Tether Conclusions

The following MATLAB Live Script details the conclusions of the tether experiments, including the resulting plots for a total of 30 experiments perfomed on the orange 4-limbed robot on the black mat.

```
% Dependencies:
%   +demos/data/visualtracking
%   +offlineanalysis/GaitTest
%   +gaitdef/Gait

% [0] == Script setup
clear; clc; close all

% Add dependencies to classpath
addpath('../');
addpath('data/visualtracking');

% Configure figure tex interpreters
set(groot, 'defaultAxesTickLabelInterpreter','latex');
set(groot, 'defaultTextInterpreter','latex');
set(0, 'DefaultAxesFontSize', 18);
```

Extract and define parameters for GaitTest() objects.

From 20220707 Experiments:

Gait B-120   [heavy - not following (restting) - left/up]

```
gait_names{1}  = 'B_120_H_NF_L.mat';
```

Gait E-120   [heavy - not following - left/up]

```
gait_names{2}  = 'E_120_H_NF_L.mat';
```

Gait E-60   [heavy - not following - left/up]

```
gait_names{3}  = 'E_60_H_NF_L.mat';
```

Gait E-60*   [heavy - not following - right/up] Caution! Not real E gait! Limb A not actuating

```
gait_names{4}  = 'Es_60_H_NF_R.mat';
```

From 20220819 Experiments:

Gait B-120   [light sheath - not following (restting) - right/up]

```
gait_names{5}  = 'B_120_S_NF_R.mat';
```

From 20220829 Experiments:

Gait B Follow (Left)*   [light sheath - following - left] Caution! Not real B gait! Limb A not actuating

```
gait_names{6}  = 'Bs_60_S_F_L.mat';
```

Gait B Follow (Right)* [light sheath - following - right] Caution! Not real B gait! Limb A not actuating

```
gait_names{7}  = 'Bs_60_S_F_R.mat';
```

Gait E Left (sheath on) [light sheath - not following - left]

```
gait_names{8}  = 'E_60_S_NF_L.mat';
```

Gait E Right (sheath on) [no sheath - not following - right]

```
gait_names{9}  = 'E_60_S_NF_R.mat';
```

Gait E Left (sheath off) [no sheath - not following - left]

```
gait_names{10} = 'E_60_NS_NF_L.mat';
```

Gait E Right (sheath off)* [no sheath - not following - right] Caution! Not real E gait! Limb B not actuating

```
gait_names{11} = 'Es_60_NS_NF_R.mat';
```

From 20220901 Experiments:

Gait E Left (sheath off) [no sheath - not following - left (flipped)]

```
gait_names{12} = 'E_60_NS_NF_Lf.mat';
```

