EECS 367 & ROB 320 Lab KinEval overview

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

Administrative

- Assignment #2: Pendularm
 - Due tonight, February 4 11:59pm
- Quiz #3: Next Monday, January 24th
 - Through gradescope, available 12:00am-11:59pm
 - Time limit of 30 minutes
 - Covers material from assignments #1,2
 - Don't discuss quiz with other students; honor code

Administrative

- Pendularm Setpoint Competition!
 - Final results published over the weekend

Lab Takeaways

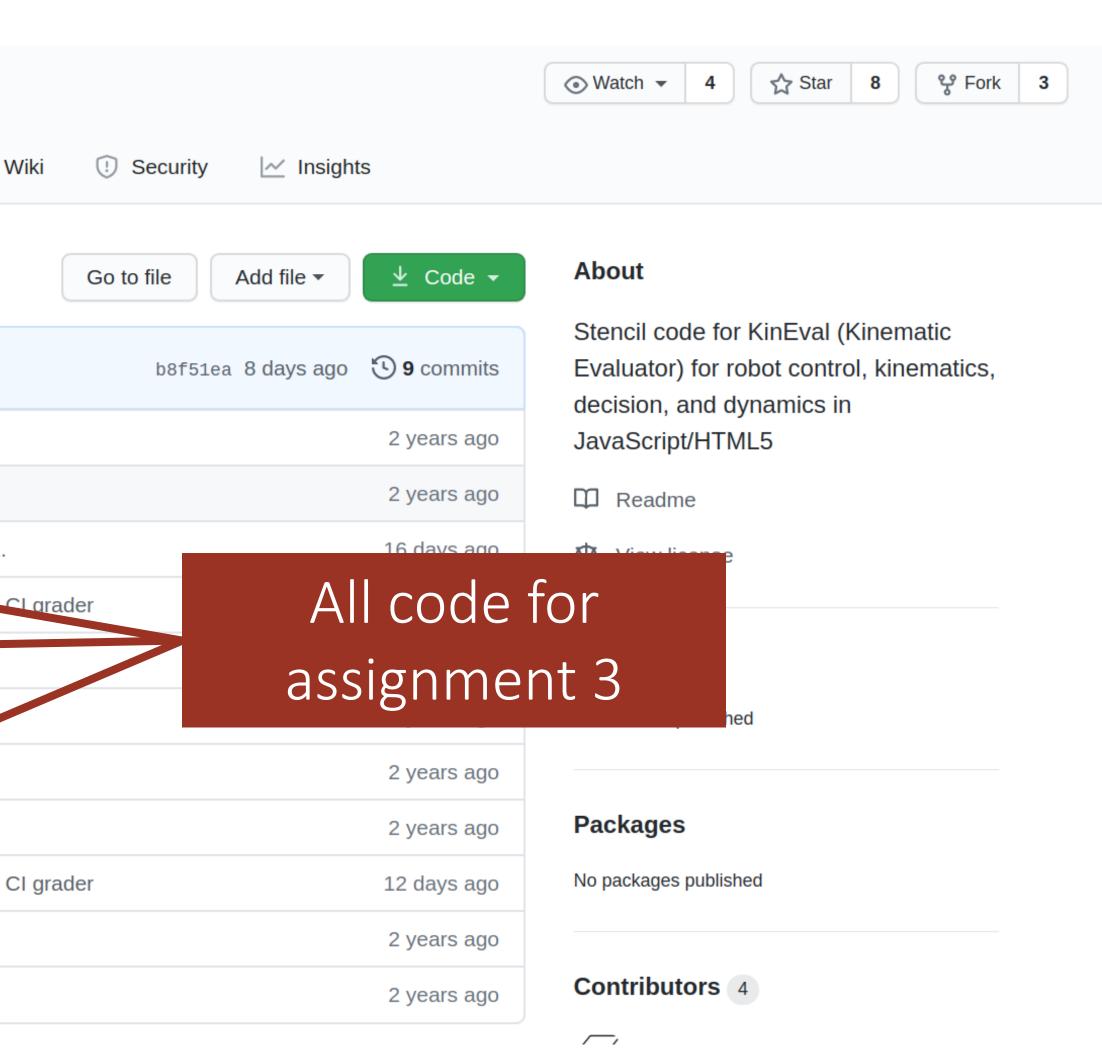
- 1. KinEval overview
- 2. KinEval walkthrough
- 3. Implementation advice
- \rightarrow How to start Assignment 3

