Final Presentation

ED 5215 - INTRODUCTION TO MOTION PLANNING

Shrung DN - Sidharth Tadeparti - Tejas Rao

Motion Planning for a Surgical Robot with RCM.

Project 8

Problem

- Planning the a path for a surgical robot (KUKA iiwa 7).
- Incorporating the Remote Centre of Motion Constraint algorithmically.

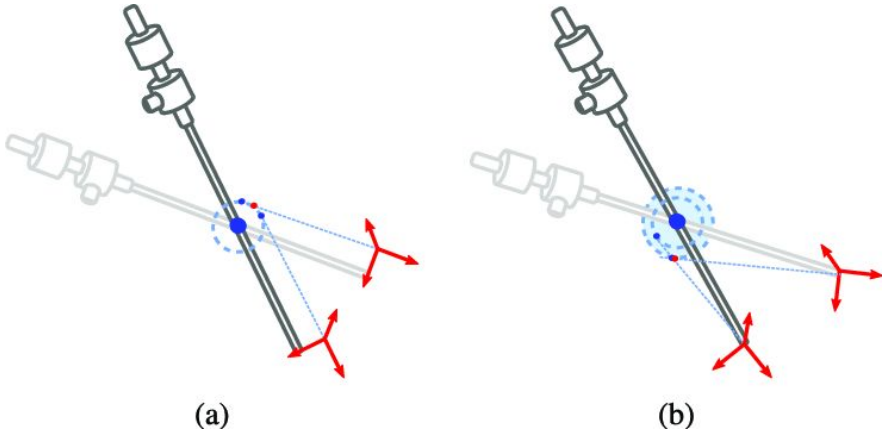
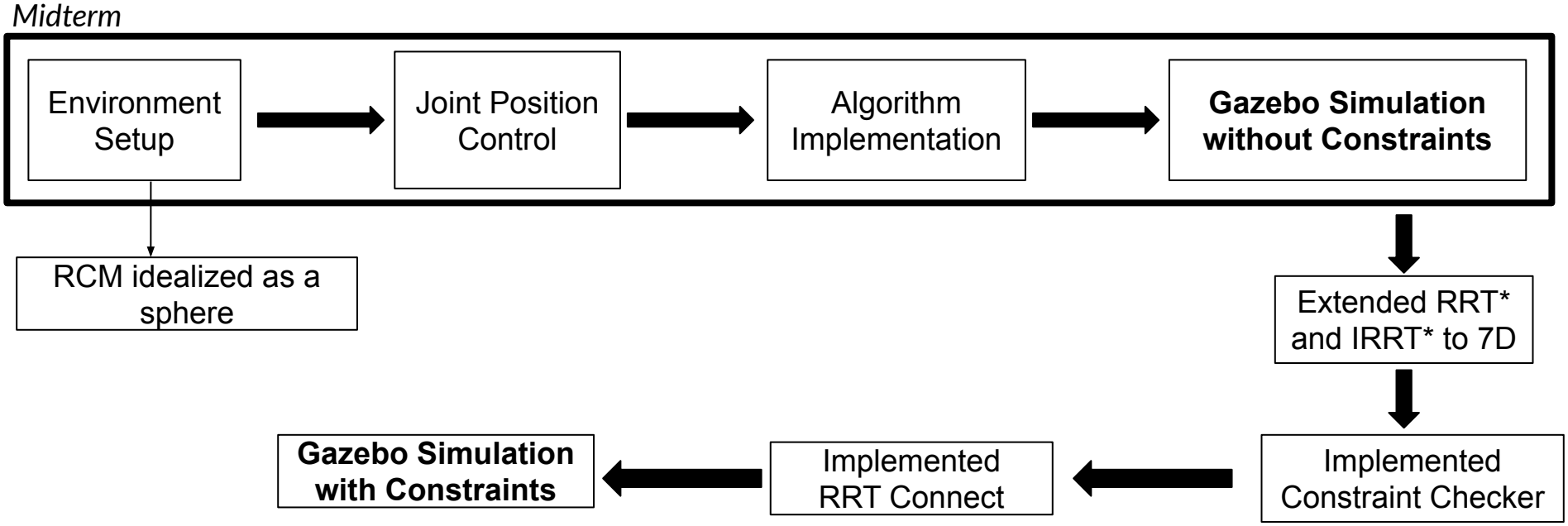


