research groups around the world

Main features

- Stand-alone version
  - command line version
  - graphical version
- Can be used as a library
- Google SketchUp plugin
  - easy to create motion planning problems
- Source code available for download
- Runs on Windows, Linux, and Apple OS X

Motion planner components

Motion planner components

- high-level planning algorithms

PRM,
RRT,
EST,
bi-tree planner,
DDRRT*,
VisPRM*

Motion planner components

- high-level planning algorithms
- sampling strategies

uniform, Gaussian, obstacle-based, bridge test

Motion planner components

- high-level planning algorithms
- sampling strategies
- connection strategies

random
neighbors,
approx. n.n.
exact n.n.

Motion planner components

- high-level planning algorithms
- sampling strategies
- connection strategies
- path generation

geodesics, best or random control, collisions

Motion planner components

- high-level planning algorithms
- sampling strategies
- connection strategies
- path generation
- state spaces

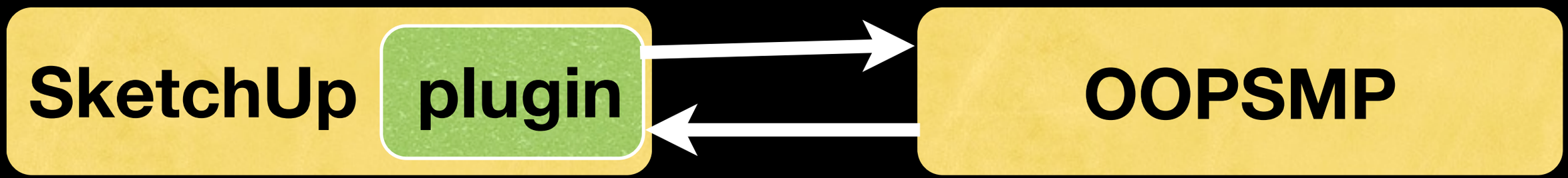
SE(2),
SE(3),
car-like
vehicles,
multiple
robots

OOPSMP workflow

- Define motion planning problem:
  - Define an environment
  - Define a robot
  - Specify queries
  - Specify global planner (PRM, RRT, etc.)
  - Specify local planner
- Run OOPSMP to solve motion planning problem

Google SketchUp:
a graphical front-end to OOPSMP

XML spec. of
motion planning problem



solution paths

Google SketchUp:
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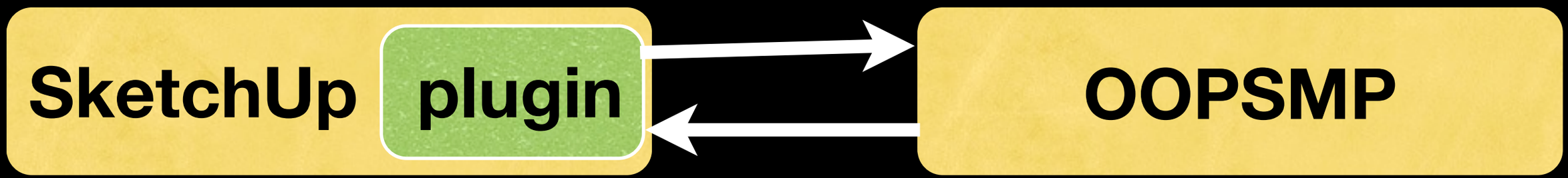
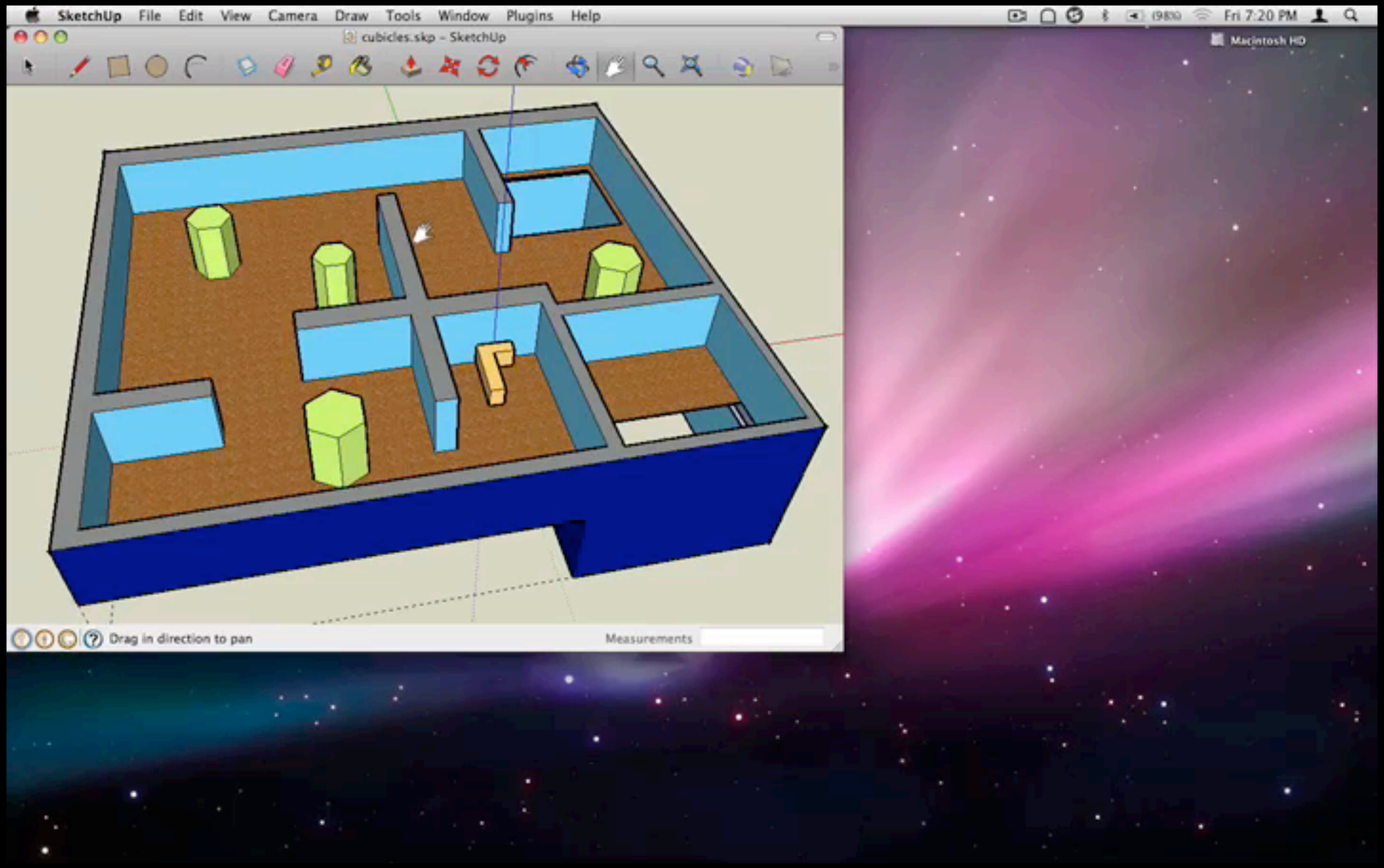