Forward Kinematics Overview

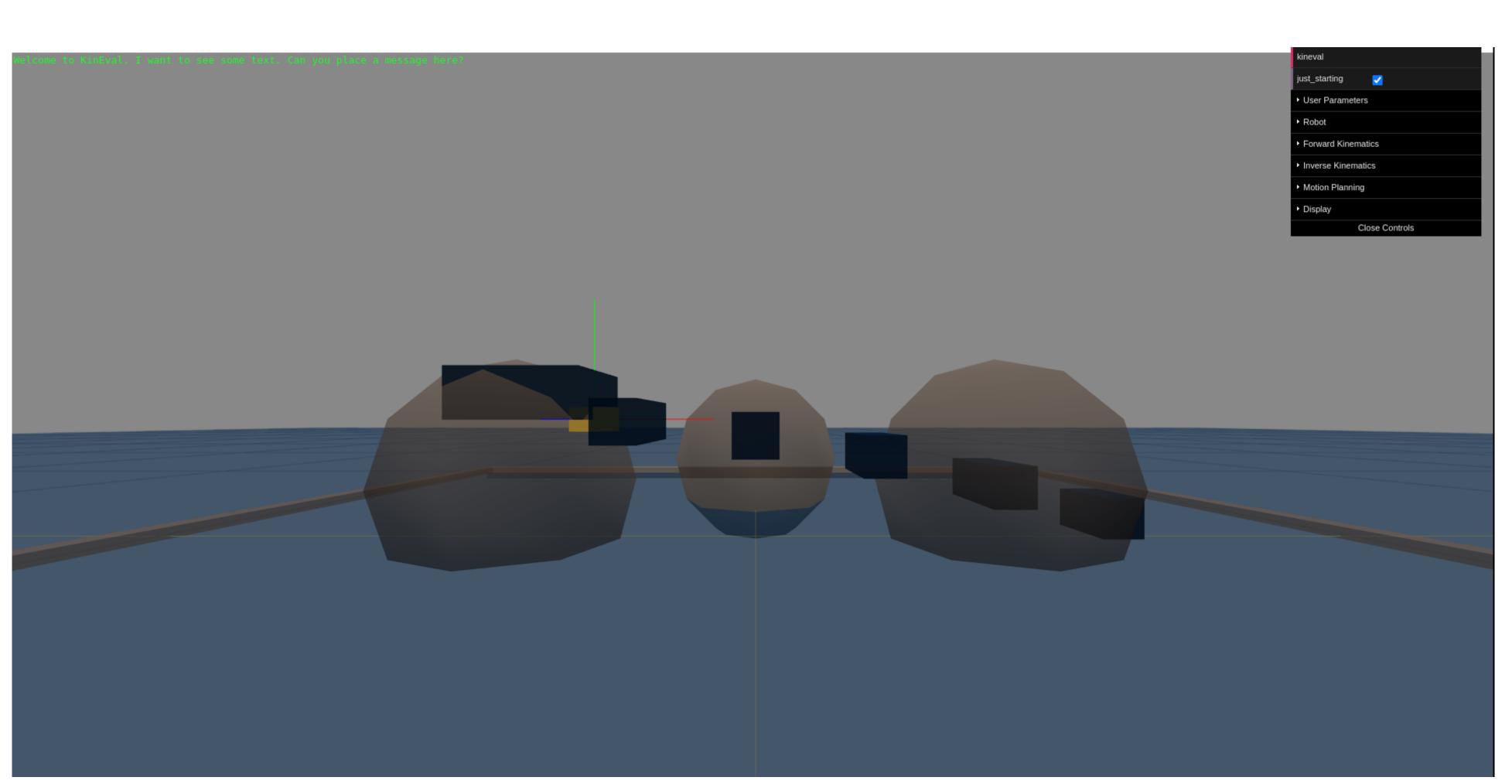


- **Assignment 3: Forward Kinematics**
- Core matrix routines
- Joint selection/rendering
- New robot definition

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home.html



home.html

home.html

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KinEval source files included here

home.html

home.html 150function my_animate() { 151 152 153 154 // //kineval.params.just_starting = false; 155 156 if (kineval.params.just_starting == true) { 157 startingPlaceholderAnimate(); 158 kineval.robotDraw(); 159 return; 160161} 162

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// update robot configuration from applied robot controls (assuming pure kinematics for now) 11

kineval.applyControls(robot);

// HANDLE USER CONTROLS // handle user input

kineval.handleUserInput();