Image Credits:Vasconcelos Et Al

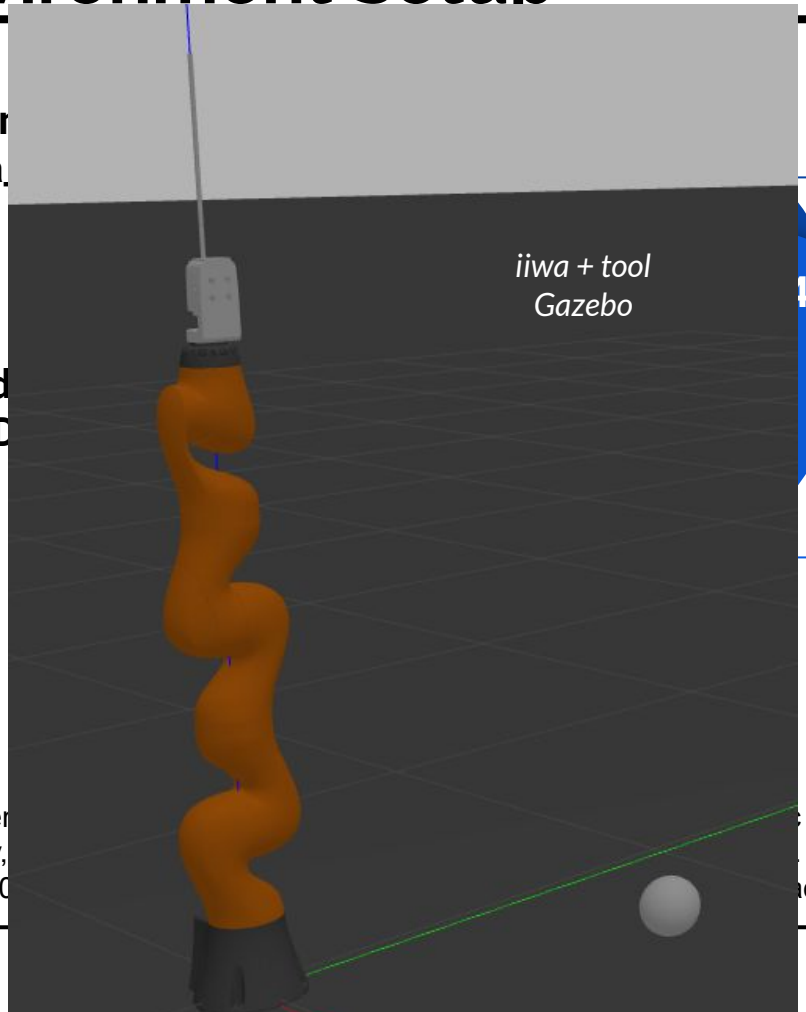
Project Progression



Environment Setup

Environ
iiwa_

Mod
URD



Global Planner Integration

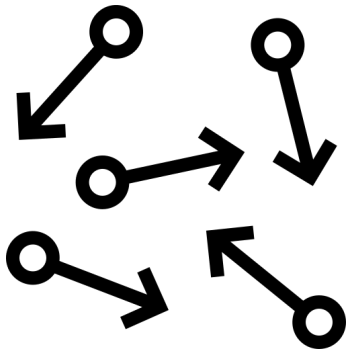
Local Planner using Moveit

Joint Angle Controller

C. Her
Study,
10.110

US Acquisitions: A First Feasibility
538-548, Feb. 2017, doi:
ack

Sampling Based Planning



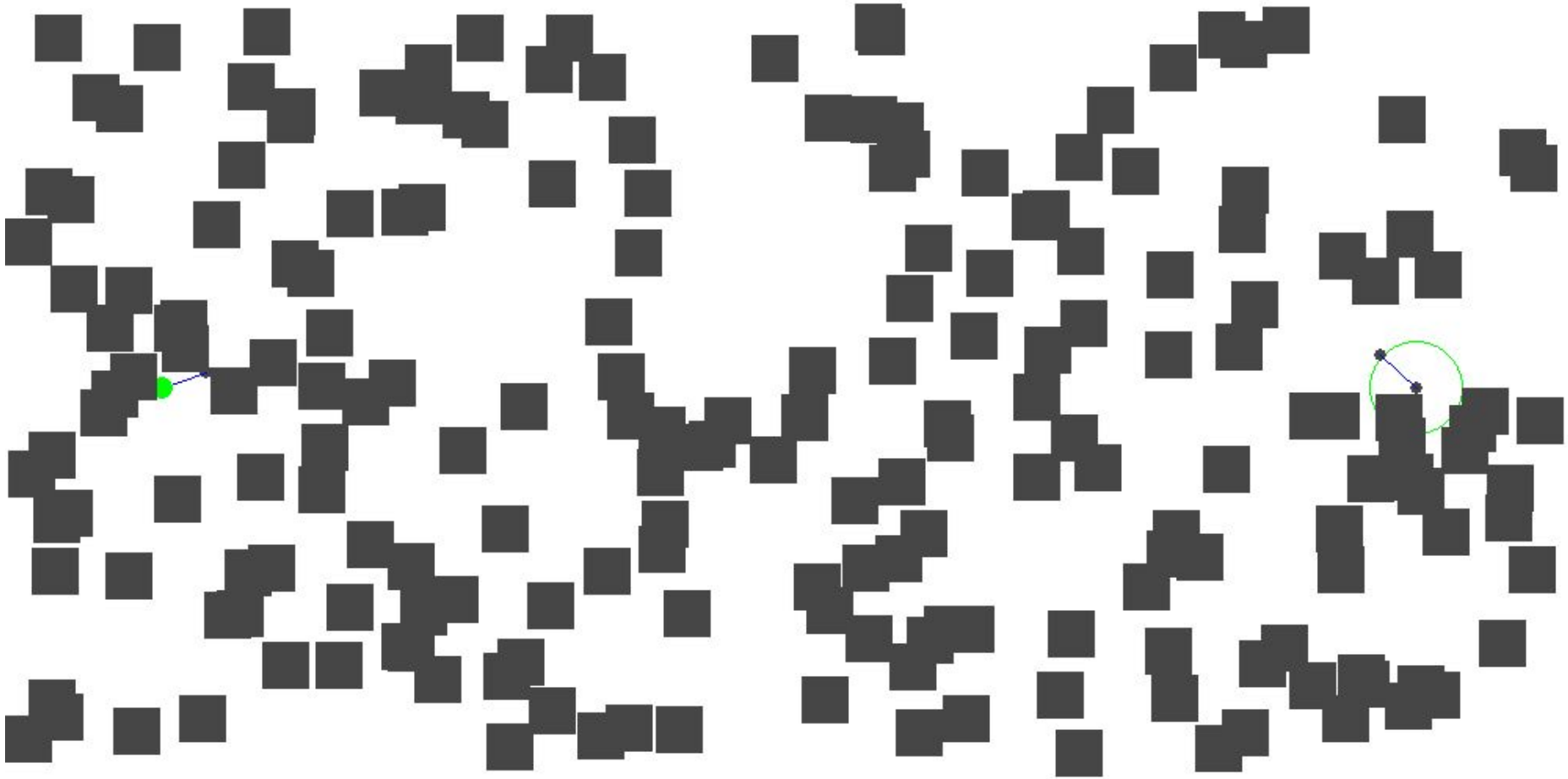
- RRT
- *RRT**
- ***Informed RRT****
- *RRT Connect*

