

# EECS 367 Lab

## RRT-Connect in Search Canvas and KinEval

# Administrative

Assignments 6 and 7 released

Assignment 6 due Monday, December 7 at 11:59pm

Assignment 7 video recording due Friday, December 4 at 11:59pm

**Pull stencil from upstream!**

No new lab material after Thanksgiving break

Extended office hours on December 4

# Lab Takeaways

1. Revisit the search canvas
  2. KinEval overview
  3. KinEval walkthrough
- How to start Assignment 6

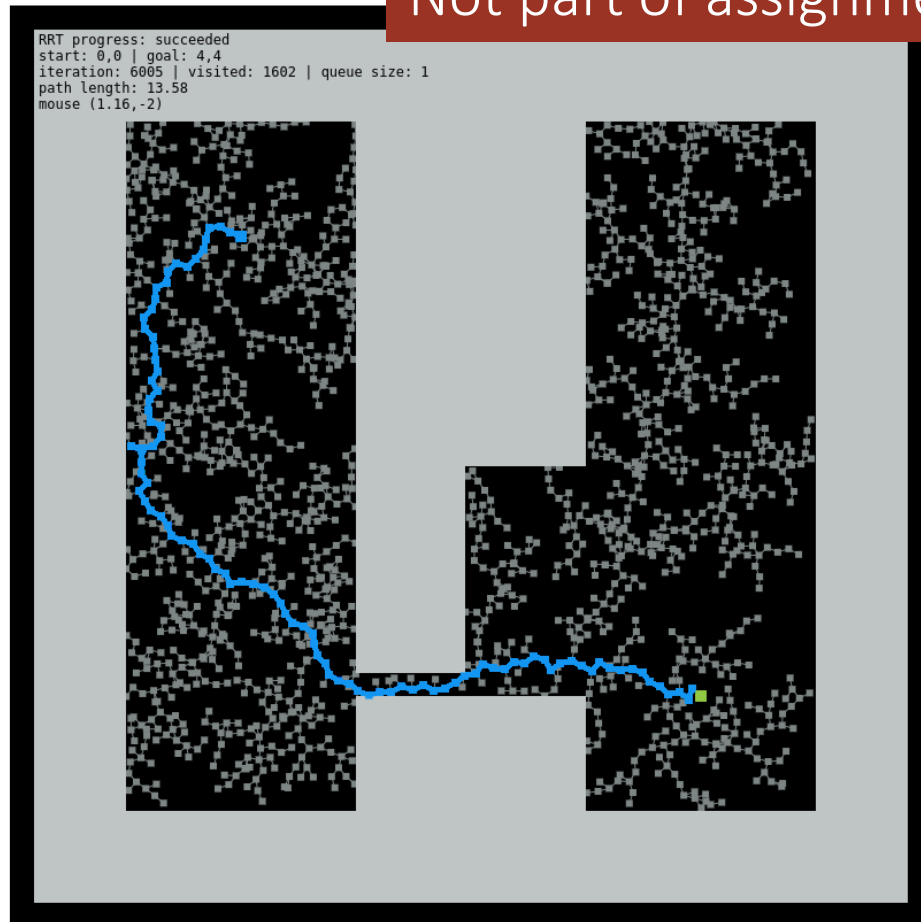
# Motion Planning Overview

Assignment 6: Motion Planning			
4	All	Collision detection	} Features assigned to all sections
2	All	2D RRT-Connect	
6	All	Configuration space RRT-Connect	
6	Grad	2D RRT-Star	} Feature assigned to grad section only