// perform forward kinematics placing robot links in space wrt configuration kineval.robotForwardKinematics();

```
// STUDENT: my_animate is where your robot's controls and movement are updated over time
```

```
// set to starting point mode is true as default (initialized in kineval.js)
    set to false once starting forward kinematics project
```

my_animate() is called at every animation frame

autorob / kineval-stencil			
Code (!) Issues 1 1 19 Pull	requests 🕞 Actions 🛄 Projects 🛄 W	/iki 🔃 Security 🗠 Insights	
ੈ ਸ branch ਓ	0 tags	Go to file Add file ▼	About
ohseejay Merge pull request	#3 from cxt98/master	b8f51ea 8 days ago 🕚 9 commits	Stencil code for KinEval (Kinematic Evaluator) for robot control, kinematics,
js	initial commit Fall 2018	2 years ago	decision, and dynamics in JavaScript/HTML5
kineval	initial commit Fall 2018	2 years ago	Readme
project_pathplan	Adds refactored stencil files for project 1.	16 days ago	小 View license
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robots	initial commit Fall 2018	2 years ago	Releases
tutorial_heapsort	initial commit Fall 2018	2 years ago	No releases published
tutorial_js	initial commit Fall 2018	2 years ago	
worlds	initial commit Fall 2018	2 years ago	Packages
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home.html	initial commit Fall 2018	2 years ago	Contributors 4

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	kineval_startingpoint.js	initial commit
	kineval_threejs.js	initial commit
	kineval_userinput.js	initial commit

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kineval startingpoint.js

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As the name suggests, this file is meant to build your comfort with the source code

kineval_startingpoint.js

kineval.startingPlaceholderUserInput = function startingPlaceholderUserInput() { 365

keyboard.pressed() will
pressed, without the need
*/
<pre>if (keyboard.pressed("shift+x")</pre>
<pre>textbar.innerHTML = "come</pre>
<pre>// STENCIL: update the vertica</pre>
}
<pre>else if (keyboard.pressed("x")</pre>
textbar.innerHTML = "movi
// STENCIL: update the vertica
}
<pre>else if (keyboard.pressed("shadowski)</pre>
<pre>// increase the jittering</pre>
<pre>textbar.innerHTML = "its</pre>
// STENCIL: update the radius
}
<pre>else if (keyboard.pressed("z")</pre>
<pre>// decrease the jittering</pre>
<pre>textbar.innerHTML = "relay</pre>
// STENCIL: update the radius
}
<pre>else if (keyboard.pressed("shadabased")</pre>
<pre>// increase spacing along</pre>
<pre>textbar.innerHTML = "sail</pre>

// STENCIL: update the global spacing variable

else if (keyboard.pressed("1")) {

/* keyboard is a threejs helper object for reading keyboard state. return true if a particular key is being ed for a callback event handler

> (")) { on down"; // make the objects move down al offset variable

')) { .ng on up"; // make the objects move up cal offset variable

nift+z")) { of the objects time for the percolator"; of the jittering

')) { of the objects x your mind, let your conscience be free"; of the jittering

ift+1")) { the x-axis between the objects away";

Light implementation exercises for controlling webpage marked with 'STENCIL'



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<> Code	() Issues 1 1; Pull requests () Actions	III Projects 🛄 Wiki 🔃 Security 🗠 Insights			
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	zhezhou1993 Factorize kineval stencil for FK p	roblems, fix bugs in previous version	70d8e4b 9 days ago 🕚 History		
	🗅 kineval.js	initial commit Fall 2018	2 years ago		
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	kineval_forward_kinematics.js	initial commit Fall 2018	2 years ago		
	kineval_inverse_kinematics.js	initial commit Fall 2018	2 years ago		
	kineval_matrix.js	Factorize kineval stencil for FK problems, fix bugs in previous version	9 days ago		
	kineval_quaternion.js	Factorize kineval stencil for FK problems, fix bugs in previous version	9 days ago		
	kineval_robot_init.js	Factorize kineval stencil for FK gradining	10 days ago		
	kineval_robot_init_joints.js	Factorize kineval stencil for FK gradining	10 days ago		
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	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		

kineval_matrix.js

kineval_matrix.js

20	
21	// STENCIL: reference matrix code has the
22	<pre>// matrix_multiply</pre>
23	// matrix_transpose
24	// matrix_pecudeinverce
25	<pre>// matrix_invert_affine</pre>
26	// vector_normalize
27	// vector_cross
28	<pre>// generate_identity</pre>
29	<pre>// generate_translation_matrix</pre>
30	<pre>// generate_rotation_matrix_X</pre>
31	<pre>// generate_rotation_matrix_Y</pre>
32	<pre>// generate_rotation_matrix_Z</pre>
33	
34	
35	
36	// **** Function stencils are provided b
37	
38	
39	
40	<pre>// function matrix_multiply(m1,m2) {</pre>
41	// // returns 2D array that is the r
42	
43	// }
44	
45	<pre>// function matrix_transpose(m) {</pre>
46	// // returns 2D array that is the r
47	

ne following functions:

Except for matrix_pseudoinverse, which is for a later assignment

pelow, please uncomment and implement them ****//

Stencils for matrix operations that you need to implement

esult of m1*m2

result of m1*m2

📮 autorob / kineval-stencil

() Issues	5 1 j	ງ Pull requests	Actions	Projects	🖽 Wiki
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kineval_forward_kinematics.js

kine	val_forward_kinematics.js
18	
19	<pre>kineval.robotForwardKinematics = fu</pre>
20	
21	<pre>if (typeof kineval.buildFKTrans</pre>
22	<pre>textbar.innerHTML = "forwar</pre>
23	return;
24	}
25	
26	<pre>// STENCIL: implement kineval.b</pre>
27	
28	}
29	
30	<pre>// STENCIL: reference code alte</pre>
31	<pre>// links and joints starting</pre>
32	// traverseFKBase
33	// traverseFKLink
34	// traverseFKJoint
35	//

unction robotForwardKinematics () {

sforms === 'undefined') {
rd kinematics not implemented";

buildFKTransforms();

Your recursive traversal of links and joints to build up matrix stack

ernates recursive traversal over from base, using following functions:

> Should result in updated .xform for each link and joint



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	kineval_controls.js	initial commit Fall 2018	2 years ago
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	kineval_inverse_kinematics.js	initial commit Fall 2018	2 years ago
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	kineval_quaternion.js	Factorize kineval stencil for FK problems, fix bugs in previous version	9 days ago
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	kineval_servo_control.js	initial commit Fall 2018	2 years ago
	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

kineval_robot_init_joints.js

	kineval_robot_init_joints.js
20	<pre>for (x in robot.joints) {</pre>
21	
22	<pre>// give the joint its</pre>
23	robot.joints[x].name =
24	
25	// initialize joint ar
26	robot.joints[x].angle
27	<pre>robot.joints[x].contro</pre>
28	<pre>robot.joints[x].servo</pre>
29	//set appropriate serv
30	<pre>robot.joints[x].servo.</pre>
31	robot.joints[x].servo.
32	<pre>robot.joints[x].servo.</pre>
33	/* STENCIL START */
34	<pre>// STENCIL: complete kinem</pre>
35	<pre>// robot description on]</pre>
36	<pre>// additionally specify</pre>

Initialize robot's internal structure between links/joints

```
name as an id
```

```
= x;
```

```
ingle value and control input value
= 0;
ol = 0;
= {};
vo gains for arm setpoint control
.p_gain = 0;
.p_desired = 0;
.d_gain = 0;
```

ematic hierarchy of robot for convenience. ly specifies parent and child links for joints. parent and child joints for each link



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🗁 ohseejay M	erge pull request #3 from cx	t98/master ····	b8f51ea <mark>8 days ago</mark>	🕑 9 commits	Stencil code for KinEval (Kinematic Evaluator) for robot control, kinematics,	
📄 js		initial commit Fall 2018		2 years ago	decision, and dynamics in JavaScript/HTML5	
kineval		initial commit Fall 2018		2 years ago	🛱 Readme	
project_path	olan	Adds refactored stencil files for project 1.		16 days ago	小 View license	
project_pend	ularm	add refactor of assignment2, tested with CI gr	rader	12 days ago		
robots		initial commit Fall 2018		2 years ago	Releases	
tutorial_heap	sort	initial commit Fall 2018		2 years ago	No releases published	
📄 tutorial_js		initial commit Fall 2018		2 years ago		
worlds		initial commit Fall 2018		2 years ago	Packages	
LICENSE		add refactor of assignment2, tested with CI gr	rader	12 days ago	No packages published	
README.m	1	initial commit Fall 2018		2 years ago		
home.html		initial commit Fall 2018		2 years ago	Contributors 4	

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robot_mr2.js	initial commit Fall 2018	2 years ago
robot_urdf_example.js	initial commit Fall 2018	2 years ago

