
```

function q_k_1 = NextState(q_k, q_dot_k, dt, max_joint_vel)
% *** KINEMATICS Simulator ***
% Takes q_k: The current state of the robot
%           (12 variables: 3 for chassis, 5 for arm, 4 for wheel angles)
%           q_dot_k: The joint and wheel velocities
%           (9 variables: 5 for arm , 4 for wheels u)
%           dt: The timestep size dt (1 parameter)
%           max_joint_vel: The maximum joint and wheel velocity magnitude (1
parameter)
%
% Returns q_k_1: The next state (configuration) of the robot (12 variables)
%
% The function NextState is based on a simple first-order Euler step:
% - new arm joint angles = (old arm joint angles) + (joint speeds)*dt
% - new wheel angles = (old wheel angles) + (wheel speeds)*dt
% - new chassis configuration is obtained from odometry, as described in
Chapter 13.4

[q_dot_k, in_bound] = bound(q_dot_k, -max_joint_vel, max_joint_vel);

q_k_1 = zeros(12,1);
% Joints Update & Wheels Update
q_k_1(4:8) = q_k(4:8) + q_dot_k(1:5)*dt;
q_k_1(9:12) = q_k(9:12) + q_dot_k(6:9)*dt;

% Odometry Update [phi, x, y]
load("youBotParams.mat", 'F')
wheel_speeds = q_dot_k(6:9);
phi_k = q_k(1);

V = F * wheel_speeds;
dV_omg = V(1) * dt;
dV_x = V(2) * dt;
dV_y = V(3) * dt;
% 2D pose exponential
if dV_omg == 0
    dq_chassis_body = [0, dV_x, dV_y]';
else
    dq_chassis_body = [dV_omg;
                      dV_x * sin(dV_omg)/dV_omg + dV_y * (cos(dV_omg) -
1)/dV_omg;
                      dV_x * (1 - cos(dV_omg))/dV_omg + dV_y *
sin(dV_omg)/dV_omg];
end
rot_odom_body = [[1, 0, 0];
                 [0, cos(phi_k), -sin(phi_k)];
                 [0, sin(phi_k), cos(phi_k)]];
dq_chassis_odom = rot_odom_body * dq_chassis_body;
q_k_1(1:3) = q_k(1:3) + dq_chassis_odom;

[q_k_1, joints_checked] = checkJointLimits(q_k_1);
% disp(joints_checked)

```

end

Not enough input arguments.

Error in NextState (line 17)

```
[q_dot_k, in_bound] = bound(q_dot_k, -max_joint_vel, max_joint_vel);  
                ^^^^^^^
```

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```
function [x_bounded, in_bound] = bound(x, lower_bound, upper_bound)
% Takes x: Value
%     lower_bound: Lower bound
%     upper_bound: Upper bound
%
% Returns x_bound: Bounded value
%     in_bound: if x within bounds

    x_bounded = max(lower_bound, min(x, upper_bound));
    in_bound = ((x >= lower_bound) + (x <= upper_bound)) == 2;
end
```

Not enough input arguments.

Error in bound (line 9)

```
    x_bounded = max(lower_bound, min(x, upper_bound));
                ^^^^^^^^^^^^^^
```

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```
function [q_checked, joints_in_bound] = checkJointLimits(q)
% Takes q: The current state of the robot
%         (12 variables: 3 for chassis, 5 for arm, 4 for wheel angles)
%
% Returns q_checked: The constrained state of the robot (12 variables)
%         joints_in_bound: if arm joints are in bound (1 array)

% Arm Joints
q_arm = q(4:8);

% Joint Lower Bounds and Upper Bounds
q_lowerBounds = [-inf, -3*pi/4, -5*pi/6, -5*pi/6, -inf]';
q_upperBounds = [inf, pi/2, 5*pi/6, 5*pi/6, inf]';

[q_arm, joints_in_bound] = bound(q_arm, q_lowerBounds, q_upperBounds);
q_checked = [q(1:3); q_arm; q(9:12)];
```

```
end
```

```
Not enough input arguments.
```

```
Error in checkJointLimits (line 9)
```

```
    q_arm = q(4:8);
           ^^^^^^^
```