# Rapidly-Exploring Random Trees (RRT)

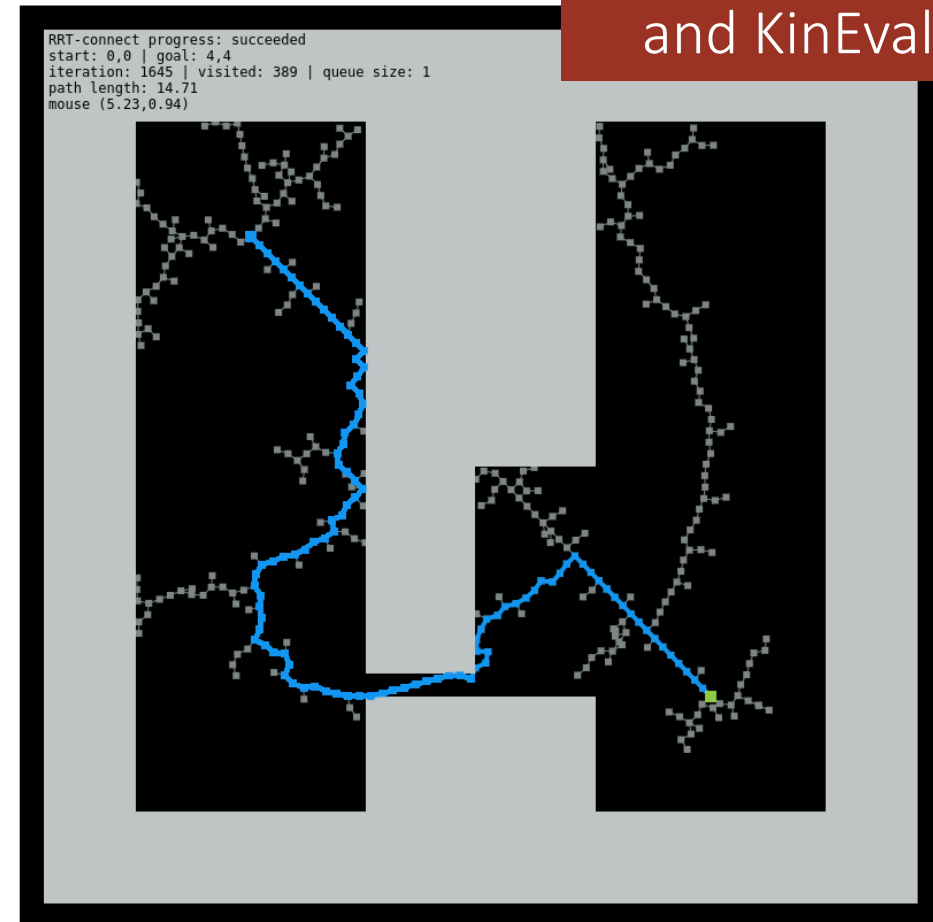
RRT

Not part of assignment



RRT-CONNECT

Will implement for 2D  
and KinEval robots



# Revisiting the Search Canvas

The screenshot shows the GitHub repository page for 'autorob / kineval-stencil'. The repository has 5 watchers, 10 stars, and 6 forks. The main navigation bar includes links for Code, Issues (1), Pull requests, Actions, Projects, Wiki, Security, and Insights. Below the navigation bar, there are buttons for 'Go to file', 'Add file', and 'Code'. The repository is currently on the 'master' branch with 1 branch and 0 tags.

The file list shows the following items:

File/Folder	Commit Message	Commit Date
js	initial commit	Fall 2018
kineval	Add matrix requirement for IK	24 days ago
<b>project_pathplan</b>	Makes assignment 6 drawing work more like assignment 1 for fa...	3 days ago
project_pendularm	fixed control set to 6 and 2d array problem in pendulum2.html	2 months ago
robots	initial commit	Fall 2018
tutorial_heapsort	initial commit	Fall 2018
tutorial_js	initial commit	Fall 2018
worlds	initial commit	Fall 2018
LICENSE	add refactor of assignment2, tested with CI grader	3 months ago
README.md	initial commit	Fall 2018
home.html	Factorize kineval stencil for FK gradining	2 months ago

The 'project\_pathplan' folder is highlighted with a red box, and a red arrow points from it to a text box on the right that reads: 'Code for 2D RRT-Connect and 2D RRT-Star [Grad] features'.