Each robot has its kinematic structure defined in URDF format within these JS files

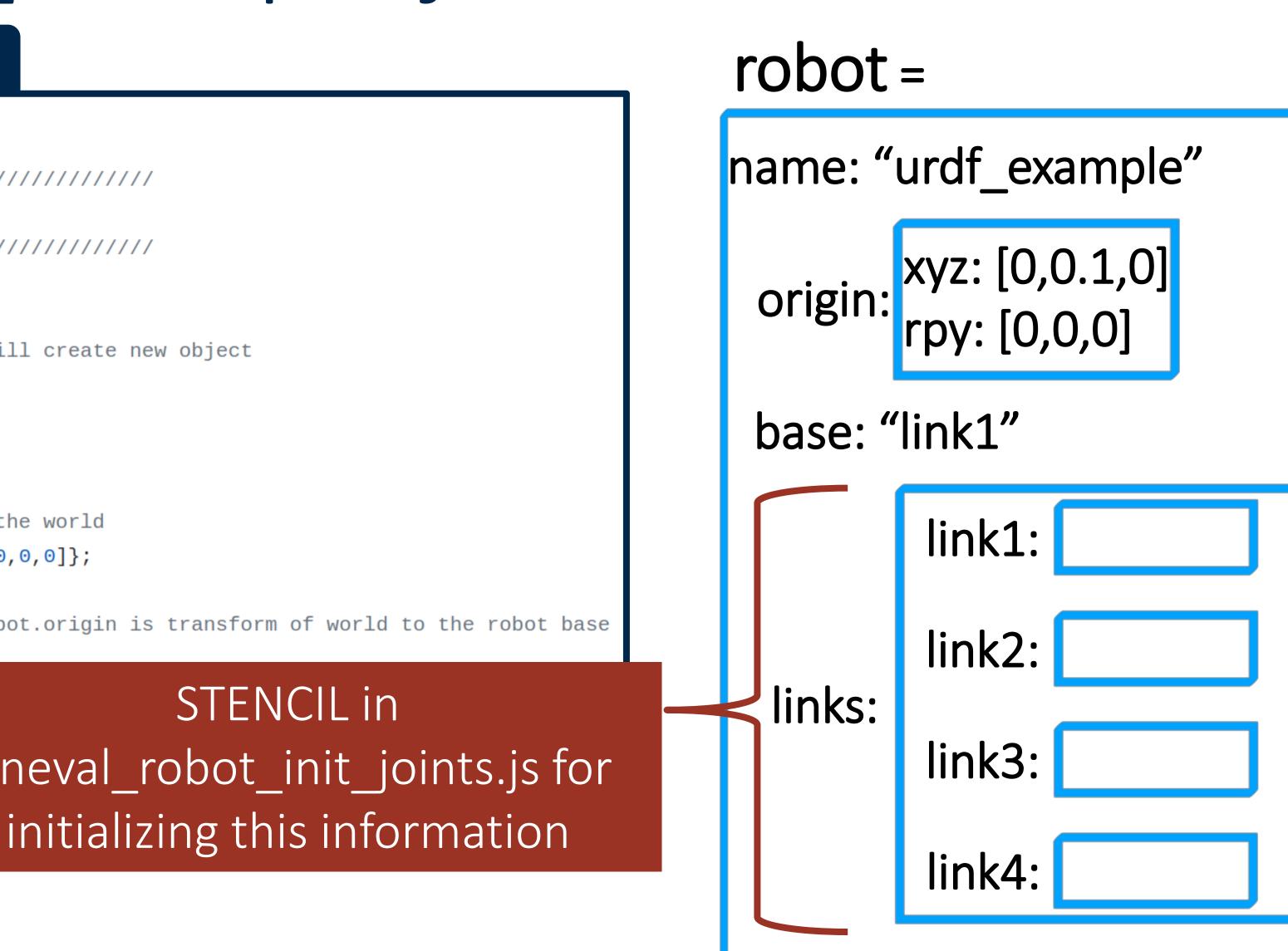
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robot urdf example.js

robot_urdf_example.js

```
CREATE ROBOT STRUCTURE
    /////
             DEFINE ROBOT AND LINKS
         // create robot data object
    robot = new Object(); // or just {} will create new object
9
    // give the robot a name
    robot.name = "urdf_example";
11
12
    // initialize start pose of robot in the world
13
    robot.origin = {xyz: [0,0.1,0], rpy:[0,0,0]};
14
15
    // specify base link of the robot; robot.origin is transform of world to the robot base
16
    robot.base = "link1";
17
                                                  STENCIL in
18
    // specify and create data obje
19
                                   kineval robot init joints.js for
    robot.links = {"link1": {}, "li
20
```



