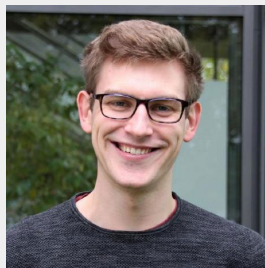


# How to Use a Dragon's Algorithm

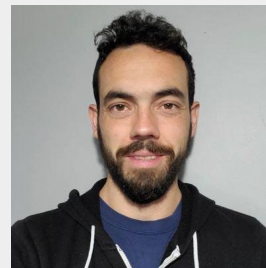
Integrating Drake with MoveIt 2



**Aditya Kamireddypalli**  
University of Edinburgh



**Sebastian Jahr**  
PickNik Robotics



**Sebastian Castro**  
The AI Institute

# How to Use a Dragon's Algorithm

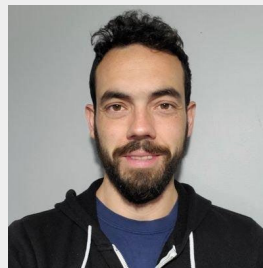
Integrating Drake with MoveIt 2



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# Outline

1. What is MoveIt & What is Drake?
2. Why integrating them?
3. Kinematic Trajectory Optimization Planner Plugin
4. Learnings, Challenges and Roadmap



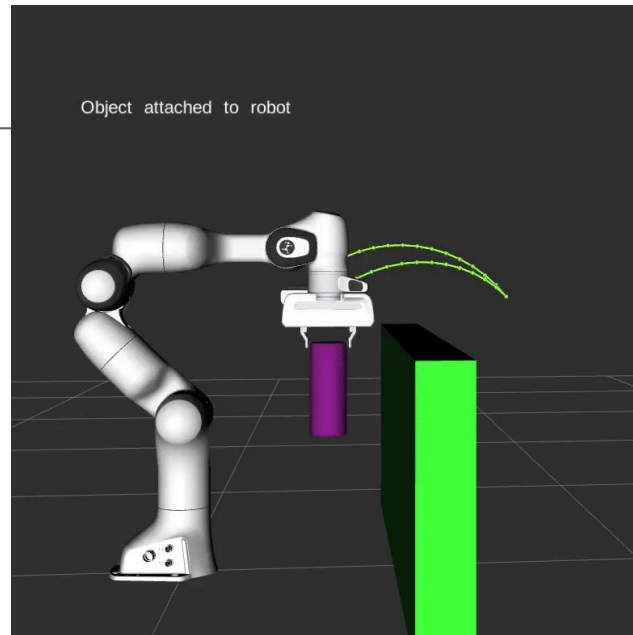
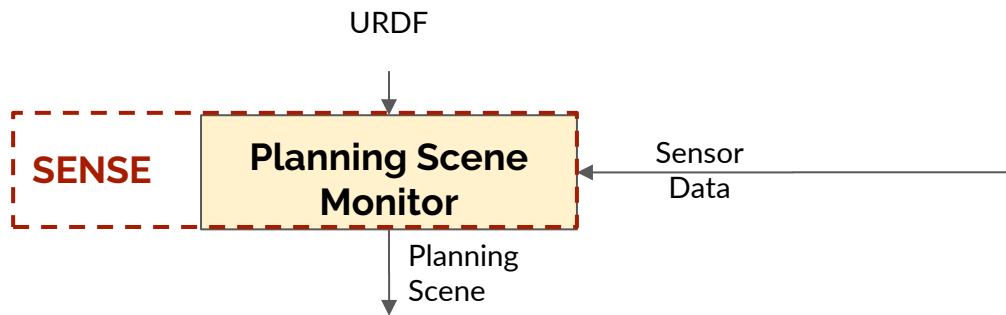
# What is MoveIt?