**About**  
Stencil code for KinEval (Kinematic Evaluator) for robot control, kinematics, decision, and dynamics in JavaScript/HTML5

**Packages**  
No packages published


**Contributors** 5

# Revisiting the Search Canvas






🖨️ [autorob](#) / [kineval-stencil](#) 👁 Watch 5 ★ Star 10 🍴 Fork 6

[<> Code](#) [! Issues 1](#) [🔗 Pull requests](#) [▶ Actions](#) [📁 Projects](#) [📖 Wiki](#) [🛡 Security](#) [📈 Insights](#)

🔗 master [kineval-stencil](#) / [project\\_pathplan](#) / Go to file Add file

 **emgoeddel** Makes assignment 6 drawing work more like assignment 1 for familiarity. 9509958 3 days ago [🕒 History](#)

..

 draw.js	Makes assignment 6 drawing work more like assignment 1 for familiarity.	3 days ago
 graph_search.js	Adds refactored stencil files for project 1.	3 months ago
 infrastructure.js	Makes assignment 6 drawing work more like assignment 1 for familiarity.	3 days ago
 <b>rrt.js</b>	Adds refactored stencil files for project 1.	3 months ago
 search_canvas.html	Adds refactored stencil files for project 1.	3 months ago

Code for 2D RRT-Connect and  
2D RRT-Star [Grad] features

# 2D RRT-Connect

Recommended: Start project  
with 2D RRT-Connect in  
`project_pathplan/rrt.js`

rrt.js

```
45  function iterateRRTConnect() {
46
47
48      // STENCIL: implement a single iteration of an RRT-Connect algorithm.
49      //   An asynch timing mechanism is used instead of a for loop to avoid
50      //   blocking and non-responsiveness in the browser.
51      //
52      //   Return "failed" if the search fails on this iteration.
53      //   Return "succeeded" if the search succeeds on this iteration.
54      //   Return "extended" otherwise.
55      //
56      //   Provided support functions:
57      //
58      //   testCollision - returns whether a given configuration is in collision
59      //   insertTreeVertex - adds and displays new configuration vertex for a tree
60      //   insertTreeEdge - adds and displays new tree edge between configurations
61      //   drawHighlightedPath - renders a highlighted path in a tree
62  }
```



# 2D RRT-Connect

Similar to Assignment 1 search algorithms, implement as a single step within the iterative algorithm

rrt.js

```
45 function iterateRRTConnect() {
46
47
48     // STENCIL: implement a single iteration of an RRT-Connect algorithm.
49     //   An asynch timing mechanism is used instead of a for loop to avoid
50     //   blocking and non-responsiveness in the browser.
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59     //   insertTreeVertex - adds and displays new configuration vertex for a tree
60     //   insertTreeEdge - adds and displays new tree edge between configurations
61     //   drawHighlightedPath - renders a highlighted path in a tree
62 }
```

# RRT Data Structure

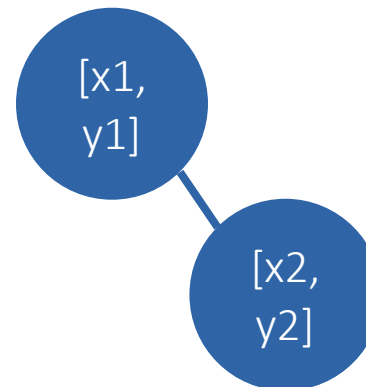
infrastructure.js

```
64 function initRRT(q) {
65
66     // create tree object
67     var tree = {};
68
69     // initialize with vertex for given configuration
70     tree.vertices = [];
71     tree.vertices[0] = {};
72     tree.vertices[0].vertex = q;
73     tree.vertices[0].edges = [];
74
75     // maintain index of newest vertex added to tree
76     tree.newest = 0;
77
78     return tree;
79 }
80
81 function insertTreeVertex(tree, q) {
82
```

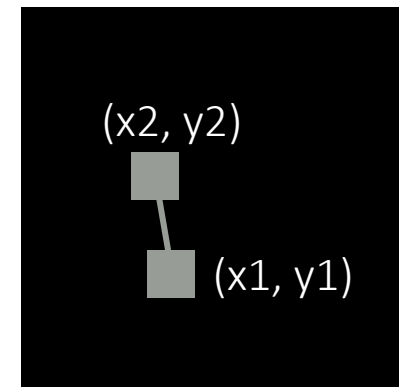
Tree implemented as a JavaScript object with array of vertices

```
tree = {"vertices":
        [
            {"vertex": [x1, y1],
             "edges": [tree.vertices[1]]},
            {"vertex": [x2, y2],
             "edges": [tree.vertices[0]]}
        ],
        "newest": 1}
```

