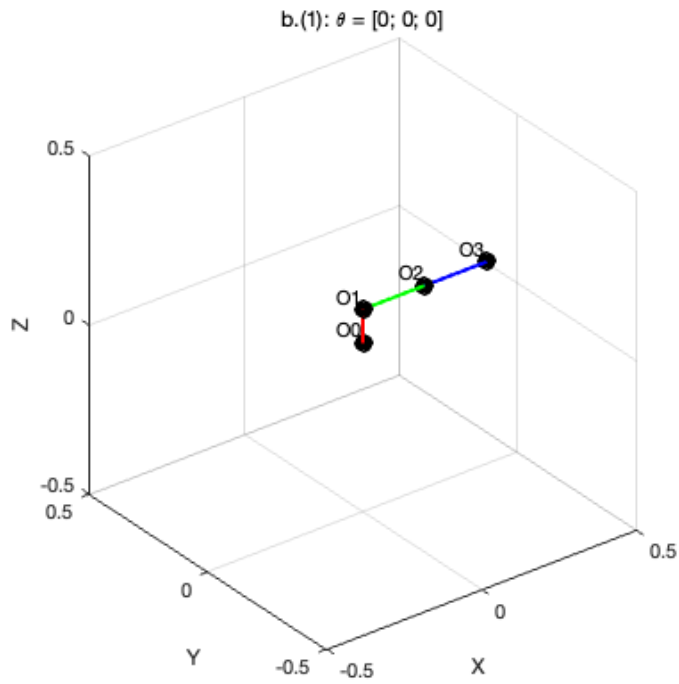# Contents

```
clc;
clear;
close all;

% parameters
a1 = 0.1;
a2 = 0.2;
a3 = 0.2;
```

b.

```
theta1 = [0; 0; 0];
theta2 = [0; pi/4; pi/4];
theta3 = [pi/6; pi/4; -pi/2];
theta4 = [pi; pi/2; pi/2];
```
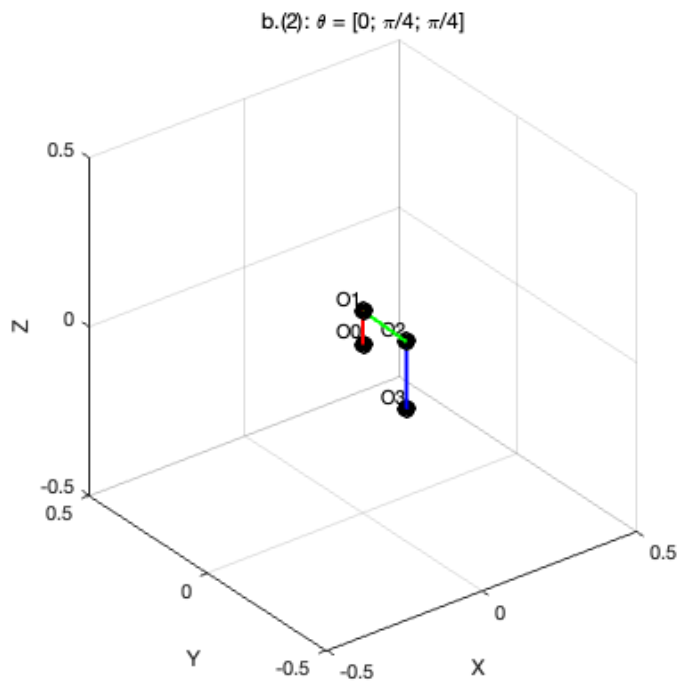
b1

```
figure;
[O0, O1, O2, O3] = calculate_joint_positions(a1, a2, a3, theta1);
plot_robot_arm(O0, O1, O2, O3);
title('b.(1): \theta = [0; 0; 0]');
```

b.(1): θ = [0; 0; 0]

b2

```
figure;
[O0, O1, O2, O3] = calculate_joint_positions(a1, a2, a3, theta2);
plot_robot_arm(O0, O1, O2, O3);
title('b.(2): \theta = [0; \pi/4; \pi/4]');
```

b.(2): θ = [0; π/4; π/4]