Gait B Follow (Left) Trial 1 [light sheath - following - left]

```
gait_names{13} = 'B_60_S_F_L.mat';

gait_names{14} = 'B_60_S_F_Lf.mat';
% Gait B Follow (Left) Trial 2 [light sheath - following - left (flipped)]
gait_names{15} = 'B_60_S_NF_L.mat';
% Gait B Left (Sheath on) Trial 1 [light sheath - following - left (flipped)]
gait_names{16} = 'B_60_S_NF_Lf.mat';
% Gait B Left (Sheath on) Trial 2 [light sheath - following - left (flipped)]

% From 20220908 Experiments:
gait_names{17} = 'B_60_S_NF_R.mat';
% Gait B Right (sheath on)  [sheath - not following - right] (not consistent / semi-following)

gait_names{18} = 'B_60_NS_F_R.mat';    % Gait B Right Follow (sheath off) Trial 1  [no sheath -
gait_names{19} = 'B_60_NS_F_R_2.mat';  % Gait B Right Follow (sheath off) Trial 2 [no sheath -
gait_names{20} = 'B_60_NS_F_L.mat';    % Gait B Left Follow (sheath off) Trial 1 [no sheath - f
gait_names{21} = 'B_60_NS_F_L_2.mat';  % Gait B Left Follow (sheath off) Trial 2 [no sheath - n

gait_names{22} = 'B_60_NS_NF_R.mat';   % Gait B Right (sheath off) Trial 1 [no sheath -  not fo
gait_names{23} = 'B_60_NS_NF_R_2.mat'; % Gait B Right (sheath off) Trial 2 [no sheath -  not fo
```

```
gait_names{24} = 'B_60_NS_NF_L.mat';   % Gait B Left (sheath off) Trial 1 [no sheath -  not fol
gait_names{25} = 'B_60_NS_NF_L_2.mat'; % Gait B Left (sheath off) Trial 2 [no sheath -  not fol

gait_names{26} = 'B_60_S_F_R.mat';    % Gait B Right Follow(sheath on)  [sheath - following - n

gait_names{27} = 'E_60_NS_NF_R.mat';   % Gait E Right (sheath off) Trial 1 [no sheath -  not fo
gait_names{28} = 'E_60_NS_NF_R_2.mat'; % Gait E Right (sheath off) Trial 2 [no sheath -  not fo
gait_names{29} = 'E_60_NS_NF_L_2.mat'; % Gait E Left (sheath off) Trial 1 [no sheath -  not fol
gait_names{30} = 'E_60_NS_NF_L_3.mat';   % Gait E Left (sheath off) Trial 2 [no sheath -  not f

if isrow(gait_names)
    gait_names = gait_names';
end

n_gaits = length(gait_names);

% Extract characteristics of each gait test.
file_names = split(gait_names, '.');
gait_characteristics = cell(n_gaits, 7);
for i = 1:n_gaits
    gait_characteristics(i, 1) = num2cell(i);
    n_underscores = count(gait_names{i}, '_');
    if n_underscores == 4
        gait_characteristics(i, 2:6) = split(file_names(i,1), '_');
        gait_characteristics(i, 7) = num2cell(1);
    else
        gait_characteristics(i, 2:7) = split(file_names(i,1), '_');
    end
end
characteristics = ["ExperimentNumber", "GaitType", "NumberOfCycles", "TetherType", ...
              "TetherProtocol", "TetherPlacement", "TrialNumber"];

experiments = cell2table(gait_characteristics, "VariableNames", ...
              characteristics);
sorted_exps = sortrows(experiments, characteristics([2, 4, 5, 6, 7]))
```

sorted_exps = 30×7 table

...

	ExperimentNumber	GaitType	NumberOfCycles	TetherType	TetherProtocol
1	1	'B'	'120'	'H'	'NF'
2	20	'B'	'60'	'NS'	'F'
3	21	'B'	'60'	'NS'	'F'
4	18	'B'	'60'	'NS'	'F'
5	19	'B'	'60'	'NS'	'F'
6	24	'B'	'60'	'NS'	'NF'
7	25	'B'	'60'	'NS'	'NF'