Data structure view



Search canvas view



# RRT Functions

## infrastructure.js

```
64 function initRRT(q) {
65
66     // create tree object
67     var tree = {};
68
69     // initialize with vertex for given configuration
70     tree.vertices = [];
71     tree.vertices[0] = {};
72     tree.vertices[0].vertex = q;
73     tree.vertices[0].edges = [];
74
75     // maintain index of newest vertex added to tree
76     tree.newest = 0;
77
78     return tree;
79 }
80
81 function insertTreeVertex(tree,q) {
82
```

Helper functions available for  
basic tree operations

## rrt.js

```
68 ///////////////////////////////////////////////////////////////////
69 //      RRT IMPLEMENTATION FUNCTIONS
70 ///////////////////////////////////////////////////////////////////
71
72 // STENCIL: implement RRT-Connect functions here, such as:
73 //   extendRRT
74 //   connectRRT
75 //   randomConfig
76 //   newConfig
77 //   findNearestNeighbor
78 //   dfsPath
```

Suggested functions for you to add  
for RRT-Connect implementation

Demo

# KinEval Overview

autorob / kineval-stencil

Watch 5 Star 10 Fork 6

Code Issues 1 Pull requests Actions Projects Wiki Security Insights

master 1 branch 0 tags

Go to file Add file Code

**odestcj** Merge pull request #8 from emgoeddel/master a7829b0 3 days ago 20 commits

js	initial commit Fall 2018	2 years ago
<b>kineval</b>	Add matrix requirement for IK	24 days ago
project_pathplan	Makes assignment 6 drawing work more like assignment 1 for fa...	3 days ago
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Readme View license