b3

```
figure;
[O0, O1, O2, O3] = calculate_joint_positions(a1, a2, a3, theta3);
```

```
plot_robot_arm(O0, O1, O2, O3);
title('b.(3): \theta = [\pi/6; \pi/4; -\pi/2]');
```
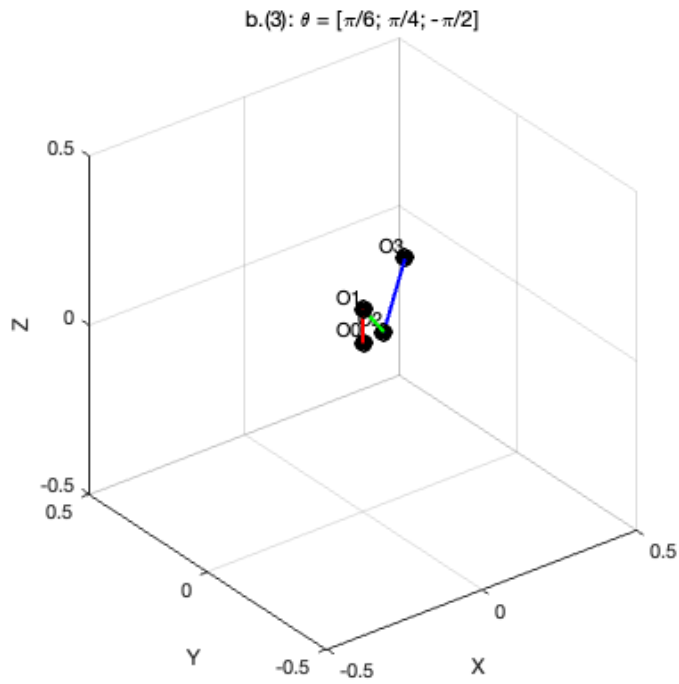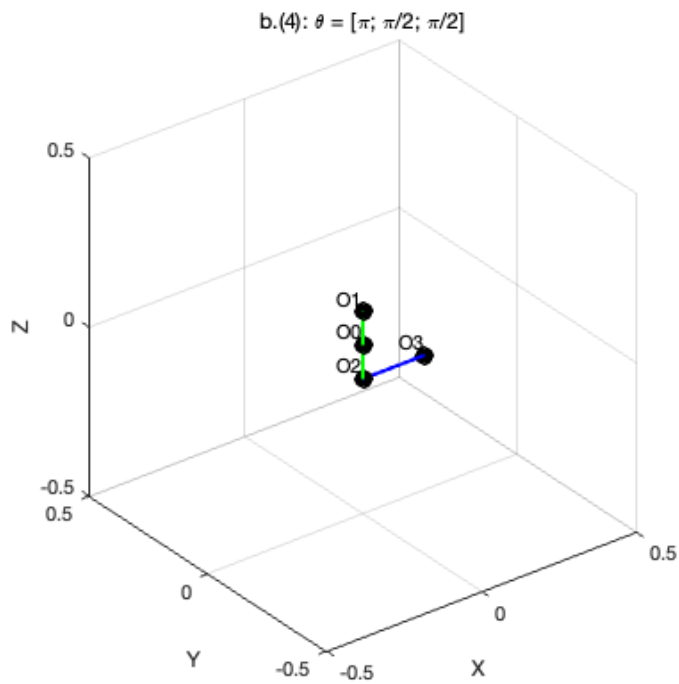
b.(3): θ = [π/6; π/4; −π/2]

b4

```
figure;
[O0, O1, O2, O3] = calculate_joint_positions(a1, a2, a3, theta4);
plot_robot_arm(O0, O1, O2, O3);
title('b.(4): \theta = [\pi; \pi/2; \pi/2]');
```

b.(4): θ = [π; π/2; π/2]

c.