	ExperimentNumber	GaitType	NumberOfCycles	TetherType	TetherProtocol
8	22	'B'	'60'	'NS'	'NF'
9	23	'B'	'60'	'NS'	'NF'
10	13	'B'	'60'	'S'	'F'
11	14	'B'	'60'	'S'	'F'
12	26	'B'	'60'	'S'	'F'
13	15	'B'	'60'	'S'	'NF'
14	16	'B'	'60'	'S'	'NF'
15	5	'B'	'120'	'S'	'NF'
16	17	'B'	'60'	'S'	'NF'
17	6	'Bs'	'60'	'S'	'F'
18	7	'Bs'	'60'	'S'	'F'
19	2	'E'	'120'	'H'	'NF'
20	3	'E'	'60'	'H'	'NF'
21	10	'E'	'60'	'NS'	'NF'
22	29	'E'	'60'	'NS'	'NF'
23	30	'E'	'60'	'NS'	'NF'
24	12	'E'	'60'	'NS'	'NF'
25	27	'E'	'60'	'NS'	'NF'
26	28	'E'	'60'	'NS'	'NF'
27	8	'E'	'60'	'S'	'NF'
28	9	'E'	'60'	'S'	'NF'
29	4	'Es'	'60'	'H'	'NF'
30	11	'Es'	'60'	'NS'	'NF'

```
% Define experimental parameters after investigating videos.
%frame_start_list = [382, 234, 141, 109, 76, 129, 88, 74, 76, 55, 983];
frame_start_list(1:4) = [382, 234, 141, 109];
frame_start_list(5) = 76;
frame_start_list(6:11) = [210, 168, 131, 131, 55, 983];
frame_start_list(12:16) = [132, 184, 278, 324, 196];
frame_start_list(17:25) = [63, 45, 39, 49, 137, 36, 63, 39, 519];
frame_start_list(26:30) = [88, 51, 64, 50, 57];


% Find marker order by investigating first frame.
marker_order_list = repmat([1 4 3 2],n_gaits, 1);
marker_order_list([1,4,5,6,7,11,13,15,17,18,19,20,22,23,24,27,28,29,30],:) = repmat([1 3 4 2],
```

```
marker_order_list([8,9,10,21,25],:) = repmat([2 4 3 1],5,1);
marker_order_list([12,14,16],:) = repmat([4 2 1 3],3,1);
marker_order_list(26,:) = repmat([2,3,4,1],1,1);

show_markers = false;     % plots first frame of each video

% Initialize the stability experiment struct.
stab_exp = struct('params', [], 'raw_data', []);

% Extract data.
for i = 1:n_gaits
    % Define robot / experiment parameters.
    stab_exp(i).params.robot_name = 'orange';
    stab_exp(i).params.substrate = 'black mat';
    stab_exp(i).params.n_markers = 4;
    stab_exp(i).params.pixel_length = 1/8.6343;     % cm per pixel

    % Define number of gait cycles run.
    if ismember(i,[1,2,5])
        stab_exp(i).params.n_cycles= 119;
    else
        stab_exp(i).params.n_cycles= 59;
    end

    % Extract and store first frame information.
    stab_exp(i).params.frame_1 = frame_start_list(i);
    stab_exp(i).params.marker_order = marker_order_list(i,:);

    % Extract and store raw data from each trial
    filename = gait_names{i};
    stab_exp(i).raw_data = load(filename).tracking_data;
    if ismember('B', gait_names{i})
        gait_sequences{i} = [16,7,5,11,14];   % Gait B (rotational)
    elseif ismember('E', gait_names{i})
        gait_sequences{i} = [9,16,1];         % Gait E (translational)
    else
        gait_sequences{i} = [];
    end
end
```

[2] == (Optional) Rotate the data w.r.t the initial global orientation.

```
% Define first experiment first frame orientation as theta = 0.
markers_x(1, :) = stab_exp(1).raw_data(1, 1:3:stab_exp(1).params.n_markers*3-2);
markers_y(1, :) = stab_exp(1).raw_data(1, 2:3:stab_exp(1).params.n_markers*3-1);
centroid(:, :, 1) = mean([markers_x(1, :); markers_y(1, :)], 2);
% Move initial position to (0,0) origin.
reference_markers = [markers_x(1, [1 3 4 2]); markers_y(1, [1 3 4 2]);]...
                    - centroid(:, :, 1);
```

```
% For each trial, rotate data to align first frame global orientations.
 for i = 1:n_gaits
    % Find initial rotation matrix for each trial to have consistent fixed frame.
    markers_x(i, :) = stab_exp(i).raw_data(1, 1:3:stab_exp(i).params.n_markers*3-2);
    markers_y(i, :) = stab_exp(i).raw_data(1, 2:3:stab_exp(i).params.n_markers*3-1);
    centroid(:, :, i) = mean([markers_x(i, :); markers_y(i, :)], 2);

    % Move initial position to (0,0) origin.
    shifted_markers = [markers_x(i, stab_exp(i).params.marker_order);
                       markers_y(i, stab_exp(i).params.marker_order)]...
                        - centroid(:, :, i);

    % Find orientation of subsequent trials w.r.t. first trial GCS.
    [regParams,~,~]= absor(reference_markers, shifted_markers);
    stab_exp(i).params.R_1 = [regParams.R zeros(2,1); 0 0 1];
 end
```

[3] == Instantiate GaitTest() objects for each experimental trial.

This analyzes the data from each trial to find motion primitive twist information.