J. D. Gammell, S. S. Srinivasa and T. D. Barfoot, "Informed RRT*: Optimal sampling-based path planning focused via direct sampling of an admissible ellipsoidal heuristic," *2014 IEEE/RSJ International Conference on Intelligent Robots and Systems*, Chicago, IL, USA, 2014, pp. 2997-3004, doi: 10.1109/IROS.2014.6942976.

RRT

*RRT**

*IRRT**



RRT Connect

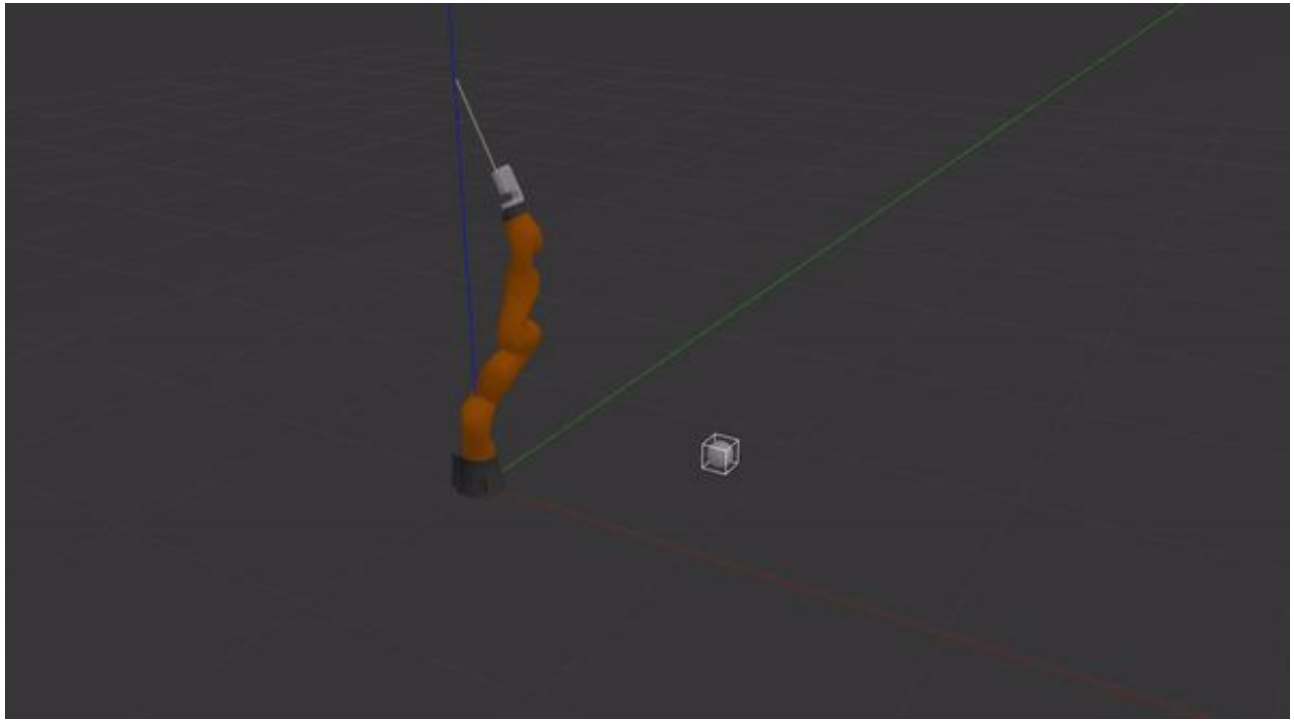
Performance on Map with Narrow Passages

RRT*

IRRT*

RRT Connect

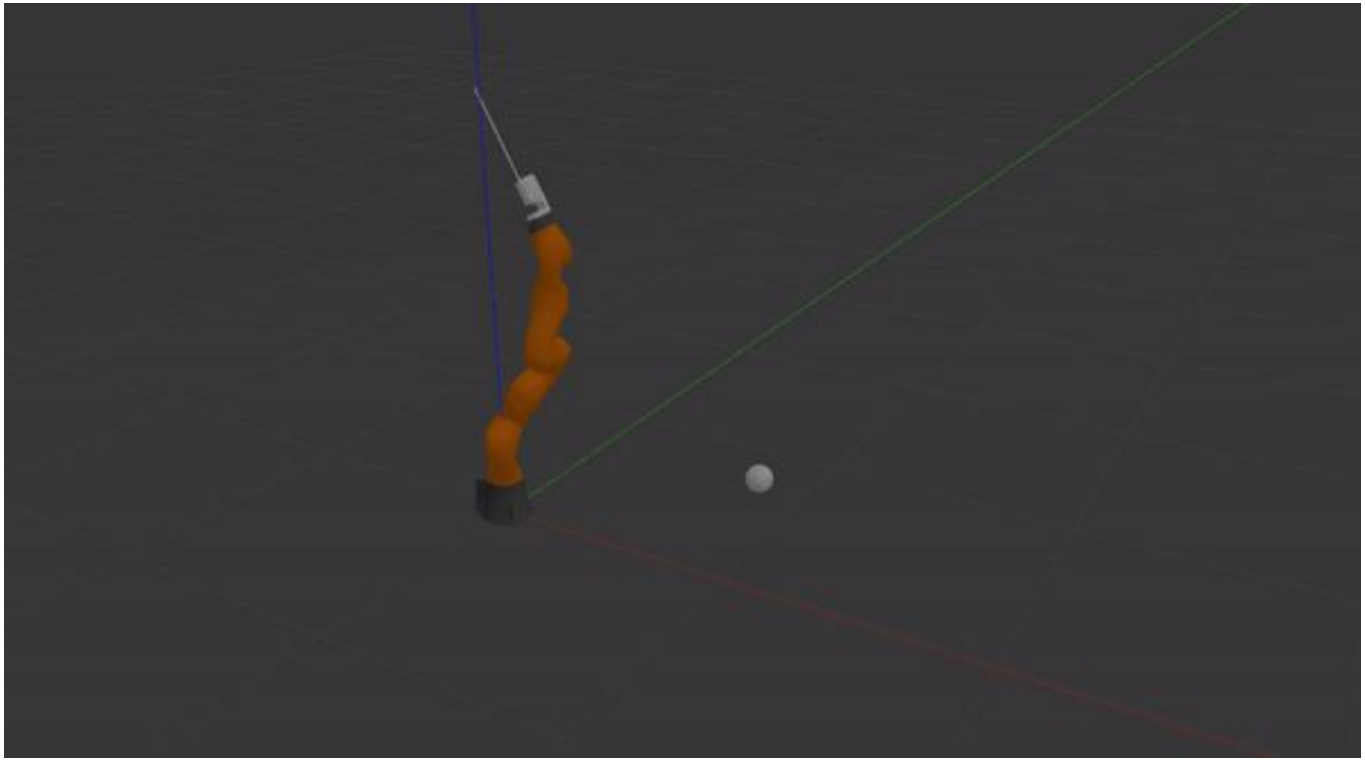
RRT



RRT

```
Flag Changed