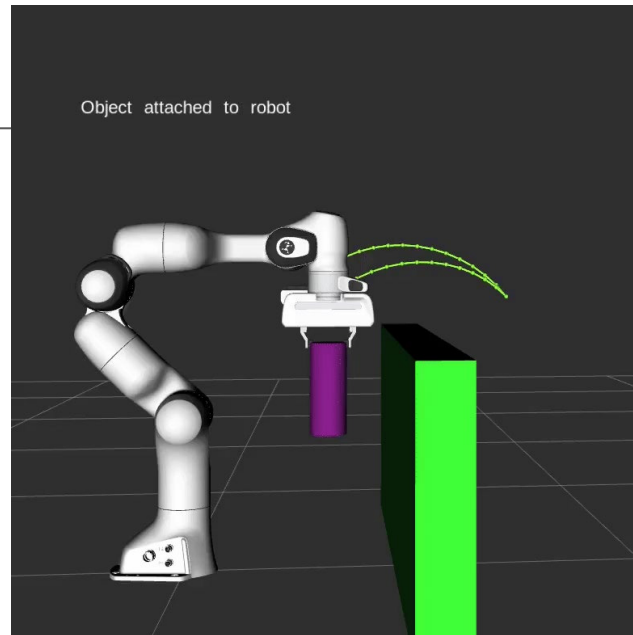
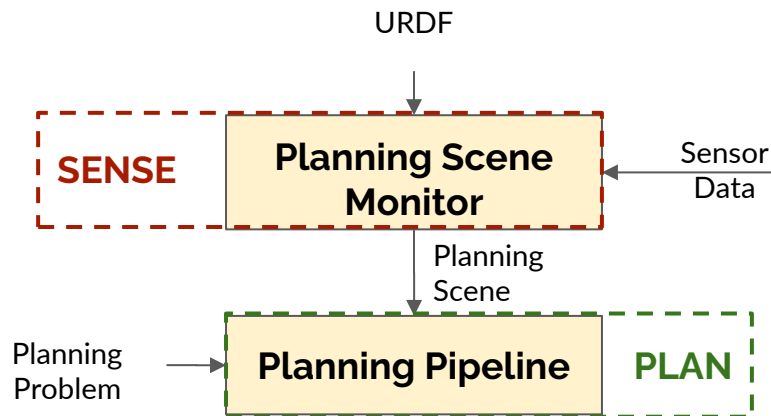
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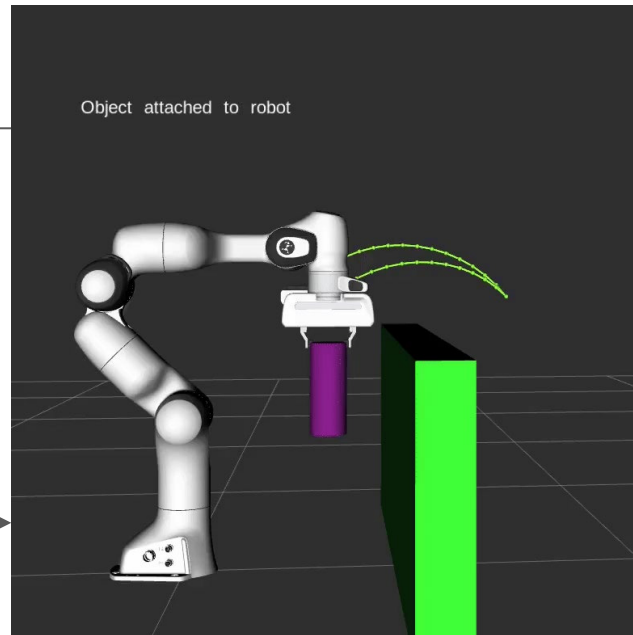
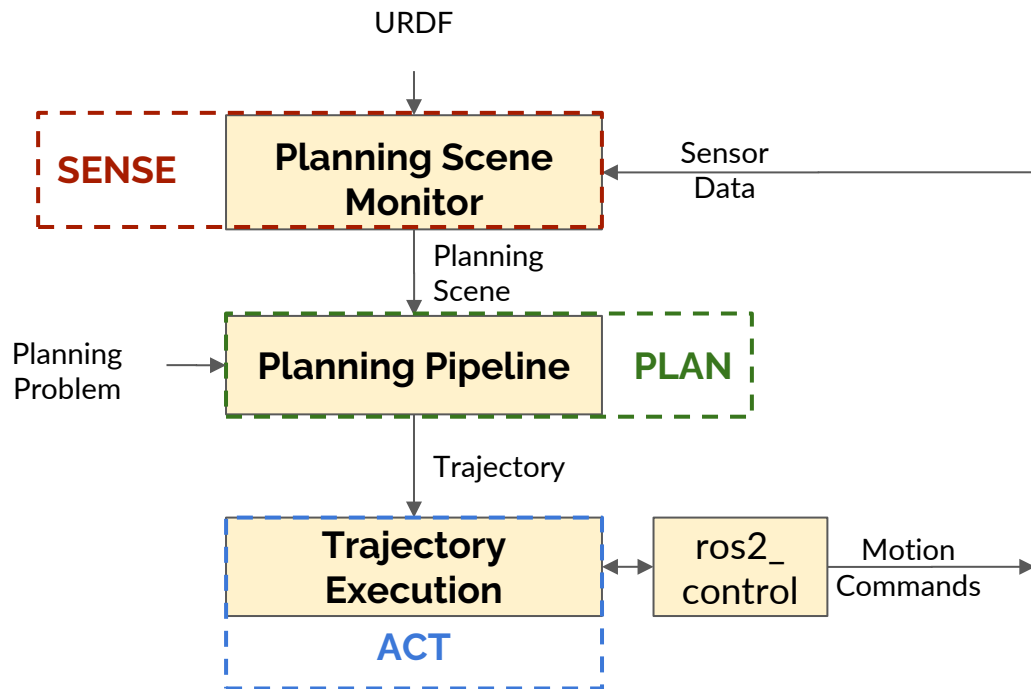
# Movelt 2 is a ROS Motion Planning Framework