arm

```matlab
theta_c = [0; pi/4; pi/4];

% Rigid Motion Matrixs
Trans = [
    1, 0, 0, 0.5;
    0, 1, 0, 0;
    0, 0, 1, 0;
    0, 0, 0, 1
];

Roll = [
    1, 0, 0, 0;
    0, 0, -1, 0;
    0, 1, 0, 0;
    0, 0, 0, 1
];

Yaw = [
    cos(pi/4), -sin(pi/4), 0, 0;
    sin(pi/4), cos(pi/4), 0, 0;
    0, 0, 1, 0;
    0, 0, 0, 1
];

% c1
H1 = Roll * Yaw * Trans;

% c2
H2 = Trans * Roll * Yaw;

% c3
H3 = Roll * Yaw * Trans;
```
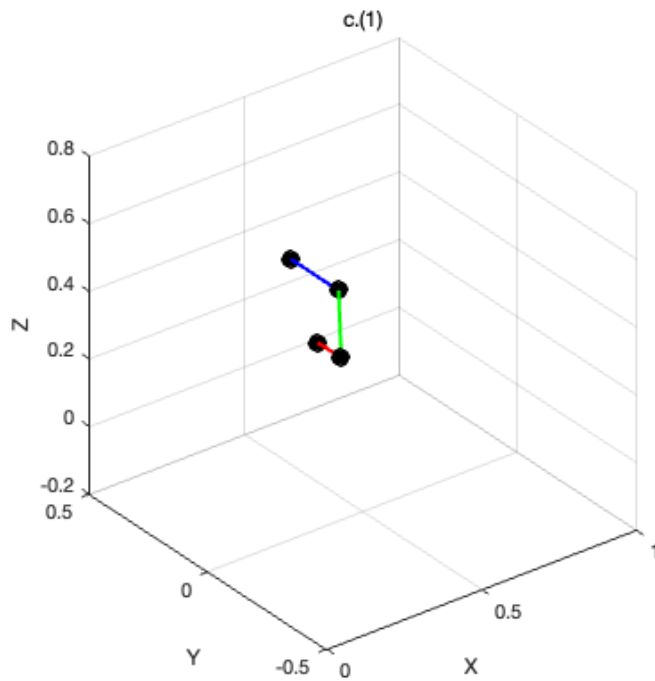
c1

```matlab
figure;
[O0, O1, O2, O3] = calculate_joint_positions(a1, a2, a3, theta_c);
plot_robot_arm_with_base(O0, O1, O2, O3, H1);
title('c.(1)');
```

c.(1)