652 0.04676599711660075
(array([-0.73955254,  0.23621331,  1.51384365]), array([[ 0.64938319,  0.480759
48, -0.58921286],
       [-0.48930654,  0.85727126,  0.16020329],
       [ 0.5821345 ,  0.18427238,  0.79193631]]))
```

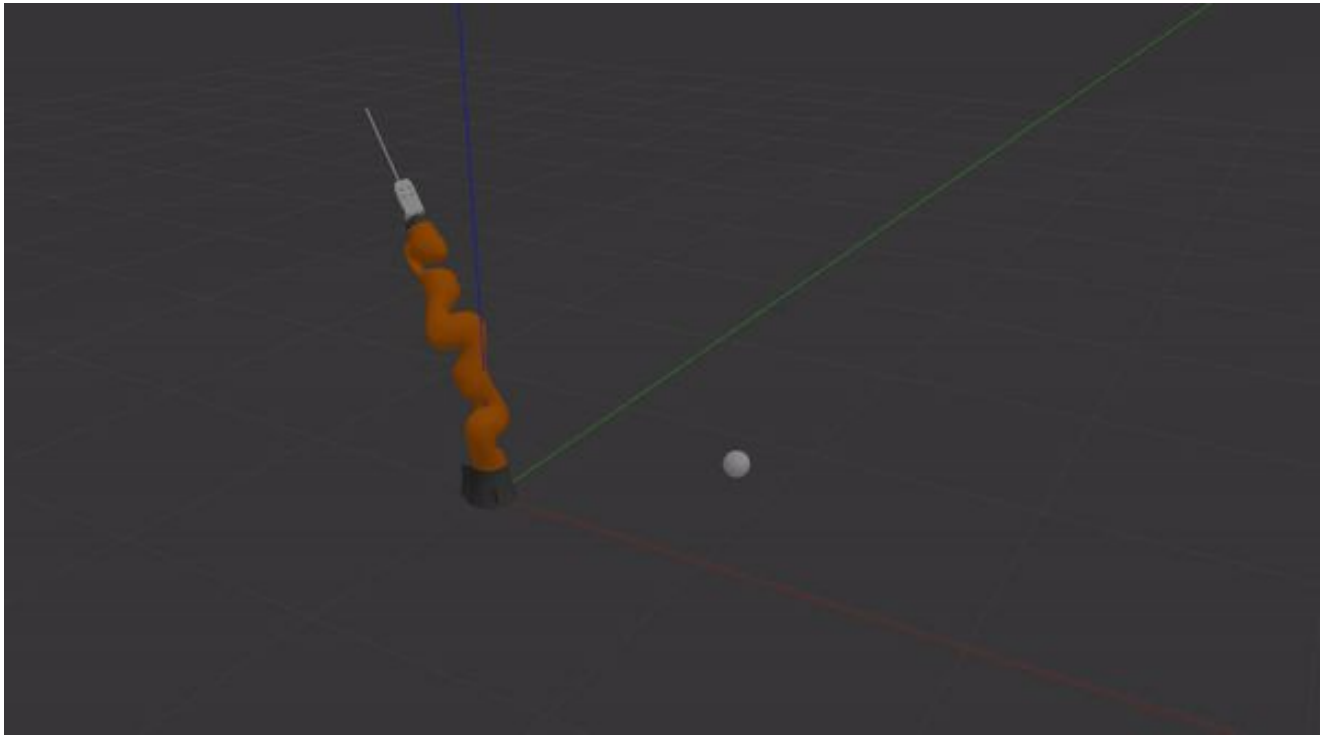
RRT*



RRT*

```
799 0.008831469738691712
Flag Changed
800 0.008389896251757081
(array([-0.75309902,  0.27036336,  1.4952715 ]), array([[ 0.61465039,  0.508541
38, -0.60298472],
       [-0.4988353 ,  0.84276175,  0.20227695],
       [ 0.61103866,  0.17646046,  0.77168223]]))
```

