EECS 367 & ROB 320 Lab **RRT-Connect in Search Canvas and KinEval**

Michigan EECS 367 Introduction to Autonomous Robotics | ROB 320 Robot Operating Systems



Administrative

- Next Wednesday, March 23
 - Due: Assignment #5 Inverse Kinematics
 - Released: Assignment #6 Motion Planning
 - Released: Assignment #7 Best use of robotics
- Lab section Friday, April 1
 - Connect to Fetch via rosbridge (optional)
 - In robotics building

Lab Takeaways

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

Motion Planning Overview

4

6

2

- Collision detection
- **2D RRT-Connect**
- **Configuration space RRT-Connect**

Assignment 6: Motion Planning

Rapidly-Exploring Random Trees (RRT)

Not part of assignment

RRT progress: succeeded start: 0,0 | goal: 4,4 iteration: 6005 | visited: 1602 | queue size: 1 path length: 13.58 mouse (1.16,-2)

RRT



RRT-CONNECT

Will implement for 2D and KinEval robots

RRT-connect progress: succeeded start: 0,0 | goal: 4,4 iteration: 1645 | visited: 389 | queue size: 1 path length: 14.71 mouse (5.23,0.94)





Revisiting the Search Canvas

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kineval	Add matrix requirement for IK
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project_pendularm	fixed control set to 0 and 2d array proble
robots	initial commit Fall 2018
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README.md	initial commit Fall 2018
home.html	Factorize kineval stencil for FK gradinin

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Revisiting the Search Canvas

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2D RRT-Connect

	rrt.js	
45	function	<pre>iterateRRTConnect() {</pre>
46		
47		
48	// s ⁻	TENCIL: implement a single :
49	//	An asynch timing mechanism
50	//	blocking and non-responsive
51	//	
52	//	Return "failed" if the sea
53	//	Return "succeeded" if the s
54	//	Return "extended" otherwise
55	//	
56	//	Provided support functions
57	//	
58	//	testCollision - returns whe
59	//	insertTreeVertex - adds and
60	//	insertTreeEdge - adds and o
61	//	drawHighlightedPath - rende
62	}	

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

iteration of an RRT-Connect algorithm. is used instead of a for loop to avoid eness in the browser.

rch fails on this iteration. search succeeds on this iteration. e.

ether a given configuration is in collision d displays new configuration vertex for a tree displays new tree edge between configurations ers a highlighted path in a tree

2D RRT-Connect

	rrt.js	
45	function	<pre>iterateRRTConnect() {</pre>
46		
47		
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49	//	An asynch timing mechanism
50	//	blocking and non-responsive
51	//	
52	//	Return "failed" if the seam
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54	//	Return "extended" otherwise
55	//	
56	//	Provided support functions
57	//	
58	//	testCollision - returns whe
59	//	insertTreeVertex - adds and
60	//	insertTreeEdge - adds and o
61	//	drawHighlightedPath - rende
62	}	

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

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rch fails on this iteration. search succeeds on this iteration. e.

ether a given configuration is in collision d displays new configuration vertex for a tree displays new tree edge between configurations ers a highlighted path in a tree



RRT Data Structure

infrastructure.js

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

Tree implemented as a JavaScript object with array of vertices



RRT Functions

infrastructure.js

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80	
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82	
	Helper functions available for
	hasic trad operations
	Dasic liee operations

	rrt.js	
68	///////////////////////////////////////	///////////////////////////////////////
69	/////	RRT IMPLEMENTATION FUNCTIONS
70	///////////////////////////////////////	///////////////////////////////////////
71		
72	// S1	<pre>FENCIL: implement RRT-Connect functions here, such</pre>
73	//	extendRRT
74	//	connectRRT
75	//	randomConfig
76	//	newConfig
77	//	findNearestNeighbor
78	//	dfsPath

Suggested functions for you to add for RRT-Connect implementation





KinEval Overview

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home.html	Factorize kineval stencil for FK gradinin





KinEval Overview

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ion detection on space RRTfeatures