c2
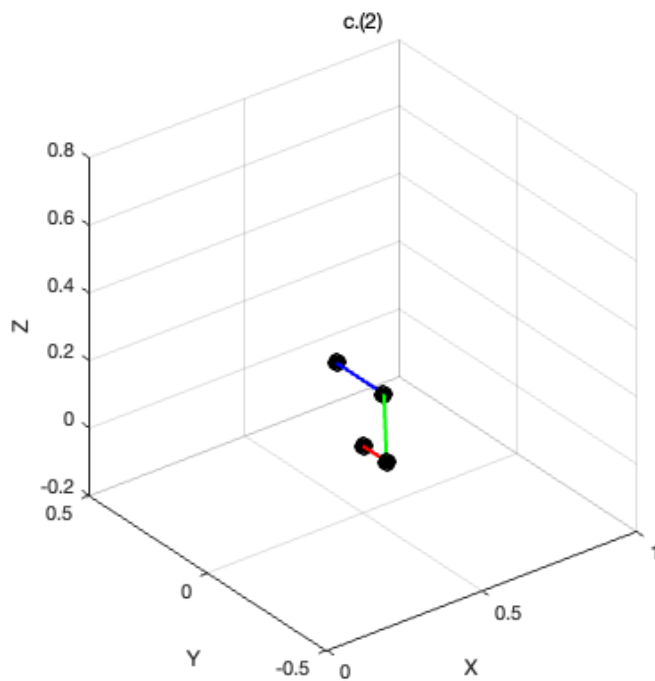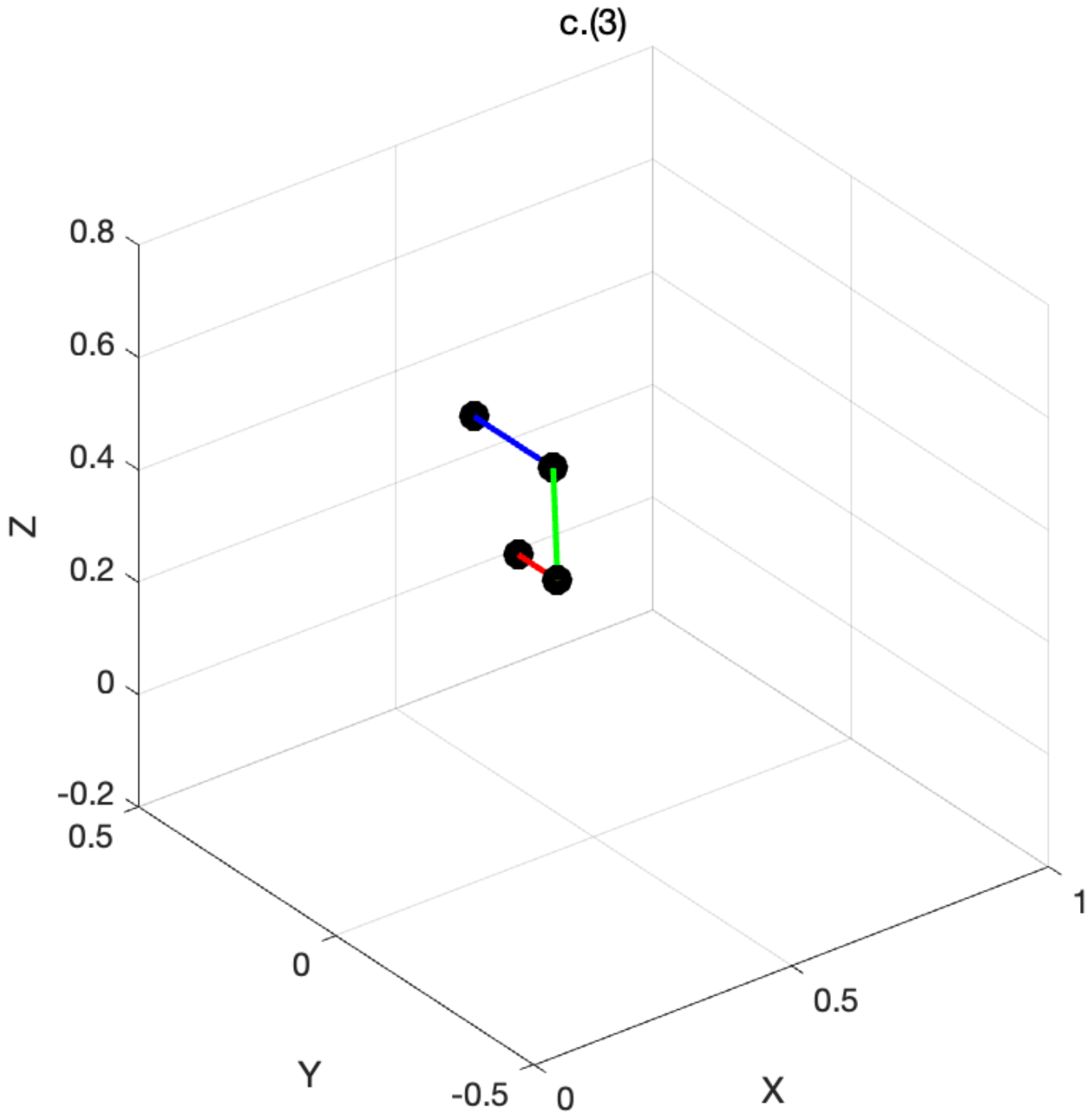
```
figure;
[O0, O1, O2, O3] = calculate_joint_positions(a1, a2, a3, theta_c);
plot_robot_arm_with_base(O0, O1, O2, O3, H2);
title('c.(2)');
```


c.(2)

c3

```
figure;
[O0, O1, O2, O3] = calculate_joint_positions(a1, a2, a3, theta_c);
```

```matlab
plot_robot_arm_with_base(O0, O1, O2, O3, H3);
title('c.(3)');
```


c.(3)