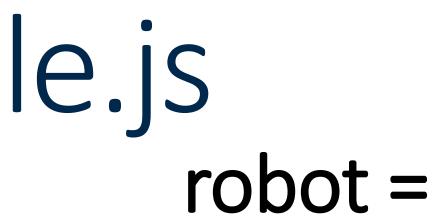


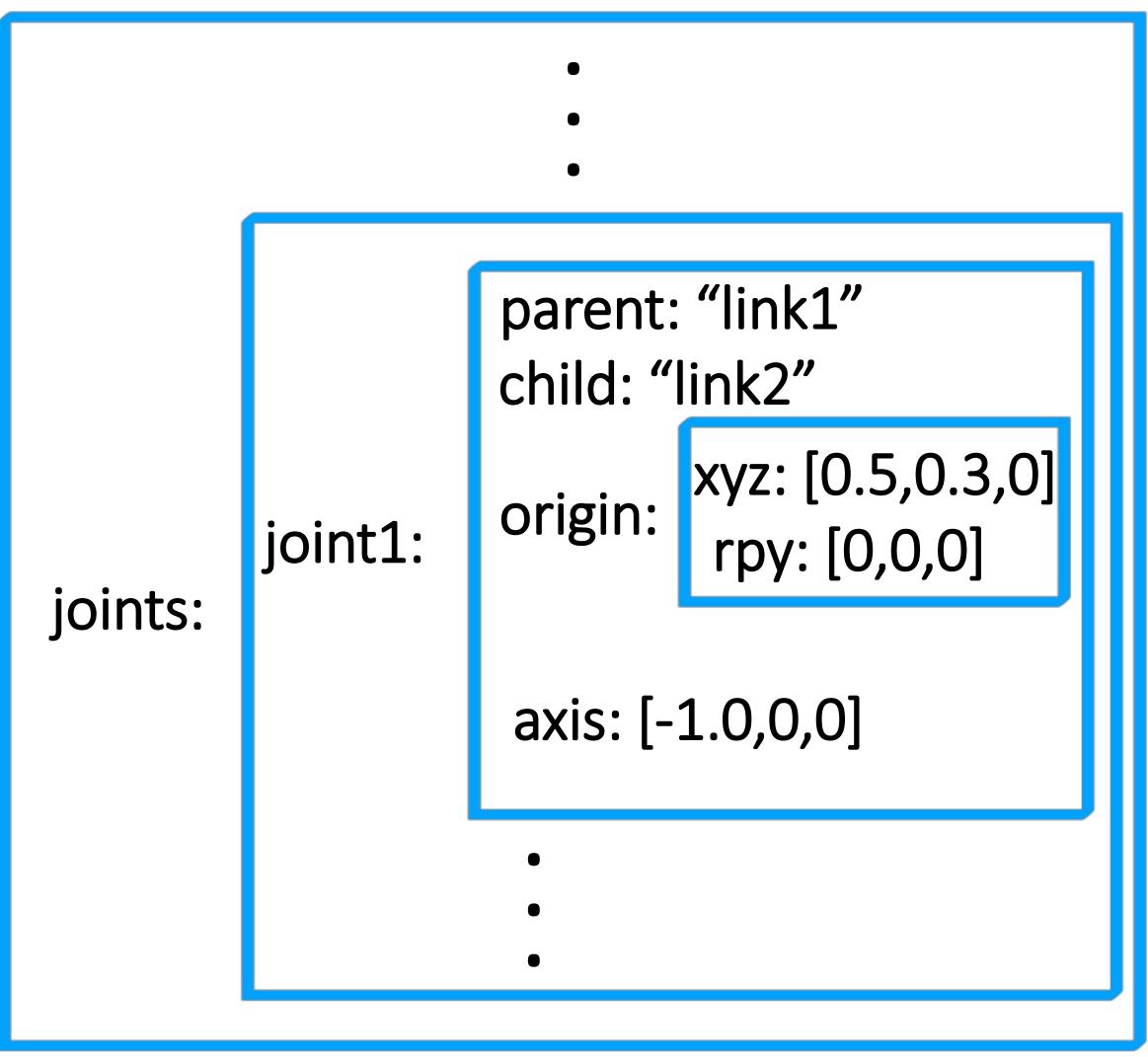


robot_urdf_example.js

robot_urdf_example.js

```
23
             DEFINE JOINTS AND KINEMATIC HIERARCHY
    25
    /*
           joint definition template
26
           // specify parent/inboard link and child/outboard link
27
28
           robot.joints.joint1 = {parent:"link1", child:"link2"};
           // joint origin's offset transform from parent link origin
29
           robot.joints.joint1.origin = {xyz: [5,3,0], rpy:[0,0,0]};
30
           // joint rotation axis
31
           robot.joints.joint1.axis = [0.0,0.0,1.0];
32
    */
33
34
35
    // roll-pitch-yaw defined by ROS as corresponding to x-y-z
36
    //http://wiki.ros.org/urdf/Tutorials/Create%20your%20own%20urdf%20file
37
38
    // specify and create data objects for the joints of the robot
39
    robot.joints = {};
40
41
    robot.joints.joint1 = {parent:"link1", child:"link2"};
42
    robot.joints.joint1.origin = {xyz: [0.5,0.3,0.0], rpy:[0,0,0]};
43
    robot.joints.joint1.axis = [-1.0,0.0,0]; // simpler axis
44
45
    robot.joints.joint2 = {parent:"link1", child:"link3"};
46
    //robot.joints.joint2.origin = {xyz: [-0.2,0.5,0], rpy:[0,0,1.57]};
    robot.joints.joint2.origin = {xyz: [-0.2,0.5,0], rpy:[0,0,Math.PI/2]};
48
    //robot.joints.joint2.axis = [-0.707,0.707,0];
49
    robot.joints.joint2.axis = [-Math.cos(Math.PI/4), Math.cos(Math.PI/4), 0];
50
51
    robot.joints.joint3 = {parent:"link3", child:"link4"};
52
```