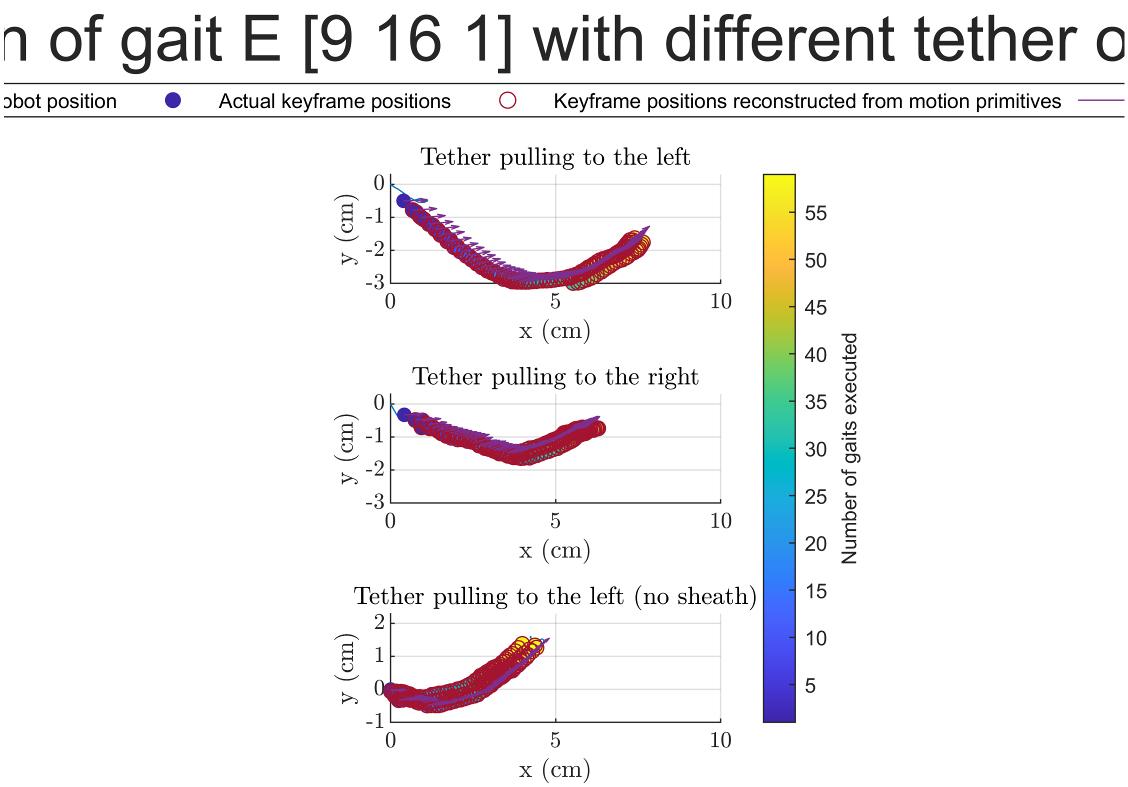
```
% Instantiate objects for each gait tested.
all_gaits = offlineanalysis.GaitTest.empty(0,n_gaits);
gait_defs = gaitdef.Gait.empty(0,n_gaits);

% Calculate twists for each gait experiment.
for i = 1:n_gaits
    all_gaits(i) = offlineanalysis.GaitTest(stab_exp(i).raw_data, ...
                                            gait_sequences{i}(1,:), ...
                                            stab_exp(i).params);
    gait_defs(i) = gaitdef.Gait(all_gaits(i), stab_exp(i).params);


    % Manually find the twists.
    % Extract gait / experiment details.
    n_cycles = all_gaits(i).n_cycles;
    len_gait = all_gaits(i).len_gait;
     for j = 1:n_cycles - 1
        % Record indexes for each motion primitive tail and head.
        tail_idx{i}(1,j) =  all_gaits(i).keyframes(len_gait*(j-1)+2);
        head_idx{i}(1,j) = all_gaits(i).keyframes(len_gait*j+2);

        % Find change in poses w.r.t. global inertial frame for each motion primitive.
        delta_poses{i}(:,j) = all_gaits(i).raw_poses(:, head_idx{i}(1,j)) - all_gaits(i).raw_p
        %delta_poses{i}(3,j) = delta_poses{i}(3,j) - delta_poses{i}(3,1);
        delta_poses{i}(1:2,j) = all_gaits(i).pixel_length*delta_poses{i}(1:2,j);
        % Find global orientation of robot at each motion primitive tail.
        global_theta{i}(:,j) = all_gaits(i).raw_poses(3, tail_idx{i}(1,j));

        % Convert from global frame to body frame.
```

```
        rot_mat =  [cos(global_theta{i}(1,j)) -sin(global_theta{i}(1,j)); sin(global_theta{i}(
        delta_poses{i}(1:2,j) = rot_mat'*delta_poses{i}(1:2,j);

        % Convert to twists.
        twists{i}(:,j)  = gait_defs(i).delta_pose_2_twist(delta_poses{i}(:,j), all_gaits(i).tr
       %twists{i}(1:2,j) = 1/(all_gaits(i).transition_time*len_gait)*delta_poses{i}(1:2,j);
       %twists{i}(3,j) = 1/(all_gaits(i).transition_time*len_gait)*delta_poses{i}(3,j);
        % Find instantaneous center of rotation.
        %cent_rot{i}(:,j) = inv(eye(2) - rot_mat)*delta_poses{i}(:, 1:2);

        % Find instantaneous radius of curvature.
        %rad_curv{i}(1,j) = norm(cent_rot{i}(:,j));
    end

end
```