IRRT*



IRRT*

```
799 3.7382803500526573e-05
Flag Changed
800 3.5513663325523744e-05
(array([-0.15726369,  0.14863311,  1.65003096]), array([[ 0.376133  , -0.801799
05, -0.46437296],
       [ 0.89206695,  0.44885027, -0.05244039],
       [ 0.25048059, -0.39452721,  0.88408583]]))
```

Extending to the KUKA IIWA 7

RCM Position

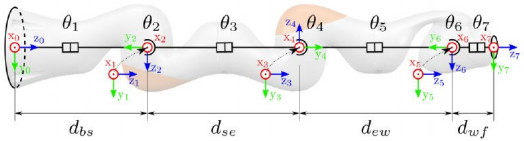
RCM Radius

RCM Orientation

Forward Kinematics DH Parameters*

Global RRT Module*

Constraint Checking



i	α_i	d_i	a_i	θ_i
1	$-\frac{\pi}{2}$	d_{bs}	0	θ_1
2	$\frac{\pi}{2}$	0	0	θ_2
3	$\frac{\pi}{2}$	d_{se}	0	θ_3
4	$-\frac{\pi}{2}$	0	0	θ_4
5	$-\frac{\pi}{2}$	d_{ew}	0	θ_5
6	$\frac{\pi}{2}$	0	0	θ_6
7	0	d_{wf}	0	θ_7

Joint Control

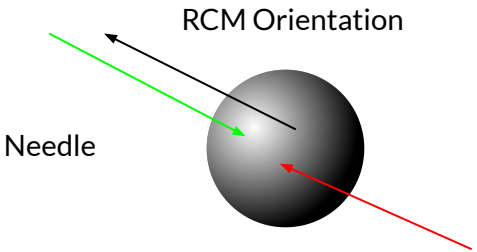
Gazebo

- **IK not Implemented**
  - Start and Goal given in C-Space
  - They both have to satisfy constraints

*https://github.com/yongan007/inverse_foward_kinematics_Kuka_iiwa

Constraint Checking

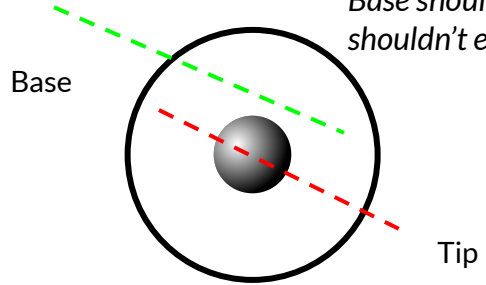
Orientation Check ✓



Inner Product

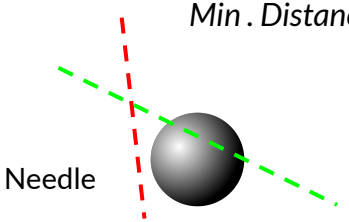
Safety Radius Check ✓

Base shouldn't enter and Tip shouldn't exit the ball.