No packages published
















**Contributors** 5

Code for collision detection  
and configuration space RRT-  
Connect features

# KinEval Overview

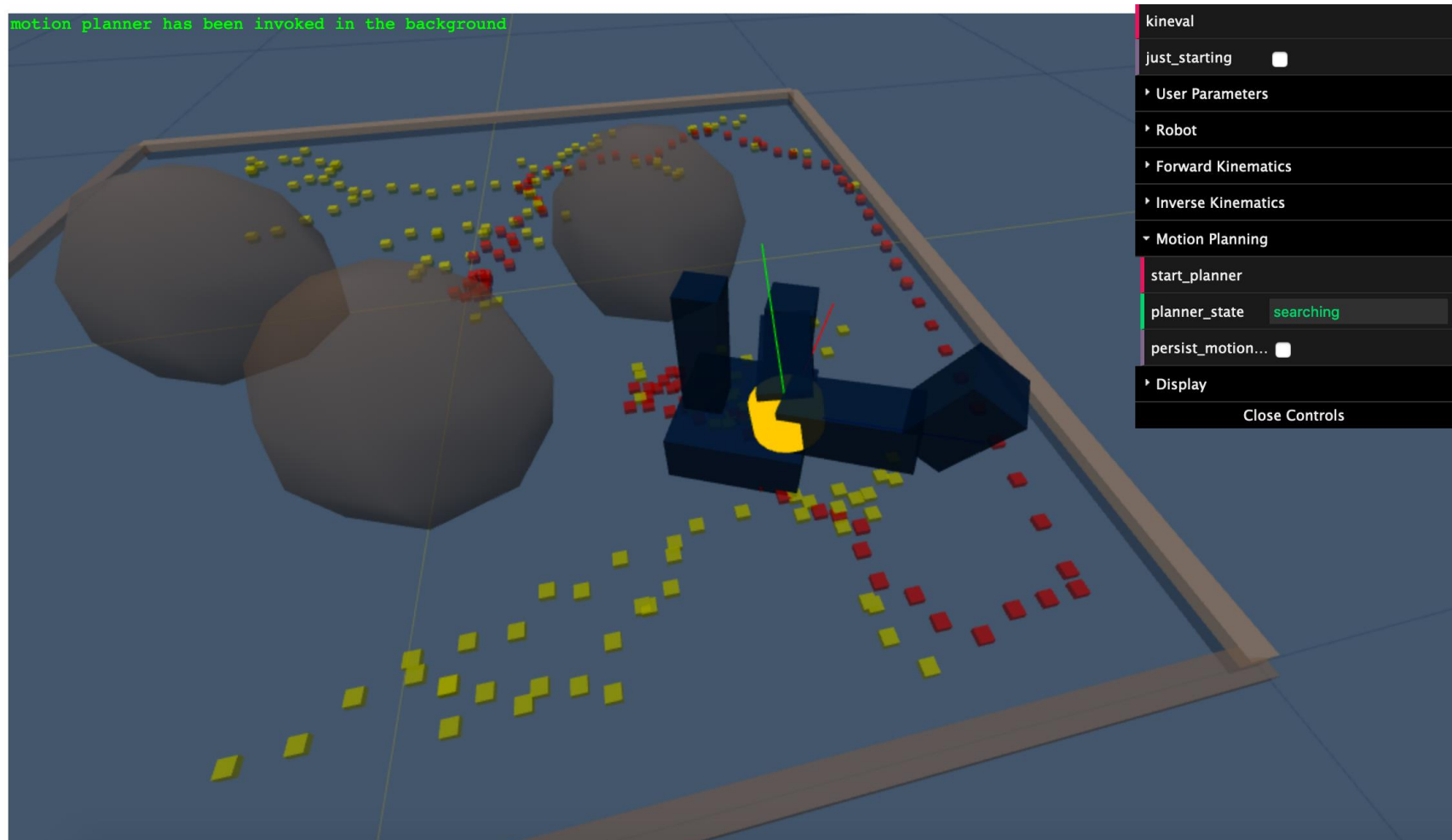
master [kineval-stencil](#) / [kineval](#) / [Go to file](#) [Add file](#)

 **zhezhou1993** Add matrix requirement for IK 537eeac 24 days ago [History](#)

..		
 kineval.js	initial commit Fall 2018	2 years ago
 kineval_collision.js	initial commit Fall 2018	2 years ago
 kineval_controls.js	initial commit Fall 2018	2 years ago
 kineval_forward_kinematics.js	initial commit Fall 2018	2 years ago
 kineval_inverse_kinematics.js	Add matrix requirement for IK	24 days ago
 kineval_matrix.js	Factorize kineval stencil for FK problems, fix bugs in previous version	2 months ago
 kineval_quaternion.js	Factorize kineval stencil for FK problems, fix bugs in previous version	2 months ago
 kineval_robot_init.js	Factorize kineval stencil for FK grading	
 kineval_robot_init_joints.js	Factorize kineval stencil for FK grading	
 kineval_rosbridge.js	initial commit Fall 2018	
 kineval_rrt_connect.js	initial commit Fall 2018	
 kineval_servo_control.js	initial commit Fall 2018	
 kineval_startingpoint.js	initial commit Fall 2018	2 years ago
 kineval_threejs.js	initial commit Fall 2018	2 years ago
 kineval_userinput.js	initial commit Fall 2018	2 years ago

Code for collision detection  
and configuration space RRT-  
Connect features

# Configuration Space RRT



# kineval\_collision.js

kineval\_collision.js

```
22 kineval.robotIsCollision = function robot_iscollision() {  
23     // test whether geometry of current configuration of robot is in collision with planning world  
24  
25     // form configuration from base location and joint angles  
26     var q_robot_config = [  
27         robot.origin.xyz[0],  
28         robot.origin.xyz[1],  
29         robot.origin.xyz[2],  
30         robot.origin.rpy[0],  
31         robot.origin.rpy[1],  
32         robot.origin.rpy[2]  
33     ];  
34  
35     q_names = {}; // store mapping between joint names and q DOFs  
36  
37     for (x in robot.joints) {  
38         q_names[x] = q_robot_config.length;  
39         q_robot_config = q_robot_config.concat(robot.joints[x].angle);  
40     }  
41  
42     // test for collision and change base color based on the result  
43     collision_result = kineval.poseIsCollision(q_robot_config);  
44  
45     robot.collision = collision_result;  
46 }
```

`q_robot_config` is an array representing current pose as point within configuration space

Dimension of configuration space is a function of the specific robot!