[4] == Plot the full motion data for each experiment.

```
% Plot both Gait B experiments.
figure(1)
t1 = tiledlayout(2,2);
nexttile;
all_gaits(1).plot;
title('Heavy left with resetting')
nexttile;
all_gaits(5).plot;
title('Sheath right with resetting')
nexttile;
all_gaits(6).plot;
title('Left following')
nexttile;
all_gaits(7).plot;
title('Right following')
lgd = legend('Continuous robot position', 'Actual keyframe positions', ...
                  'Keyframe positions reconstructed from motion primitives','robot orientation
lgd.Layout.Tile = 'north';
lgd.Orientation = 'horizontal';
a = colorbar;
a.Label.String = 'Number of gaits executed';
a.Layout.Tile = 'east';
title(t1, 'Comparison of four experiements of Gait B [16,7,5,11,14]','FontSize',24)

% Plot Gait E with moving tether.
figure(2)
t1 = tiledlayout(1,2,'TileSpacing','compact');
nexttile;
all_gaits(6).plot;
title('Left following')
nexttile;
all_gaits(7).plot;
```

```
title('Right following')
lgd = legend('Continuous robot position', 'Actual keyframe positions', ...
                  'Keyframe positions reconstructed from motion primitives','robot orientation
lgd.Layout.Tile = 'north';
lgd.Orientation = 'horizontal';
a = colorbar;
a.Label.String = 'Number of gaits executed';
a.Layout.Tile = 'east';
title(t1, 'Comparison of two experiements of Gait B [16,7,5,11,14]','FontSize',24)

% Plot Gait E with fixed tethers.
figure(3)
t3 = tiledlayout(3,1,'TileSpacing','compact');

nexttile;
all_gaits(8).plot;
title('Tether pulling to the left')
ylim([-3 0.3])
xlim([0 10])

nexttile;
all_gaits(9).plot;
title('Tether pulling to the right')
ylim([-3 0.3])
xlim([0 10])

nexttile;
all_gaits(10).plot;
title('Tether pulling to the left (no sheath)')
ylim([-1 2.3])
xlim([0 10])

% nexttile;
% all_gaits(11).plot;
% title('Tether pulling to the right (no sheath)')



lgd = legend('Continuous robot position', 'Actual keyframe positions', ...
                  'Keyframe positions reconstructed from motion primitives','robot orientation

lgd.Layout.Tile = 'north';
lgd.Orientation = 'horizontal';
a = colorbar;
a.Label.String = 'Number of gaits executed';
a.Layout.Tile = 'east';
title(t3, 'Comparison of gait E [9 16 1] with different tether orientations','FontSize',24)
```



[4] == Plot the twist data for each experiment.