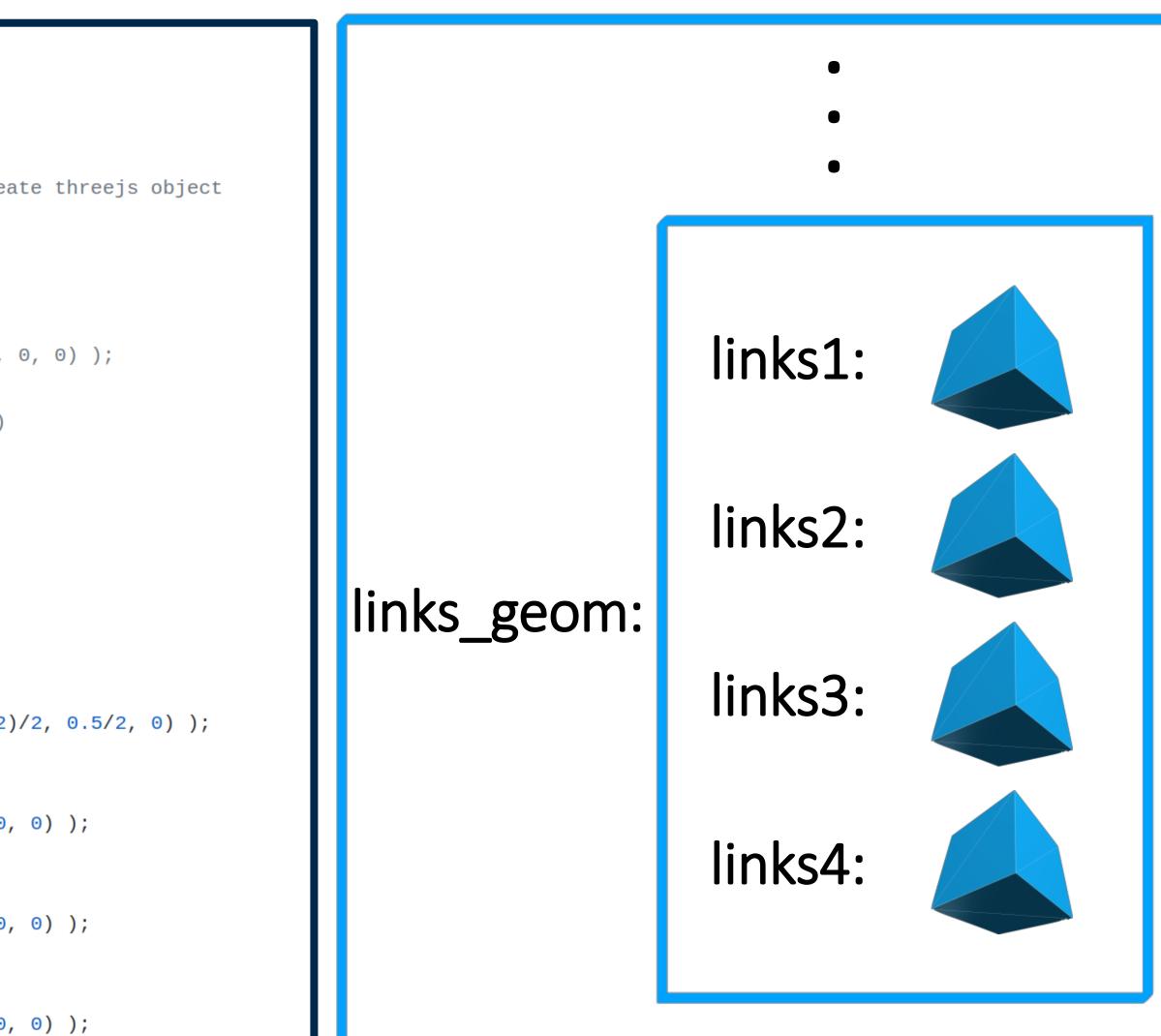
robot urdf example.js

robot_urdf_example.js

```
64
             DEFINE LINK threejs GEOMETRIES
    /////
65
    66
67
       threejs geometry definition template, will be used by THREE.Mesh() to create threejs object
68
        // create threejs geometry and insert into links_geom data object
69
        links_geom["link1"] = new THREE.CubeGeometry( 5+2, 2, 2 );
70
71
        // example of translating geometry (in object space)
72
        links_geom["link1"].applyMatrix( new THREE.Matrix4().makeTranslation(5/2, 0, 0) );
73
74
        // example of rotating geometry 45 degrees about y-axis (in object space)
75
        var temp3axis = new THREE.Vector3(0,1,0);
76
        links_geom["link1"].rotateOnAxis(temp3axis,Math.PI/4);
77
    */
78
79
    // define threejs geometries and associate with robot links
80
    links_geom = {};
81
82
    links_geom["link1"] = new THREE.CubeGeometry( 0.7+0.2, 0.5+0.2, 0.2 );
83
    links_geom["link1"].applyMatrix( new THREE.Matrix4().makeTranslation((0.5-0.2)/2, 0.5/2, 0) );
84
85
    links_geom["link2"] = new THREE.CubeGeometry( 0.5+0.2, 0.2, 0.2 );
86
    links_geom["link2"].applyMatrix( new THREE.Matrix4().makeTranslation(0.5/2, 0, 0) );
87
88
    links_geom["link3"] = new THREE.CubeGeometry( 0.5+0.2, 0.2, 0.2 );
89
    links_geom["link3"].applyMatrix( new THREE.Matrix4().makeTranslation(0.5/2, 0, 0) );
90
91
    links_geom["link4"] = new THREE.CubeGeometry( 0.5+0.2, 0.2, 0.2 );
92
    links_geom["link4"].applyMatrix( new THREE.Matrix4().makeTranslation(0.5/2, 0, 0) );
93
```



robot =





Using URDF Data Structure