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# Movelt 2 is a ROS Motion Planning Framework



More Information: <https://moveit.picknik.ai/main/index.html>

# What is Drake?



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# Model-Based Design and Verification for Robotics

Drake is a robotics C++ software (with Python bindings) maintained by the Robot Locomotion Group from MIT and Toyota Research Institute



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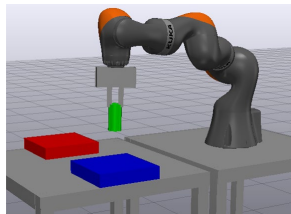


# Model-Based Design and Verification for Robotics

Drake is a robotics C++ software (with Python bindings) maintained by the Robot Locomotion Group from MIT and Toyota Research Institute

## Multibody Dynamics

Drake's physics engine to simulate dynamic environments with rigid and compliant bodies.

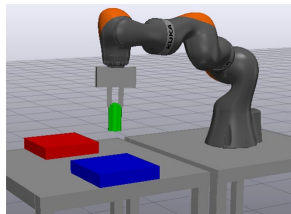


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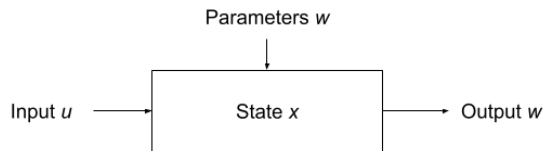
## Multibody Dynamics

Drake's physics engine to simulate dynamic environments with rigid and compliant bodies.



## Systems Framework

Model complex systems as block diagrams consisting of subsystems like this:

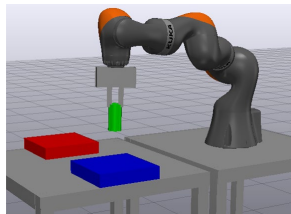


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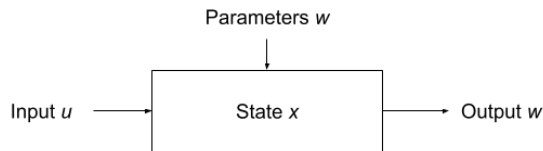
## Multibody Dynamics

Drake's physics engine to simulate dynamic environments with rigid and compliant bodies.



## Systems Framework

Model complex systems as block diagrams consisting of subsystems like this:



## Optimization Framework

API to formulate mathematical programs and solve them with open source or commercial solvers.

$$\begin{aligned} \min_{\alpha, T} \quad & T, \\ \text{subject to} \quad & X^{G_{start}} = f_{kin}(q_{\alpha}(0)), \\ & X^{G_{goal}} = f_{kin}(q_{\alpha}(T)), \\ & \forall t, \quad |\dot{q}_{\alpha}(t)| \leq v_{max}. \end{aligned}$$

More Information: <https://drake.mit.edu/>

# Why integrating them & How?



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# Why putting Drake into MoveIt

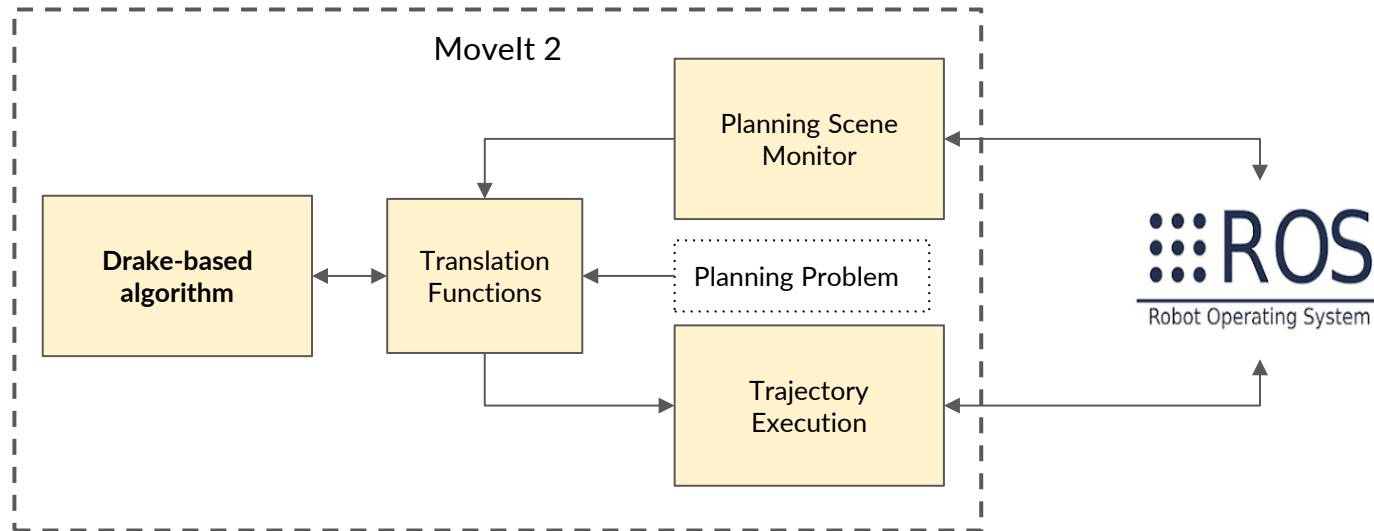
MoveIt is well-integrated into ROS ecosystem and can do the integration work to bring the Drake ecosystem into existing applications.