Function: cal point O

```matlab
function [O0, O1, O2, O3] = calculate_joint_positions(a1, a2, a3, theta)
    theta1 = theta(1);
    theta2 = theta(2);
    theta3 = theta(3);

    % Matrix
    T1 = [
        cos(theta1), -sin(theta1), 0, 0;
        sin(theta1), cos(theta1),  0, 0;
        0,           0,            1, a1;
        0,           0,            0, 1
    ];
```

```matlab
    T2 = [
        cos(theta2), 0, sin(theta2), a2*cos(theta2);
        0,           1, 0,           0;
        -sin(theta2),0, cos(theta2), -a2*sin(theta2);
        0,           0, 0,           1
    ];

    T3 = [
        cos(theta3), 0, sin(theta3), a3*cos(theta3);
        0,           1, 0,           0;
        -sin(theta3),0, cos(theta3), -a3*sin(theta3);
        0,           0, 0,           1
    ];

    % vectors
    O_1 = T1;
    O_2 = T1 * T2;
    O_3 = T1 * T2 * T3;

    % coordinates
    O0 = [0; 0; 0];
    O1 = O_1(1:3, 4);
    O2 = O_2(1:3, 4);
    O3 = O_3(1:3, 4);
end
```

Plot b

```matlab
function plot_robot_arm(O0, O1, O2, O3)

    % lines
    plot3([O0(1), O1(1)], [O0(2), O1(2)], [O0(3), O1(3)], 'r', 'LineWidth', 2); hold on;
    plot3([O1(1), O2(1)], [O1(2), O2(2)], [O1(3), O2(3)], 'g', 'LineWidth', 2);
    plot3([O2(1), O3(1)], [O2(2), O3(2)], [O2(3), O3(3)], 'b', 'LineWidth', 2);

    % joints
    plot3(O0(1), O0(2), O0(3), 'ko', 'MarkerSize', 10, 'MarkerFaceColor', 'k');
    plot3(O1(1), O1(2), O1(3), 'ko', 'MarkerSize', 10, 'MarkerFaceColor', 'k');
    plot3(O2(1), O2(2), O2(3), 'ko', 'MarkerSize', 10, 'MarkerFaceColor', 'k');
    plot3(O3(1), O3(2), O3(3), 'ko', 'MarkerSize', 10, 'MarkerFaceColor', 'k');

    % remarks
    text(O0(1), O0(2), O0(3), 'O0', 'VerticalAlignment', 'bottom', 'HorizontalAlignment', 'right');
    text(O1(1), O1(2), O1(3), 'O1', 'VerticalAlignment', 'bottom', 'HorizontalAlignment', 'right');
    text(O2(1), O2(2), O2(3), 'O2', 'VerticalAlignment', 'bottom', 'HorizontalAlignment', 'right');
    text(O3(1), O3(2), O3(3), 'O3', 'VerticalAlignment', 'bottom', 'HorizontalAlignment', 'right');

    xlabel('X'); ylabel('Y'); zlabel('Z');
    axis equal;
    grid on;
    axis([-0.5 0.5 -0.5 0.5 -0.5 0.5]);
    view(3);
end
```

plot c

```matlab
function plot_robot_arm_with_base(O0, O1, O2, O3, T_base)

    % rotated coordinates
    O0_new = T_base * [O0; 1];
    O1_new = T_base * [O1; 1];
    O2_new = T_base * [O2; 1];
    O3_new = T_base * [O3; 1];
```

```matlab
    plot3([O0_new(1), O1_new(1)], [O0_new(2), O1_new(2)], [O0_new(3), O1_new(3)], 'r', 'LineWidth', 2); hold on;
    plot3([O1_new(1), O2_new(1)], [O1_new(2), O2_new(2)], [O1_new(3), O2_new(3)], 'g', 'LineWidth', 2);
    plot3([O2_new(1), O3_new(1)], [O2_new(2), O3_new(2)], [O2_new(3), O3_new(3)], 'b', 'LineWidth', 2);

    plot3(O0_new(1), O0_new(2), O0_new(3), 'ko', 'MarkerSize', 10, 'MarkerFaceColor', 'k');
    plot3(O1_new(1), O1_new(2), O1_new(3), 'ko', 'MarkerSize', 10, 'MarkerFaceColor', 'k');
    plot3(O2_new(1), O2_new(2), O2_new(3), 'ko', 'MarkerSize', 10, 'MarkerFaceColor', 'k');
    plot3(O3_new(1), O3_new(2), O3_new(3), 'ko', 'MarkerSize', 10, 'MarkerFaceColor', 'k');

    xlabel('X'); ylabel('Y'); zlabel('Z');
    axis equal;
    grid on;
    axis([0 1 -0.5 0.5 -0.2 0.8]);
    view(3);
end
```

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