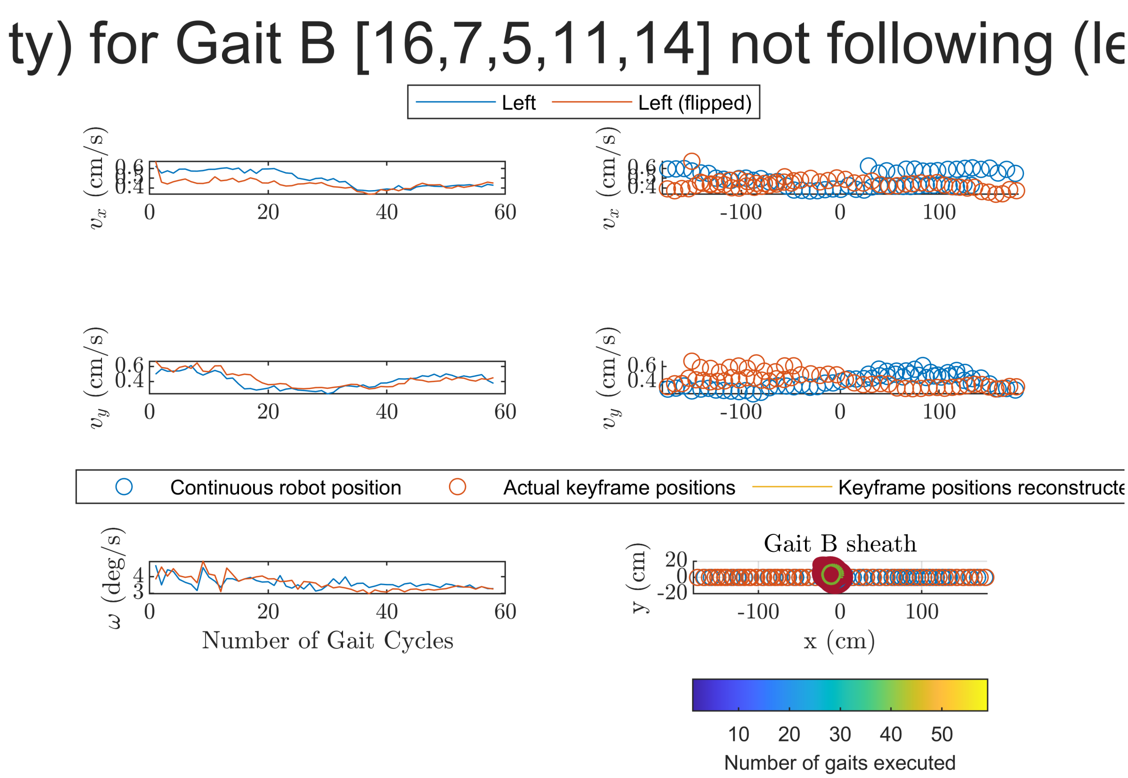
```
figure(4)
trial_labels = {'Heavy Left','Left', 'Right', 'Left (No Sheath)'};
t_4 = plot_twists(twists, global_theta, [3,8,9,10], trial_labels,[]);
title(t_4, 'Twist (body velocity) for two experiments of Gait E [9,16,1]', 'FontSize',22)

figure(5)
ylims = [-.3 .53;
         -.05 .67;
         -1.9 5.8;
         -0.3 0.6;
         -0.05 0.7;
         -0.02 0.1];
trial_labels = {'Left resetting', 'Right resetting'};
t_5 = plot_twists(twists, global_theta, [1,5], trial_labels,ylims);
title(t_5,'Twist (body velocity) for two experiments of Gait B [16,7,5,11,14] with different te

nexttile(2);
scatter(rad2deg(global_theta{1}(1,:)),twists{1}(1,:))
hold on
scatter(rad2deg(global_theta{5}(1,:)),twists{5}(1,:))
xlim([-180 180])
ylim([-0.3 0.6])
ylabel('$v_x$ (cm/s)')
```

```
nexttile(4);
scatter(rad2deg(global_theta{1}(1,:)),twists{1}(2,:))
hold on
scatter(rad2deg(global_theta{5}(1,:)),twists{5}(2,:))
xlim([-180 180])
ylim([-0.05 0.7])
ylabel('$v_y$ (cm/s)')

nexttile(6);
scatter(rad2deg(global_theta{1}(1,:)),twists{5}(3,:))
hold on
scatter(rad2deg(global_theta{5}(1,:)),twists{5}(3,:))
xlim([-180 180])
ylim([-0.02 0.1])
ylabel('$\omega$ (deg/s)')


xlabel('Global robot orientation $\theta_G$ (deg)')

figure(6)

t = tiledlayout(3,2);

nexttile;
plot(twists{6}(1,:))
hold on
plot(twists{7}(1,:))
ylabel('$v_x$ (cm/s)')

nexttile(3);
plot(twists{6}(2,:))
hold on
plot(twists{7}(2,:))
ylabel('$v_y$ (cm/s)')

nexttile(5);
plot(rad2deg(twists{6}(3,:)))
hold on
plot(rad2deg(twists{7}(3,:)))
ylabel('$\omega$ (deg/s)')

lgd = legend('Left following', 'Right following');