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Parameters

lengths saved in meters

```
x_0e = 0.033;  
x_b0 = 0.1662;  
  
% chassis frame {b} is at a height of z0  
z0 = 0.0963;  
% youBot dimensions  
z1 = 0.0026;  
z2 = 0.147;  
z3 = 0.155;  
z4 = 0.135;  
z5 = 0.2176;  
  
% front-back distance between the wheels: 2*l  
l = 0.47 / 2;  
% side-to-side distance between the wheels: 2*w  
w = 0.3 / 2;  
% radius of the wheels: r  
r = 0.0475;
```

Body Frame Screw Axes

```
B1 = [0, 0, 1, 0, x_0e, 0]';  
B2 = [0, -1, 0, -(z3+z4+z5), 0, 0]';  
B3 = [0, -1, 0, -(z4+z5), 0, 0]';  
B4 = [0, -1, 0, -z5, 0, 0]';  
B5 = [0, 0, 1, 0, 0, 0]';  
  
B = [B1, B2, B3, B4, B5];
```

Zero E-E Config

end-effector frame {e} to arm base frame {0}

```
M_0e = [[1, 0, 0, x_0e];  
        [0, 1, 0, 0];  
        [0, 0, 1, z2+z3+z4+z5];  
        [0, 0, 0, 1]];
```

youBot Configs

arm base frame {0} to chassis frame {b} (static transform)

```
T_b0 = [[1, 0, 0, x_b0];  
        [0, 1, 0, 0];  
        [0, 0, 1, z1];  
        [0, 0, 0, 1]];  
  
% Velocity Forward Kinematics of Chassis  
F = (r/4) .* [[-1/(1 + w), 1/(1 + w), 1/(1 + w), -1/(1 + w)];  
             [1, 1, 1, 1];  
             [-1, 1, -1, 1]];  
  
save youBotParams.mat z0 l w r B M_0e T_b0 F
```

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```
clear; close all; clc;
```