RCM Check ✓

Min . Distance from Centre < εr



Self Collision Check

- Not Explicitly Specified
- Control Fails implicitly
  - Path Rendered Invalid

Key Assumption: Needle is Slender, Treated as a Line and Inflated

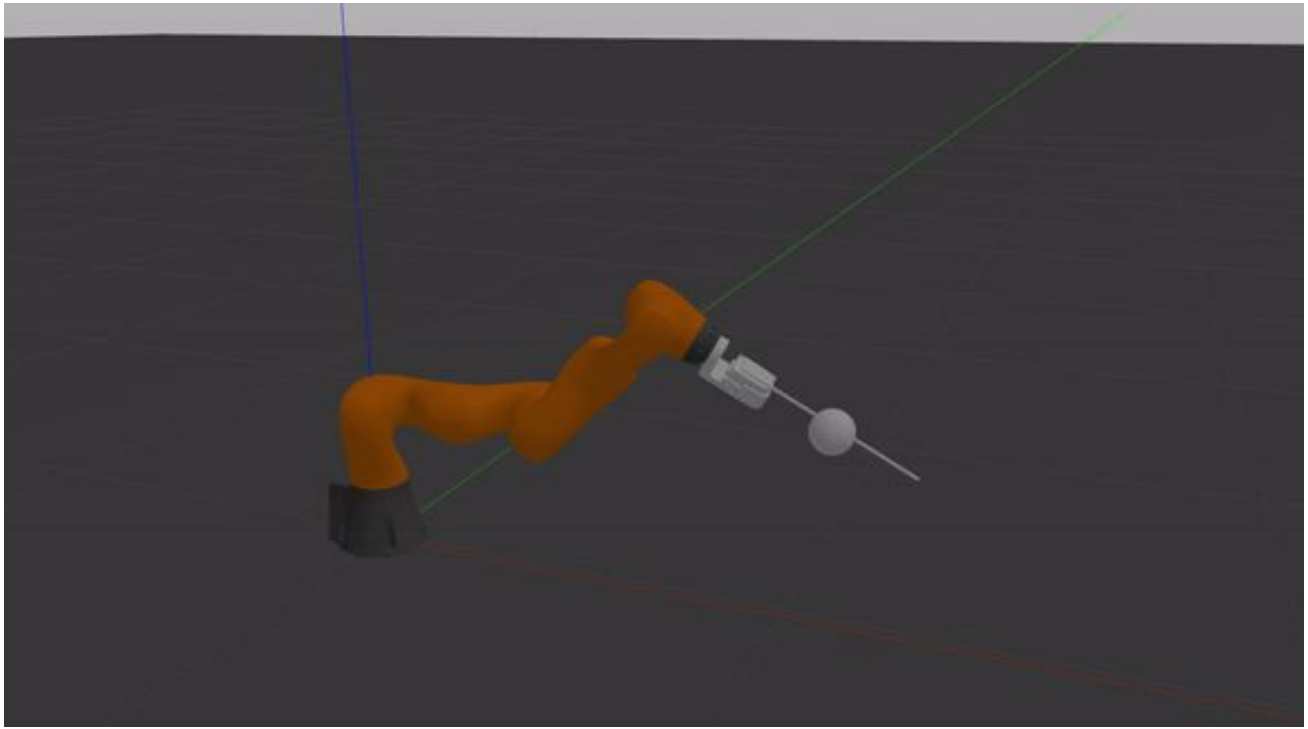
Simulations with Constraint

- Initial and Goal Position chosen through Random Sampling

- RCM **Radius** = 50 mm (Depicted as Sphere)
- RCM **Orientation** = [-1,-1,1]
- RCM **Coordinates** = [1.05 ,0.15 ,0.37]

- Safety Radius Condition Ignored

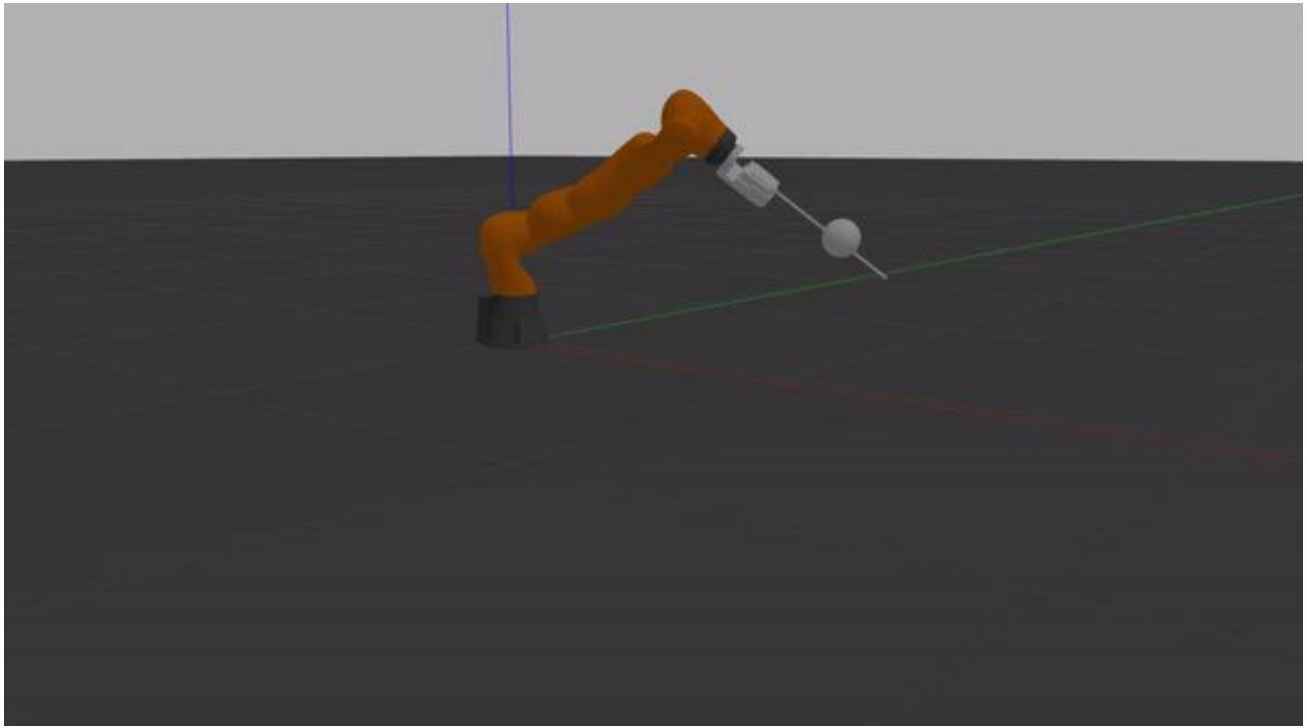
RRT - Without Constraint Check



RRT - Without of Constraint Check

```
256 0.067411952849474 11
257 0.06404135520700048
258 0.06083928744665036
259 0.05698413117492423
260 0.05413492461617804
261 0.051428178385369124
Flag Changed
262 0.048856769466100694
(array([1.2281911 , 0.20994658, 0.29392847]), array([[-0.51514395, -0.03528783,  0.85637695],
       [ 0.22415808,  0.95883027,  0.17434929],
       [-0.82727255,  0.28177879, -0.48602556]]))
```