([drake-ros](#) -> experimental examples)

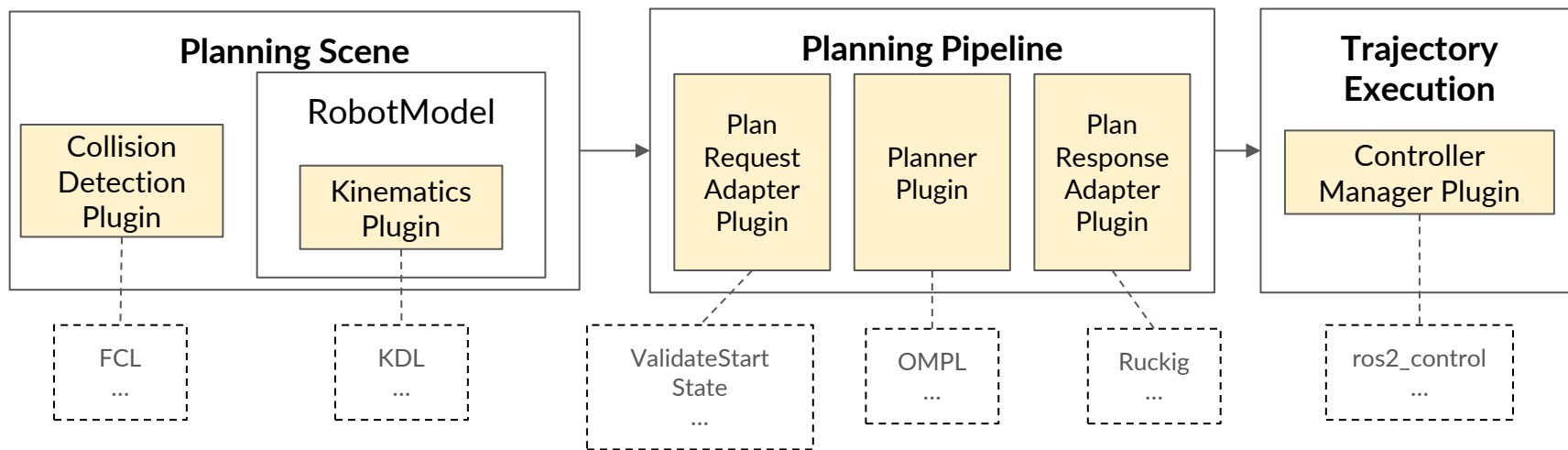
Drake provides state-of-the-art optimization capabilities and access to top-notch optimization solvers



## ... and How?



# Movelt's Plugin System



Plugins integrate algorithms from 3rd party libraries into the moveit planning pipeline



# Kinematic Trajectory Optimization (KTOpt) as a Planner Plugin



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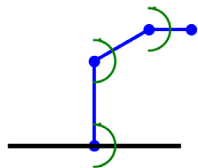


# What is KTOpt ?

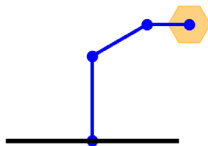
$$\begin{aligned} \min_{\alpha, T} \quad & T, \\ \text{subject to} \quad & X^{G_{start}} = f_{kin}(q_{\alpha}(0)), \\ & X^{G_{goal}} = f_{kin}(q_{\alpha}(T)), \\ & \forall t, \quad |\dot{q}_{\alpha}(t)| \leq v_{max}. \end{aligned}$$

# What is KTOpt ?

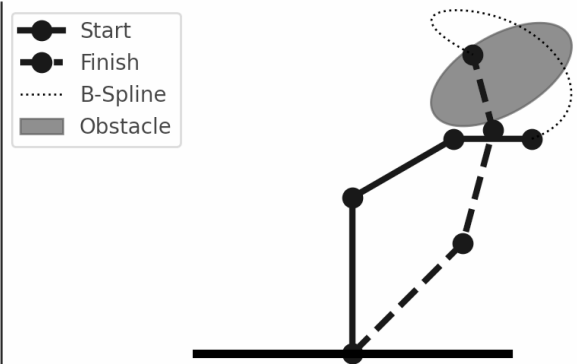
$$\begin{aligned} \min_{\alpha, T} \quad & T, \\ \text{subject to} \quad & X^{G_{start}} = f_{kin}(q_{\alpha}(0)), \\ & X^{G_{goal}} = f_{kin}(q_{\alpha}(T)), \\ & \forall t, \quad |\dot{q}_{\alpha}(t)| \leq v_{max}. \end{aligned}$$