```
q_dot = [pi/4 pi/4 pi/4 pi/4 pi/4 -1 1 1 -1]';
```

```
dt = 0.01;
```

```
max_joint_vel = 200;
```

```
t = [0:dt:1];
```

```
q = zeros(12,length(t));
```

```
for i = 2:length(t)
```

```
    q(:, i) = NextState(q(:, i-1), q_dot, dt, max_joint_vel);
```

```
end
```

```
disp(q')
```

```
writematrix(q', 'testData_NextState.csv')
```

Columns 1 through 7

0	0	0	0	0	0	0
0.0012	0	0	0.0079	0.0079	0.0079	0.0079
0.0025	0	0	0.0157	0.0157	0.0157	0.0157
0.0037	0	0	0.0236	0.0236	0.0236	0.0236
0.0049	0	0	0.0314	0.0314	0.0314	0.0314
0.0062	0	0	0.0393	0.0393	0.0393	0.0393
0.0074	0	0	0.0471	0.0471	0.0471	0.0471
0.0086	0	0	0.0550	0.0550	0.0550	0.0550
0.0099	0	0	0.0628	0.0628	0.0628	0.0628
0.0111	0	0	0.0707	0.0707	0.0707	0.0707
0.0123	0	0	0.0785	0.0785	0.0785	0.0785
0.0136	0	0	0.0864	0.0864	0.0864	0.0864
0.0148	0	0	0.0942	0.0942	0.0942	0.0942
0.0160	0	0	0.1021	0.1021	0.1021	0.1021
0.0173	0	0	0.1100	0.1100	0.1100	0.1100
0.0185	0	0	0.1178	0.1178	0.1178	0.1178
0.0197	0	0	0.1257	0.1257	0.1257	0.1257
0.0210	0	0	0.1335	0.1335	0.1335	0.1335
0.0222	0	0	0.1414	0.1414	0.1414	0.1414
0.0234	0	0	0.1492	0.1492	0.1492	0.1492
0.0247	0	0	0.1571	0.1571	0.1571	0.1571
0.0259	0	0	0.1649	0.1649	0.1649	0.1649
0.0271	0	0	0.1728	0.1728	0.1728	0.1728
0.0284	0	0	0.1806	0.1806	0.1806	0.1806
0.0296	0	0	0.1885	0.1885	0.1885	0.1885
0.0308	0	0	0.1963	0.1963	0.1963	0.1963
0.0321	0	0	0.2042	0.2042	0.2042	0.2042
0.0333	0	0	0.2121	0.2121	0.2121	0.2121
0.0345	0	0	0.2199	0.2199	0.2199	0.2199
0.0358	0	0	0.2278	0.2278	0.2278	0.2278
0.0370	0	0	0.2356	0.2356	0.2356	0.2356
0.0382	0	0	0.2435	0.2435	0.2435	0.2435
0.0395	0	0	0.2513	0.2513	0.2513	0.2513
0.0407	0	0	0.2592	0.2592	0.2592	0.2592
0.0419	0	0	0.2670	0.2670	0.2670	0.2670

0.0432	0	0	0.2749	0.2749	0.2749	0.2749
0.0444	0	0	0.2827	0.2827	0.2827	0.2827
0.0456	0	0	0.2906	0.2906	0.2906	0.2906
0.0469	0	0	0.2985	0.2985	0.2985	0.2985
0.0481	0	0	0.3063	0.3063	0.3063	0.3063
0.0494	0	0	0.3142	0.3142	0.3142	0.3142
0.0506	0	0	0.3220	0.3220	0.3220	0.3220
0.0518	0	0	0.3299	0.3299	0.3299	0.3299
0.0531	0	0	0.3377	0.3377	0.3377	0.3377
0.0543	0	0	0.3456	0.3456	0.3456	0.3456
0.0555	0	0	0.3534	0.3534	0.3534	0.3534
0.0568	0	0	0.3613	0.3613	0.3613	0.3613
0.0580	0	0	0.3691	0.3691	0.3691	0.3691
0.0592	0	0	0.3770	0.3770	0.3770	0.3770
0.0605	0	0	0.3848	0.3848	0.3848	0.3848
0.0617	0	0	0.3927	0.3927	0.3927	0.3927
0.0629	0	0	0.4006	0.4006	0.4006	0.4006
0.0642	0	0	0.4084	0.4084	0.4084	0.4084
0.0654	0	0	0.4163	0.4163	0.4163	0.4163
0.0666	0	0	0.4241	0.4241	0.4241	0.4241
0.0679	0	0	0.4320	0.4320	0.4320	0.4320
0.0691	0	0	0.4398	0.4398	0.4398	0.4398
0.0703	0	0	0.4477	0.4477	0.4477	0.4477
0.0716	0	0	0.4555	0.4555	0.4555	0.4555
0.0728	0	0	0.4634	0.4634	0.4634	0.4634
0.0740	0	0	0.4712	0.4712	0.4712	0.4712