# kineval\_collision.js

kineval\_collision.js

```
49 kineval.poseIsCollision = function robot_collision_test(q) {  
50     // perform collision test of robot geometry against planning world  
51  
52     // test base origin (not extents) against world boundary extents  
53     if ((q[0]<robot_boundary[0][0])||(q[0]>robot_boundary[1][0])||(q[2]<robot_boundary[0][2])||(q[2]>robot_boundary[1][2]))  
54         return robot.base;  
55  
56     // traverse robot kinematics to test each body for collision  
57     // STENCIL: implement forward kinematics for collision detection  
58     //return robot_collision_forward_kinematics(q);  
59  
60 }
```

STENCIL: Check each link for collision with spherical obstacles

## Collision detection pseudocode:

For each link in robot

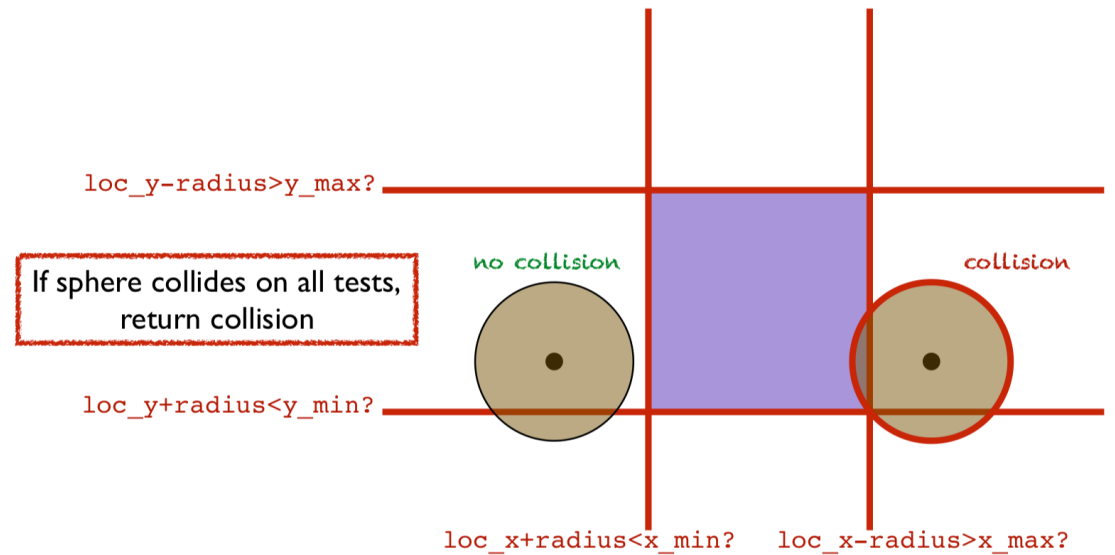
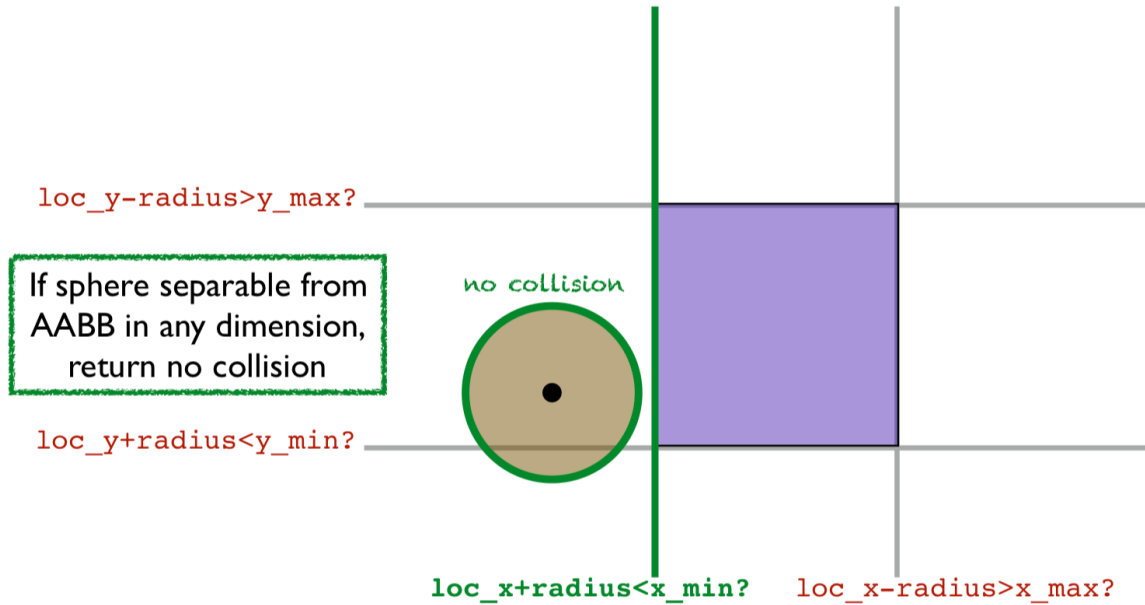
For each obstacle in world