lgd.Orientation = 'horizontal';
lgd.Layout.Tile = 'north';
xlabel('Number of Gait Cycles')
title(t,'Twist (body velocity) for two experiments of Gait B [16,7,5,11,14] with light tether',

nexttile(2);
scatter(rad2deg(global_theta{6}(1,:)),twists{6}(1,:))
```

```
hold on
scatter(rad2deg(global_theta{7}(1,:)),twists{7}(1,:))
xlim([-180 180])
ylim([-0.3 0.6])
ylabel('$v_x$ (cm/s)')

nexttile(4);
scatter(rad2deg(global_theta{6}(1,:)),twists{6}(2,:))
hold on
scatter(rad2deg(global_theta{7}(1,:)),twists{7}(2,:))
xlim([-180 180])
ylim([-0.05 0.7])
ylabel('$v_y$ (cm/s)')

nexttile(6);
scatter(rad2deg(global_theta{6}(1,:)),twists{6}(3,:))
hold on
scatter(rad2deg(global_theta{7}(1,:)),twists{7}(3,:))
xlim([-180 180])
ylim([-0.02 0.1])
ylabel('$\omega$ (deg/s)')


xlabel('Global robot orientation $\theta_G$ (deg)')

% Plot both Gait B experiments.
figure(7)
t1 = tiledlayout(1,2);
nexttile;
all_gaits(15).plot;
title('Trial 1')
nexttile;
all_gaits(16).plot;
title('Trial 2 (flipped)')

lgd = legend('Continuous robot position', 'Actual keyframe positions', ...
                  'Keyframe positions reconstructed from motion primitives','robot orientation
lgd.Layout.Tile = 'north';
lgd.Orientation = 'horizontal';
a = colorbar;
a.Label.String = 'Number of gaits executed';
a.Layout.Tile = 'south';
title(t1, 'Gait B [16,7,5,11,14] not following (left) with light sheath','FontSize',24)


figure(8)
all_gaits(10).plot;
lgd = legend('Continuous robot position', 'Actual keyframe positions', ...
                  'Keyframe positions reconstructed from motion primitives','robot orientation
lgd.Orientation = 'horizontal';
```