0.0753	0	0	0.4791	0.4791	0.4791	0.4791
0.0765	0	0	0.4869	0.4869	0.4869	0.4869
0.0777	0	0	0.4948	0.4948	0.4948	0.4948
0.0790	0	0	0.5027	0.5027	0.5027	0.5027
0.0802	0	0	0.5105	0.5105	0.5105	0.5105
0.0814	0	0	0.5184	0.5184	0.5184	0.5184
0.0827	0	0	0.5262	0.5262	0.5262	0.5262
0.0839	0	0	0.5341	0.5341	0.5341	0.5341
0.0851	0	0	0.5419	0.5419	0.5419	0.5419
0.0864	0	0	0.5498	0.5498	0.5498	0.5498
0.0876	0	0	0.5576	0.5576	0.5576	0.5576
0.0888	0	0	0.5655	0.5655	0.5655	0.5655
0.0901	0	0	0.5733	0.5733	0.5733	0.5733
0.0913	0	0	0.5812	0.5812	0.5812	0.5812
0.0925	0	0	0.5890	0.5890	0.5890	0.5890
0.0938	0	0	0.5969	0.5969	0.5969	0.5969
0.0950	0	0	0.6048	0.6048	0.6048	0.6048
0.0962	0	0	0.6126	0.6126	0.6126	0.6126
0.0975	0	0	0.6205	0.6205	0.6205	0.6205
0.0987	0	0	0.6283	0.6283	0.6283	0.6283
0.0999	0	0	0.6362	0.6362	0.6362	0.6362
0.1012	0	0	0.6440	0.6440	0.6440	0.6440
0.1024	0	0	0.6519	0.6519	0.6519	0.6519
0.1036	0	0	0.6597	0.6597	0.6597	0.6597
0.1049	0	0	0.6676	0.6676	0.6676	0.6676
0.1061	0	0	0.6754	0.6754	0.6754	0.6754
0.1073	0	0	0.6833	0.6833	0.6833	0.6833
0.1086	0	0	0.6912	0.6912	0.6912	0.6912

0.1098	0	0	0.6990	0.6990	0.6990	0.6990
0.1110	0	0	0.7069	0.7069	0.7069	0.7069
0.1123	0	0	0.7147	0.7147	0.7147	0.7147
0.1135	0	0	0.7226	0.7226	0.7226	0.7226
0.1147	0	0	0.7304	0.7304	0.7304	0.7304
0.1160	0	0	0.7383	0.7383	0.7383	0.7383
0.1172	0	0	0.7461	0.7461	0.7461	0.7461
0.1184	0	0	0.7540	0.7540	0.7540	0.7540
0.1197	0	0	0.7618	0.7618	0.7618	0.7618
0.1209	0	0	0.7697	0.7697	0.7697	0.7697
0.1221	0	0	0.7775	0.7775	0.7775	0.7775
0.1234	0	0	0.7854	0.7854	0.7854	0.7854

Columns 8 through 12

0	0	0	0	0
0.0079	-0.0100	0.0100	0.0100	-0.0100
0.0157	-0.0200	0.0200	0.0200	-0.0200
0.0236	-0.0300	0.0300	0.0300	-0.0300
0.0314	-0.0400	0.0400	0.0400	-0.0400
0.0393	-0.0500	0.0500	0.0500	-0.0500
0.0471	-0.0600	0.0600	0.0600	-0.0600
0.0550	-0.0700	0.0700	0.0700	-0.0700
0.0628	-0.0800	0.0800	0.0800	-0.0800
0.0707	-0.0900	0.0900	0.0900	-0.0900
0.0785	-0.1000	0.1000	0.1000	-0.1000
0.0864	-0.1100	0.1100	0.1100	-0.1100
0.0942	-0.1200	0.1200	0.1200	-0.1200
0.1021	-0.1300	0.1300	0.1300	-0.1300
0.1100	-0.1400	0.1400	0.1400	-0.1400
0.1178	-0.1500	0.1500	0.1500	-0.1500
0.1257	-0.1600	0.1600	0.1600	-0.1600
0.1335	-0.1700	0.1700	0.1700	-0.1700
0.1414	-0.1800	0.1800	0.1800	-0.1800
0.1492	-0.1900	0.1900	0.1900	-0.1900
0.1571	-0.2000	0.2000	0.2000	-0.2000
0.1649	-0.2100	0.2100	0.2100	-0.2100
0.1728	-0.2200	0.2200	0.2200	-0.2200
0.1806	-0.2300	0.2300	0.2300	-0.2300
0.1885	-0.2400	0.2400	0.2400	-0.2400
0.1963	-0.2500	0.2500	0.2500	-0.2500
0.2042	-0.2600	0.2600	0.2600	-0.2600
0.2121	-0.2700	0.2700	0.2700	-0.2700
0.2199	-0.2800	0.2800	0.2800	-0.2800
0.2278	-0.2900	0.2900	0.2900	-0.2900
0.2356	-0.3000	0.3000	0.3000	-0.3000