Kinematic Constraints

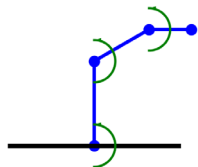


Path Constraints

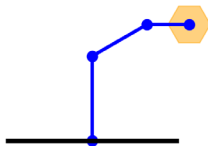


# What is KTOpt ?

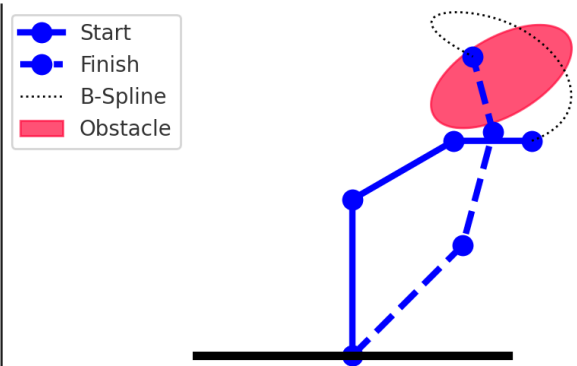
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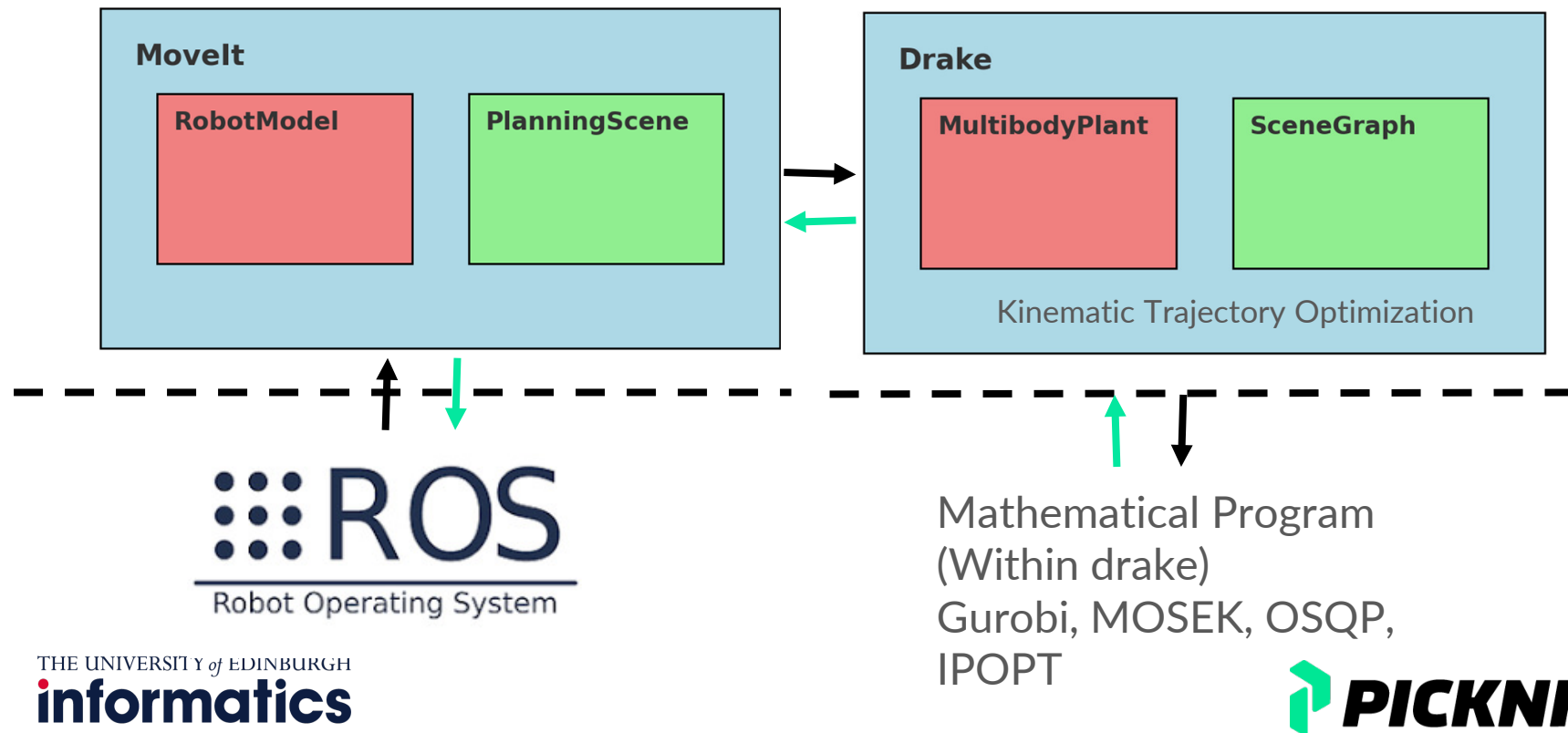
Kinematic Constraints