solution paths

Pros: ease of use, access to many 3D models

Cons: does not (yet) support all OOPSMP features,
not available for Linux

Motion planning with OOPSMP & SketchUp



OOPSMP Plug & Play

OOPSMP input

- XML input
  - Pros: self-describing, easy to parse/generate
  - Cons: very verbose
- OOPSMP XML files can include other XML files
  - Can reuse environment/robot for many motion planning problems

XML code for example

PRM.xml

```
1  <factory instance="Manager">
2    <call fn="setProgram">
3      <arg type="pointer">
4        <factory instance="MotionPlannerProgram">
5          <call fn="setFileNames">…
19         <call fn="setQueries">…
51         <call fn="setCoreRobotData">…
220        <call fn="setMotionPlanner">…
247        <call fn="setPreprocessTime">…
250        <call fn="setSolveTime">…
253      </factory>
254    </arg>
255  </call>
256</factory>
```

Line: 257 Column: 1 XML Tab Size: 2

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create object

call object's method

Line: 257 Column: 1 XML Tab Size: 2

XML code maps to C++ objects/methods

Main Page | Namespaces | Classes | Files | Directories | Related Pages

Alphabetical List | Class List | Class Hierarchy | Class Members

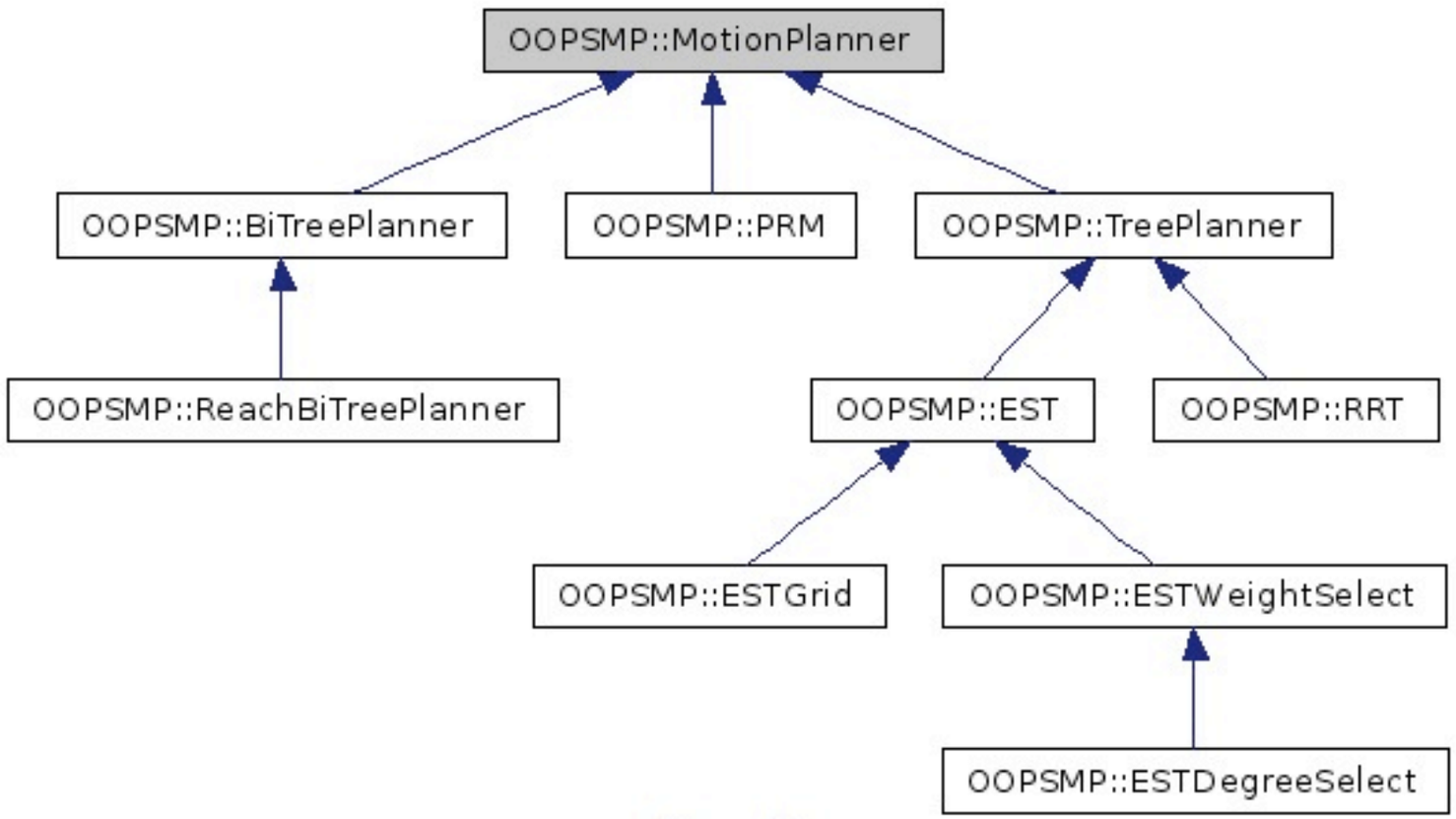
OOPSMP::MotionPlanner

OOPSMP::MotionPlanner Class Reference

Common functionality every motion planner should provide [written by Erion Plaku]. More...

#include <OOPSMPMotionPlanner.H>

Inheritance diagram for OOPSMP::MotionPlanner:



[legend]

XML code maps to C++ objects/methods

Free the memory allocated to different data elements.

Access motion planner data

bool	**areGapsAllowed** (void) const *Indicate whether gaps are allowed in path connections, i.e., path from a to b does not necessarily end at b , but somewhere near b.*
Query_t	**getQuery** (void) const *Access the current query the motion planner is solving.*