If intersection(link, obstacle)

Return link is in collision

Return no collision

# AABB Link Collision Detection



# kineval\_collision.js

kineval\_collision.js

```
64 function traverse_collision_forward_kinematics_link(link,mstack,q) {
65
66     /* test collision FK
67     console.log(link);
68     */
69     if (typeof link.visual !== 'undefined') {
70         var local_link_xform = matrix_multiply(mstack,generate_translation_matrix(link.visual.origin.xyz[0],link
71     }
72     else {
73         var local_link_xform = matrix_multiply(mstack,generate_identity());
74     }
75
76     // test collision by transforming obstacles in world to link space
77     /*
78     mstack_inv = matrix_invert_affine(mstack);
79     */
80     mstack_inv = numeric.inv(mstack);
81
82     var i;
83     var j;
84
85     // test each obstacle against link bbox geometry by transforming obstacle into link frame and testing against
86     //for (j=0;j<robot_obstacles.length;j++) {
87     for (j in robot_obstacles) {
88
89         var obstacle_local = matrix_multiply(mstack_inv,robot_obstacles[j].location);
90
91         // assume link is in collision as default
92         var in_collision = true;
```

Need to compute `mstack`  
for use here

AABB collision check for a link provided  
for you in this function, but you need to  
add the rest of FK traversal

# kineval\_rrt.js

Implement  
robot\_rrt\_planner\_iterate() as a  
single iteration of the RRT-Connect  
planning algorithm