Path Constraints



# Transcribing between Drake and MoveIt

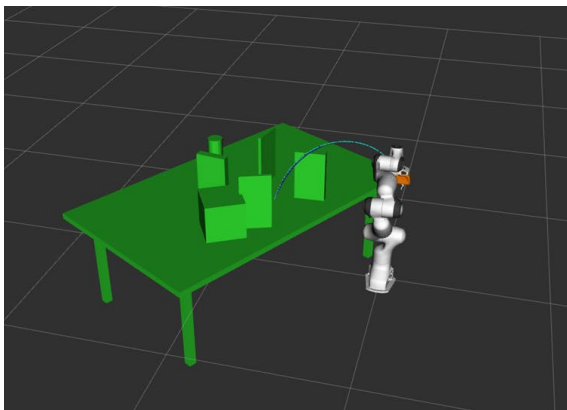


# Transcribing between Drake and Moveit

## MoveIt's Representation

- Scene geometry - PlanningScene
- Robot Kinematics - RobotModel

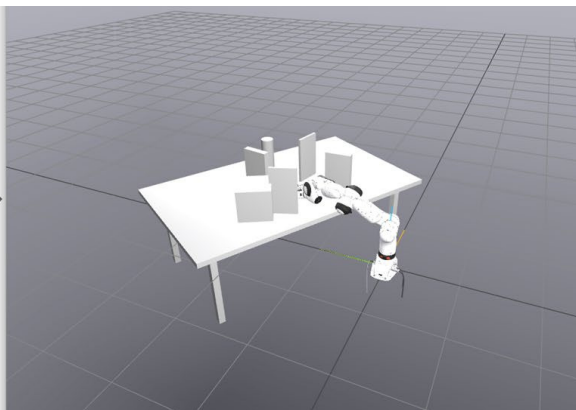
MoveIt



## Drake's Representation

- Scene geometry - SceneGraph
- Robot Kinematics - MultibodyPlant

Drake



# Transcribing between Drake and Moveit

## MoveIt's Representation

- Scene geometry - PlanningScene
- Robot Kinematics - RobotModel

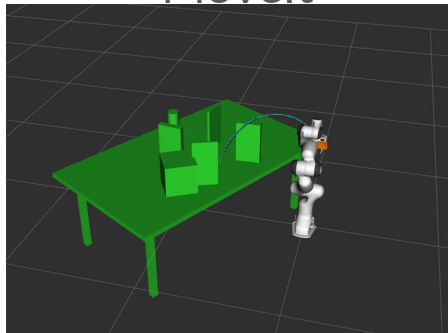
## Drake's Representation

- Scene geometry - SceneGraph
- Robot Kinematics - MultibodyPlant

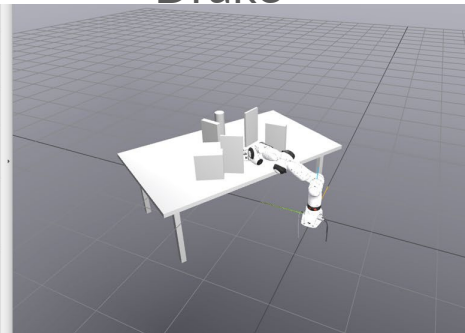
## Constraints - 3 sources

- Runtime parameters, via `generate_parameter_library`
- Constraints in MoveIt's in-built planning request messages
- Robot Model (joint limits, etc.)