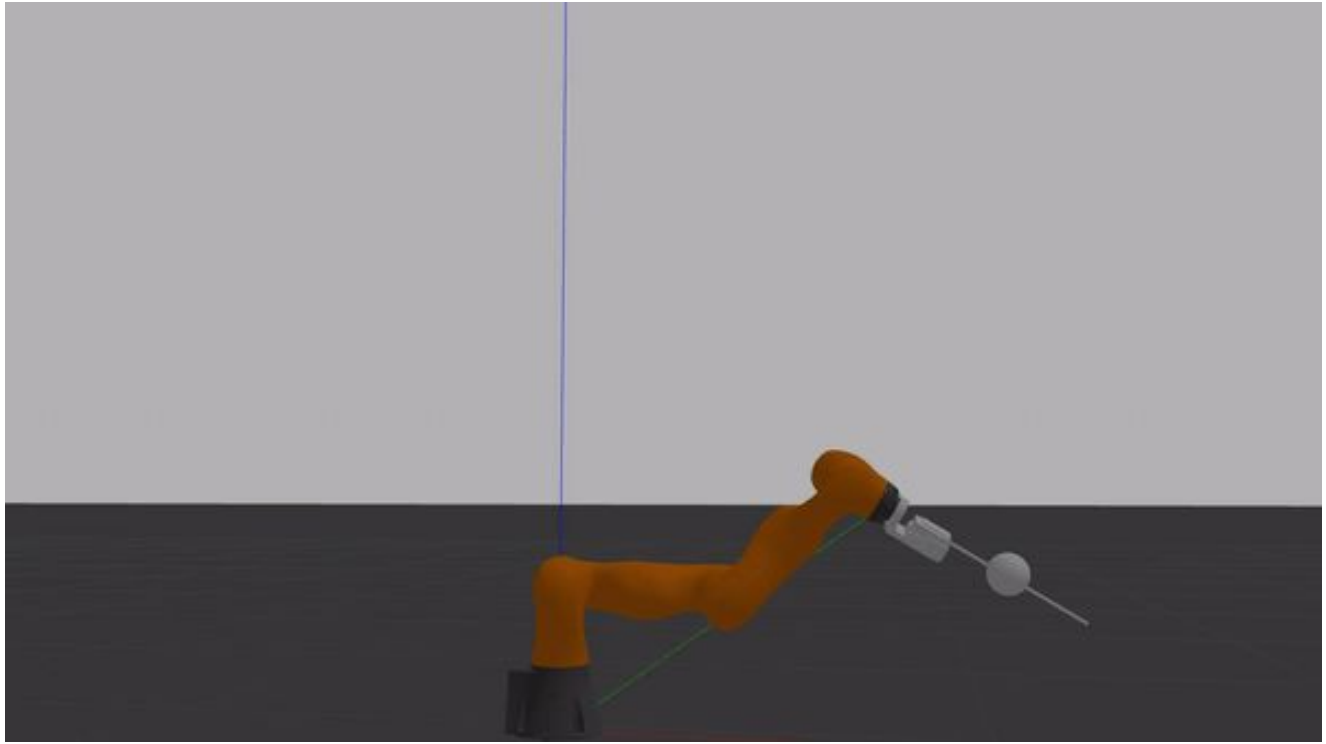
RRT - With Constraint Check



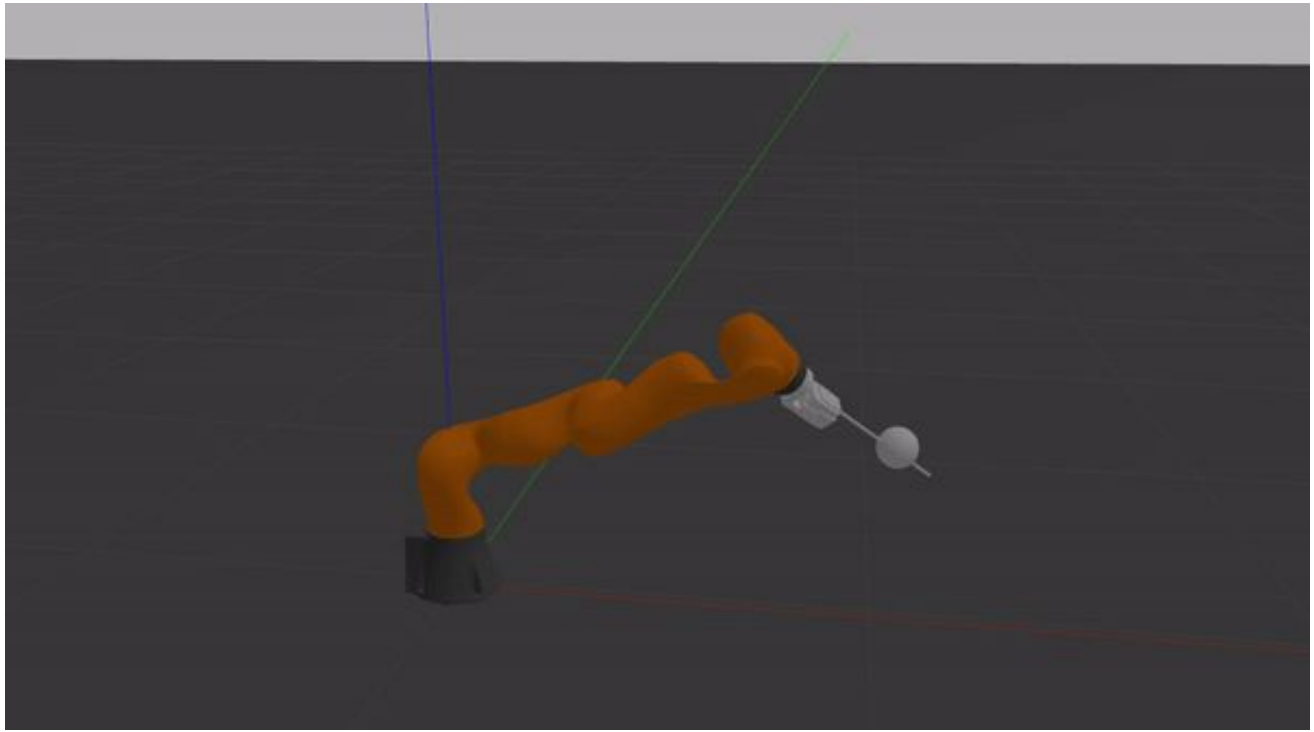
RRT - With Constraint Check

```
307 0.05318102019840496
308 0.05318102019840496
Flag Changed
309 0.04892023095408264
(array([1.13329715, 0.23691709, 0.31940769]), array([[-0.73133128, -0.20695641,  0.6498643 ],
       [ 0.21470324,  0.83454205,  0.5073875 ],
       [-0.64734618,  0.51059632, -0.56589249]]))
```