virtual bool	**isProblemSolved** (void) const=0 *Indicate whether the current motion planning query has been solved or not.*

Setup motion planner

void	**setCoreRobotData** (CoreRobotData_t crd) *Setup the core robot data, i.e., motion planning components.*
virtual void	**allowGaps** (const bool allowGaps) *Indicate whether or not gaps are allowed, i.e., path from a to b does not necessarily end at b , but somewhere near b.*
virtual void	**setQuery** (Query_t query) ***Set** the motion planning qeury.*

Use motion planner to solve one or more queries

virtual void	**solveMultipleQueries** (const double ptime, const double stime, Queries_t queries, const int *perm=NULL)=0 *Solve multiple motion planning queries.*
virtual void	**solveSingleQuery** (const double ptime, const double stime, Query_t query) *Solve a single motion planning query.*

Solve the current motion planner query

OOPSMP Plug & Play

Can add new global planners, local planners, collision checkers, etc. without having to recompile main OOPSMP code:

- Derive from abstract classes that define API
- Bundle new code in a plugin
- New code automatically accessible from XML

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  - Path-Directed Subdivision of Trees (PDST)
  - TemporalHyDICE (planner for hybrid systems + LTL)
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  - *Get support for articulated mechanisms “for free”!*
- Add support for COLLADA 1.5
  - file format for geometry, kinematics, physics

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With OOPSMP it is relatively easy to:

- "play" with various state-of-the-art sampling-based motion planning algorithms,
- add new algorithms,
- develop new benchmarks,
- perform parameter sweeps,
- compare algorithm performance,
- embed motion planning system in larger robotic system.

OOPSMP team

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