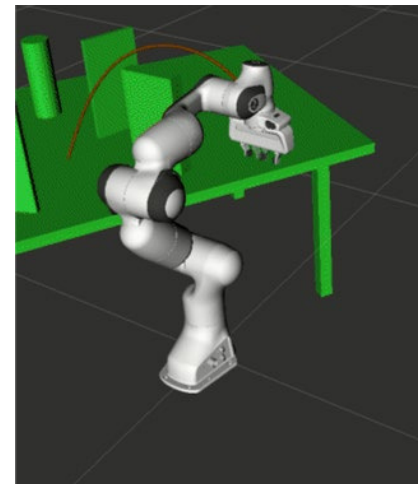
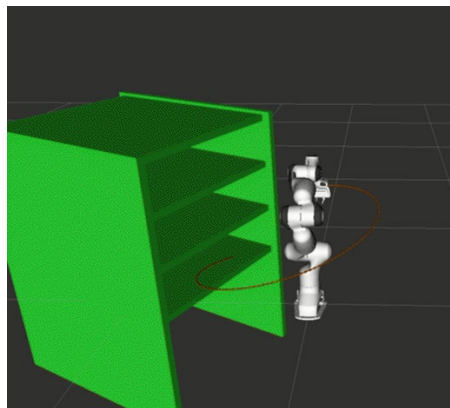
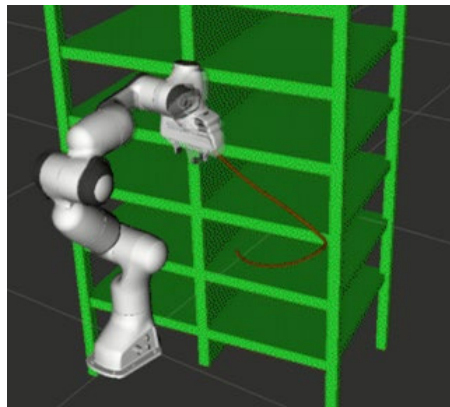
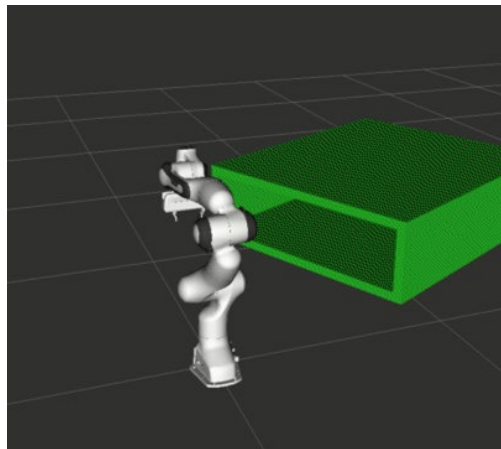
MoveIt



Drake

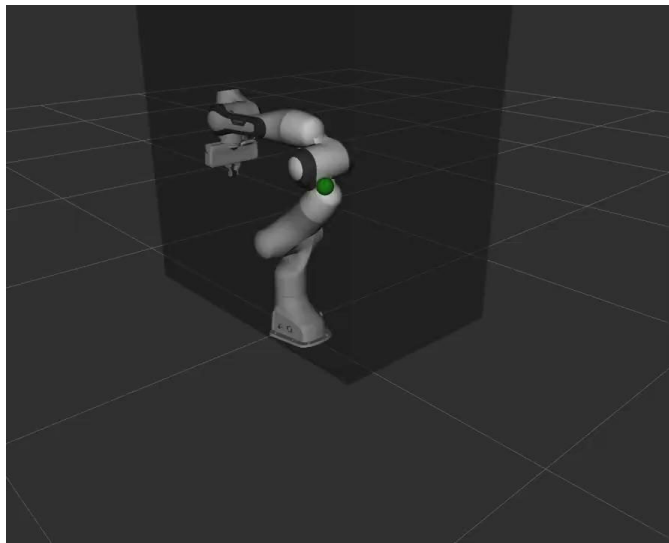


# Results - Transcription of Geometry



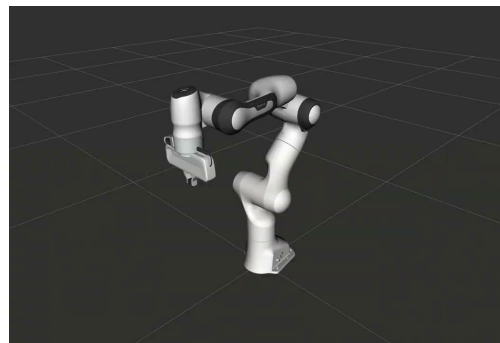


# Results - Constrained Planning



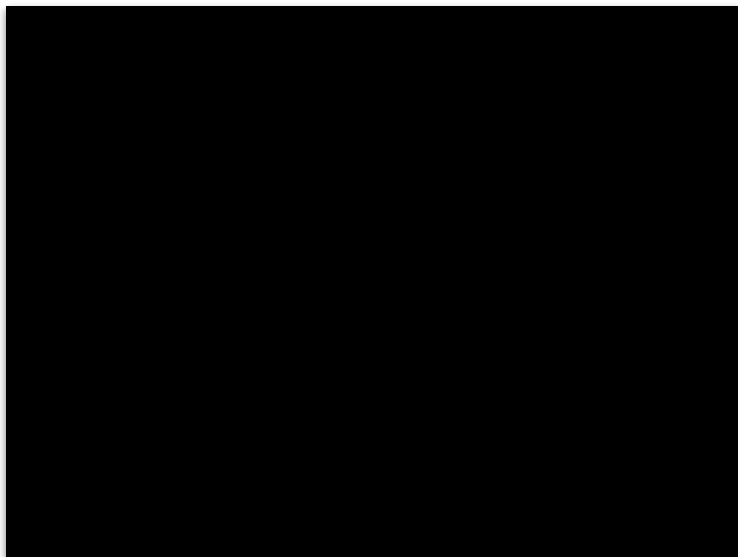
Mixed Orientation and Position Constraints