RRT*



IRRT*



IRRT*

```
500 0.048114171835360035
[(-0.10970045321657067, 1.1963818704615823, 0.26023408162197564, 0.150791060332
83973, 0.38023022527940253, 1.3501104928746075, -0.050712513604397616)]
(array([1.13725798, 0.23154791, 0.32392503]), array([[-0.72155817, -0.21681819,
  0.65752846],
       [ 0.20772428,  0.83815322,  0.50433105],
       [-0.66045774,  0.50048882, -0.5597379 ]]))
```

Looking Ahead

MINIMUM

EXTENDED

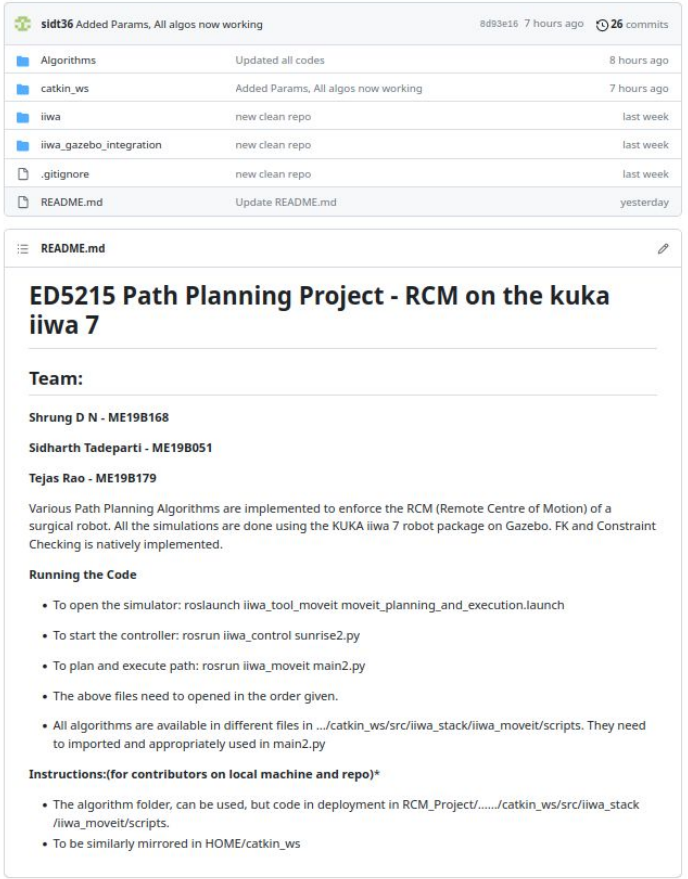
Date	Milestone
2nd March	Project Proposal
7th March	Setup Environment
17th March	Algorithm Implementation (A1)
21st March (Delayed)	Baseline Results and Simulation (Collision Checker)
~~24~~ 29th March	Mid-Term Presentation
~~**31th March**~~	HRM (A2)
~~5~~th April*	Extended Simulations
~~6th April~~	Hardware Testing
19th April	Final Presentation and Report

Additional Deliverables (Report)

- Deflating the RCM to 5 mm.
  - Running the algorithms for a longer time.
  - Gradual decrease in RCM radius.
- Comparative Analysis of Algorithms.
  - Time
  - Performance
- Analyzing different goal definitions.
  - Querying in Configuration Space
  - Querying in Task Space
- An examination of HRMs for the Problem.

Github Repository

Code is complete
(master branch)



sidt36 Added Params, All algos now working — 8d93e16 — 7 hours ago — 26 commits

Algorithms	Updated all codes	8 hours ago
catkin_ws	Added Params, All algos now working	7 hours ago
iiwa	new clean repo	last week
iiwa_gazebo_integration	new clean repo	last week
.gitignore	new clean repo	last week
README.md	Update README.md	yesterday

README.md

ED5215 Path Planning Project - RCM on the kuka iiwa 7

Team:

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Tejas Rao - ME19B179

Various Path Planning Algorithms are implemented to enforce the RCM (Remote Centre of Motion) of a surgical robot. All the simulations are done using the KUKA iiwa 7 robot package on Gazebo. FK and Constraint Checking is natively implemented.

Running the Code

- To open the simulator: roslaunch iiwa_tool_moveit moveit_planning_and_execution.launch
- To start the controller: rosrun iiwa_control sunrise2.py
- To plan and execute path: rosrun iiwa_moveit main2.py
- The above files need to opened in the order given.
- All algorithms are available in different files in .../catkin_ws/src/iiwa_stack/iiwa_moveit/scripts. They need to imported and appropriately used in main2.py

Instructions:(for contributors on local machine and repo)*

- The algorithm folder, can be used, but code in deployment in RCM_Project/...../catkin_ws/src/iiwa_stack /iiwa_moveit/scripts.
- To be similarly mirrored in HOME/catkin_ws

Future Work

- Start and Goal in Task Space
  - IK aware Path Planning
- Allowing for Insertion Operations
  - Guidance through RCM from outside.
- Improving Computational Efficiency
  - Multi-Threading

END OF PRESENTATION