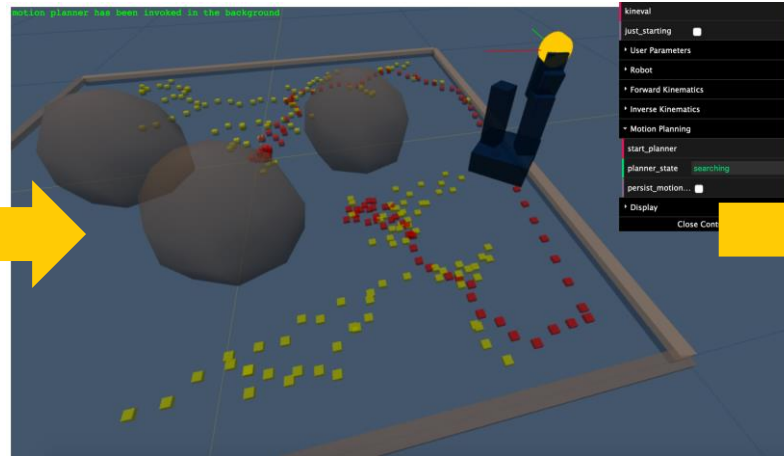
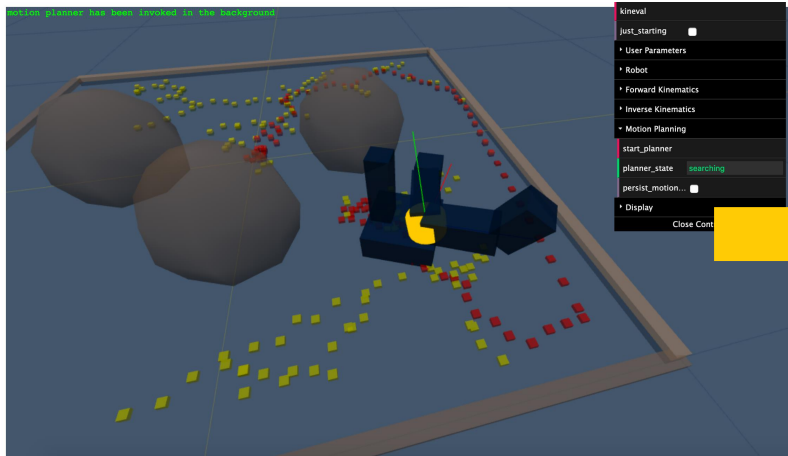
kineval\_rrt.js

```
132 function robot_rrt_planner_iterate() {
133
134     var i;
135     rrt_alg = 1; // 0: basic rrt (OPTIONAL), 1: rrt_connect (REQUIRED)
136
137     if (rrt_iterate && (Date.now()-cur_time > 10)) {
138         cur_time = Date.now();
139
140         // STENCIL: implement single rrt iteration here. an asynch timing mechanism
141         // is used instead of a for loop to avoid blocking and non-responsiveness
142         // in the browser.
143         //
144         // once plan is found, highlight vertices of found path by:
145         // tree.vertices[i].vertex[j].geom.material.color = {r:1,g:0,b:0};
146         //
147         // provided support functions:
148         //
149         // kineval.poseIsCollision - returns if a configuration is in collision
150         // tree_init - creates a tree of configurations
151         // tree_add_vertex - adds and displays new configuration vertex for a tree
152         // tree_add_edge - adds and displays new tree edge between configurations
153     }
154
155 }
```

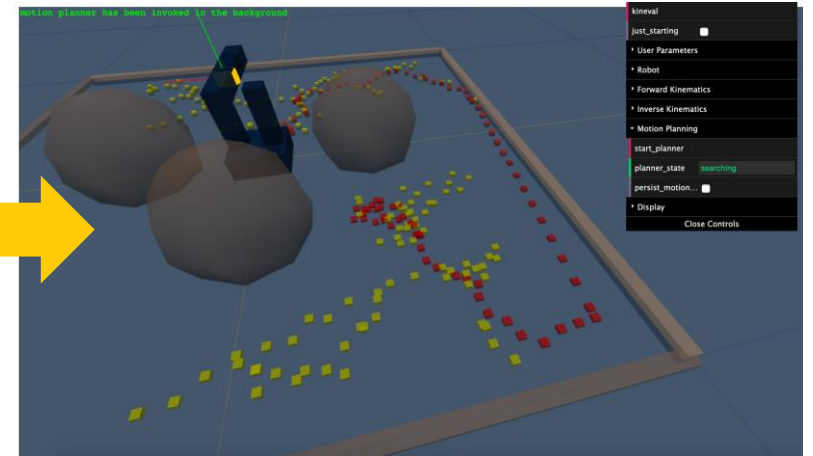
Include any helper functions in this file

# Desired Result

Arbitrary initial configuration



Collision free path to home



B

Backward step  
along motion plan

N

Forward step  
along motion plan

Demo

# Final Tips

CI grader is a **rough guideline**, so you must do your own testing to verify correct implementation

Make sure you use the robot's **full configuration space**, including all joint DOFs, and not just base movement in the ground plane

Do not move the robot outside of the X-Z plane

- No translation along Y axis

- No rotation around X or Z axes