Orientation Constraints



Position Box Constraints

# Results - Comparison



Planner	Avg. Path Length	Success/problems
OMPL	9.355	6/7
Stomp	9.13	3/7
KTOpt	9.92	6/7

# Learnings, Challenges and Roadmap



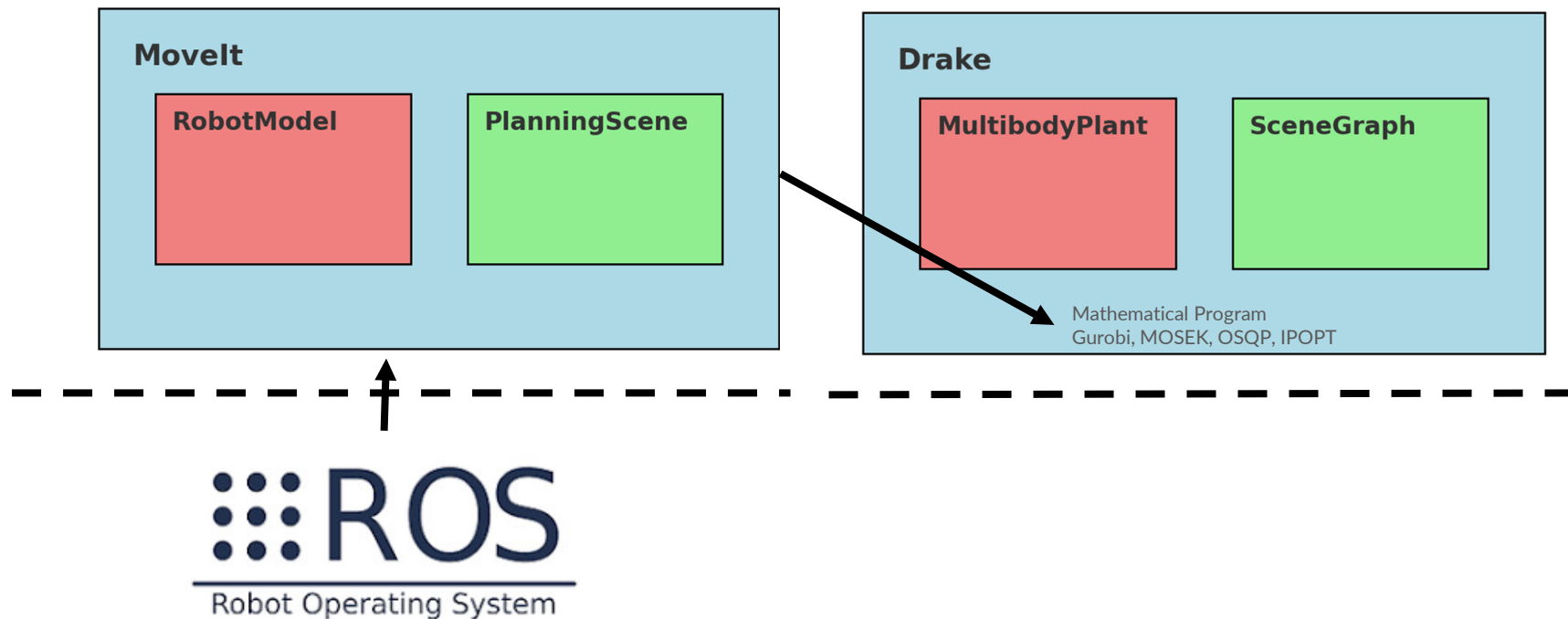
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# Learnings & Challenges

- Design principles vary for each framework
  - MoveIt built for real robot control
  - Drake built for verification and testing of mathematical programs and optimal controllers.
- URDF Incompatibility
  - Most ROS URDF utilise STL and OBJ mesh specification.
  - Drake supports only Wavefront OBJ and glTF formats. The plugin utilises *RobotLocomotion/models*
- Open planning scene transcription problems
  - Difficulty in transcribing mesh and octomap from moveit into Drake

# Roadmap and Future Ideas



# Roadmap & Future Ideas

- Version 0.1 of `moveit_drake`
- Chaining Motion plans
  - Use a sampling based motion plan to come up with a feasible traj
  - Seed the optimization based Motion Plan to generate optimal trajectories
- Benchmark KTOpt against other planners
- Expose more algorithms as plugins
  - TOPPRA (Under review)
  - Global IK
  - Graph of Convex Sets (GCS)
- Use Drake for dynamic online planning
  - DiffIK ros2\_controller for local QP reactive planning
- Looking for new contributors!

# moveit\_drake



[https://github.com/moveit/moveit\\_drake](https://github.com/moveit/moveit_drake)



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