0.2435	-0.3100	0.3100	0.3100	-0.3100
0.2513	-0.3200	0.3200	0.3200	-0.3200
0.2592	-0.3300	0.3300	0.3300	-0.3300
0.2670	-0.3400	0.3400	0.3400	-0.3400
0.2749	-0.3500	0.3500	0.3500	-0.3500
0.2827	-0.3600	0.3600	0.3600	-0.3600
0.2906	-0.3700	0.3700	0.3700	-0.3700
0.2985	-0.3800	0.3800	0.3800	-0.3800

0.3063	-0.3900	0.3900	0.3900	-0.3900
0.3142	-0.4000	0.4000	0.4000	-0.4000
0.3220	-0.4100	0.4100	0.4100	-0.4100
0.3299	-0.4200	0.4200	0.4200	-0.4200
0.3377	-0.4300	0.4300	0.4300	-0.4300
0.3456	-0.4400	0.4400	0.4400	-0.4400
0.3534	-0.4500	0.4500	0.4500	-0.4500
0.3613	-0.4600	0.4600	0.4600	-0.4600
0.3691	-0.4700	0.4700	0.4700	-0.4700
0.3770	-0.4800	0.4800	0.4800	-0.4800
0.3848	-0.4900	0.4900	0.4900	-0.4900
0.3927	-0.5000	0.5000	0.5000	-0.5000
0.4006	-0.5100	0.5100	0.5100	-0.5100
0.4084	-0.5200	0.5200	0.5200	-0.5200
0.4163	-0.5300	0.5300	0.5300	-0.5300
0.4241	-0.5400	0.5400	0.5400	-0.5400
0.4320	-0.5500	0.5500	0.5500	-0.5500
0.4398	-0.5600	0.5600	0.5600	-0.5600
0.4477	-0.5700	0.5700	0.5700	-0.5700
0.4555	-0.5800	0.5800	0.5800	-0.5800
0.4634	-0.5900	0.5900	0.5900	-0.5900
0.4712	-0.6000	0.6000	0.6000	-0.6000
0.4791	-0.6100	0.6100	0.6100	-0.6100
0.4869	-0.6200	0.6200	0.6200	-0.6200
0.4948	-0.6300	0.6300	0.6300	-0.6300
0.5027	-0.6400	0.6400	0.6400	-0.6400
0.5105	-0.6500	0.6500	0.6500	-0.6500
0.5184	-0.6600	0.6600	0.6600	-0.6600
0.5262	-0.6700	0.6700	0.6700	-0.6700
0.5341	-0.6800	0.6800	0.6800	-0.6800
0.5419	-0.6900	0.6900	0.6900	-0.6900
0.5498	-0.7000	0.7000	0.7000	-0.7000
0.5576	-0.7100	0.7100	0.7100	-0.7100
0.5655	-0.7200	0.7200	0.7200	-0.7200
0.5733	-0.7300	0.7300	0.7300	-0.7300
0.5812	-0.7400	0.7400	0.7400	-0.7400
0.5890	-0.7500	0.7500	0.7500	-0.7500
0.5969	-0.7600	0.7600	0.7600	-0.7600
0.6048	-0.7700	0.7700	0.7700	-0.7700
0.6126	-0.7800	0.7800	0.7800	-0.7800
0.6205	-0.7900	0.7900	0.7900	-0.7900
0.6283	-0.8000	0.8000	0.8000	-0.8000
0.6362	-0.8100	0.8100	0.8100	-0.8100
0.6440	-0.8200	0.8200	0.8200	-0.8200
0.6519	-0.8300	0.8300	0.8300	-0.8300
0.6597	-0.8400	0.8400	0.8400	-0.8400
0.6676	-0.8500	0.8500	0.8500	-0.8500
0.6754	-0.8600	0.8600	0.8600	-0.8600
0.6833	-0.8700	0.8700	0.8700	-0.8700
0.6912	-0.8800	0.8800	0.8800	-0.8800
0.6990	-0.8900	0.8900	0.8900	-0.8900
0.7069	-0.9000	0.9000	0.9000	-0.9000
0.7147	-0.9100	0.9100	0.9100	-0.9100
0.7226	-0.9200	0.9200	0.9200	-0.9200

0.7304	-0.9300	0.9300	0.9300	-0.9300
0.7383	-0.9400	0.9400	0.9400	-0.9400
0.7461	-0.9500	0.9500	0.9500	-0.9500
0.7540	-0.9600	0.9600	0.9600	-0.9600
0.7618	-0.9700	0.9700	0.9700	-0.9700
0.7697	-0.9800	0.9800	0.9800	-0.9800
0.7775	-0.9900	0.9900	0.9900	-0.9900
0.7854	-1.0000	1.0000	1.0000	-1.0000

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Milestone 2 Video Link:

https://youtu.be/zyI5_ieC4NQ