Configuration Space RRT



kineval_collision.js

kineval_collision.js

22	<pre>kineval.robotIsCollision = function robot_iscollisi</pre>
23	<pre>// test whether geometry of current configurati</pre>
24	
25	<pre>// form configuration from base location and jo</pre>
26	<pre>var q_robot_config = [</pre>
27	<pre>robot.origin.xyz[0],</pre>
28	<pre>robot.origin.xyz[1],</pre>
29	<pre>robot.origin.xyz[2],</pre>
30	<pre>robot.origin.rpy[0],</pre>
31	<pre>robot.origin.rpy[1],</pre>
32	<pre>robot.origin.rpy[2]</pre>
33];
34	
35	<pre>q_names = {}; // store mapping between joint n</pre>
36	
37	<pre>for (x in robot.joints) {</pre>
38	<pre>q_names[x] = q_robot_config.length;</pre>
39	<pre>q_robot_config = q_robot_config.concat(robo</pre>
40	}
41	
42	<pre>// test for collision and change base color bas</pre>
43	collision_result = kineval.poseIsCollision(q_ro
44	
45	<pre>robot.collision = collision_result;</pre>
46	}



kineval_collision.js

kineval	col	lision	.js

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



STENCIL: Check each link for collision with spherical obstacles

ndary extents ry[1][0])||(q[2]<robot_boundary[0][2])||(q[2]>robot_boundary[1][2]))

collision ion detection

> 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





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kineval_collision.js

kineval_collision.js

64	func	<pre>ction traverse_collision_forward_kinematics_link(link,mstack,q) {</pre>
65		
66		/* test collision FK
67		<pre>console.log(link);</pre>
68		*/
69		<pre>if (typeof link.visual !== 'undefined') {</pre>
70		<pre>var local_link_xform = matrix_multiply(mstack,generate_transl</pre>
71		}
72		else {
73		<pre>var local_link_xform = matrix_multiply(mstack,generate_identi</pre>
74		}
75		
76		<pre>// test collision by transforming obstacles in world to link spac</pre>
77	/*	
78		<pre>mstack_inv = matrix_invert_affine(mstack);</pre>
79	*/	
80		<pre>mstack_inv = numeric.inv(mstack);</pre>
81		
82		var i;
83		var j;
84		
85		<pre>// test each obstacle against link bbox geometry by transforming</pre>
86		//for (j=0;j <robot_obstacles.length;j++) td="" {<=""></robot_obstacles.length;j++)>
87		<pre>for (j in robot_obstacles) {</pre>
88		
89		<pre>var obstacle_local = matrix_multiply(mstack_inv,robot_obstacl</pre>
90		
91		<pre>// assume link is in collision as default</pre>
92		<pre>var in_collision = true;</pre>



_translation_matrix(link.visual.origin.xyz[0],link

_identity());

nk space

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

orming obstacle into link frame and testing agains

obstacles[j].location);



kineval_rrt.js

	kineval_rrt.js
132	<pre>function robot_rrt_planner_iterate() {</pre>
133	
134	var i;
135	<pre>rrt_alg = 1; // 0: basic rrt (OPTI</pre>
136	
137	<pre>if (rrt_iterate && (Date.now()-cur_</pre>
138	<pre>cur_time = Date.now();</pre>
139	
140	<pre>// STENCIL: implement single rrt it</pre>
141	<pre>// is used instead of a for loop</pre>
142	// in the browser.
143	//
144	<pre>// once plan is found, highlight</pre>
145	<pre>// tree.vertices[i].vertex[j].g</pre>
146	//
147	<pre>// provided support functions:</pre>
148	//
149	<pre>// kineval.poseIsCollision - retu</pre>
150	<pre>// tree_init - creates a tree of</pre>
151	<pre>// tree_add_vertex - adds and dis</pre>
152	<pre>// tree_add_edge - adds and displ</pre>
153	}
154	

155

Implement

robot_rrt_planner_iterate() as a single iteration of the RRT-Connect planning algorithm

t (OPTIONAL), 1: rrt_connect (REQUIRED)

```
()-cur_time > 10)) {
```

rrt iteration here. an asynch timing mechanism r loop to avoid blocking and non-responsiveness

```
hlight vertices of found path by:
ex[j].geom.material.color = {r:1,g:0,b:0};
```

```
- returns if a configuration is in collision
ree of configurations
```

and displays new configuration vertex for a tree d displays new tree edge between configurations

Include any helper functions in this file



Desired Result

Arbitrary initial configuration





Backward stepForward stepalong motion planalong motion plan

Collision free path to home



Final Tips

- correct implementation
- 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

Cl grader is a rough guideline, so you must do your own testing to verify

Make sure you use the robot's **full configuration space**, including all joint