Get the base link object: robot.links[robot.base] Get link's parent joint's transform: robot.joints[link.parent].xform Get joint's child link: robot.links[joint.child] Get joint's parent link's joint children: robot.links[joint.parent].children

Implementation Advice

Be aware of **global variable scope** In scope across all included JavaScript files Change a global variable in one file, and that change will be reflected for all other files

Be aware of direction of transform in .xform .xform represents component frame to world frame transform Rotate then translate!

Motivation of Assignment

Robots exist as a collection of parts within an environment

Collectively, the robot has information relating each part to all other parts

Independent of individual component information and environment

Can acquire knowledge of the environment through sensing Robot's internal information is a source of prior knowledge about the environment Has information that it exists in a known configuration within environment

- Each part has information like geometry, configuration state, control signal...
- By definition, this information is independent from other parts and environment

Motivation of Assignment

- Robots exist as a collection of parts within an environment Collectively, the robot has information relating each part to all other parts
- Can acquire knowledge of the environment through sensing
- To accomplish some desired task, our robot should make use of all available knowledge; its actions should be as fully informed as possible We need to be able to relate each source of information Transform all information into a unified frame of reference = forward kinematics

Lab Takeaways

- 1. KinEval overview
- 2. KinEval walkthrough
- 3. Implementation advice
- \rightarrow How to start Assignment 3