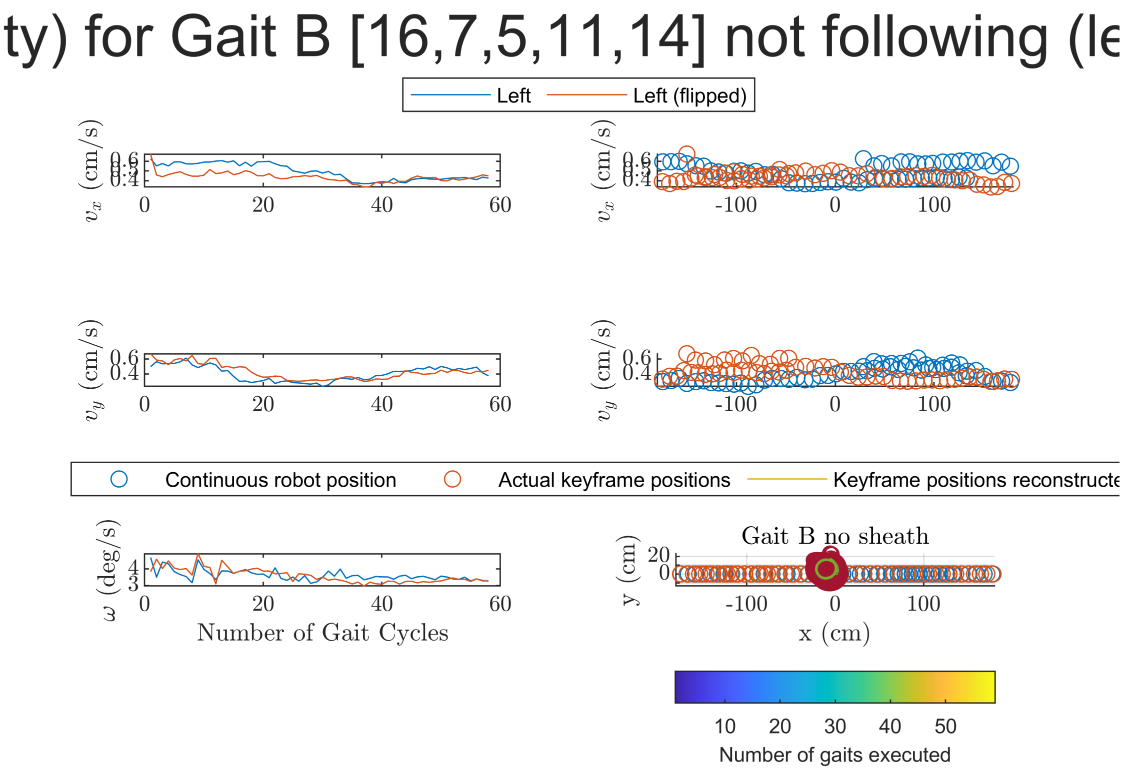
```
lgd.Location = 'northoutside';

a = colorbar('southoutside');
a.Label.String = 'Number of gaits executed';
%E_60_NS_NF_L
title('Gait E [9 16 1] not following (left) with no sheath')


figure(9)
t = tiledlayout(3,2);
nexttile;
plot(twists{15}(1,:))
hold on
plot(twists{16}(1,:))
ylabel('$v_x$ (cm/s)')

nexttile(3);
plot(twists{15}(2,:))
hold on
plot(twists{16}(2,:))
ylabel('$v_y$ (cm/s)')

nexttile(5);
plot(rad2deg(twists{15}(3,:)))
hold on
plot(rad2deg(twists{16}(3,:)))
ylabel('$\omega$ (deg/s)')

lgd = legend('Left', 'Left (flipped)');
lgd.Orientation = 'horizontal';
lgd.Layout.Tile = 'north';
xlabel('Number of Gait Cycles')
title(t,'Twist (body velocity) for Gait B [16,7,5,11,14] not following (left) with light sheat

nexttile(2);
scatter(rad2deg(global_theta{15}(1,:)),twists{15}(1,:))
hold on
scatter(rad2deg(global_theta{16}(1,:)),twists{16}(1,:))
xlim([-180 180])
ylabel('$v_x$ (cm/s)')

nexttile(4);
scatter(rad2deg(global_theta{15}(1,:)),twists{15}(2,:))
hold on
scatter(rad2deg(global_theta{16}(1,:)),twists{16}(2,:))
xlim([-180 180])
ylabel('$v_y$ (cm/s)')

nexttile(6);
scatter(rad2deg(global_theta{15}(1,:)),twists{15}(3,:))
```

```
hold on
scatter(rad2deg(global_theta{16}(1,:)),twists{16}(3,:))
xlim([-180 180])
ylabel('$\omega$ (deg/s)')


xlabel('Global robot orientation $\theta_G$ (deg)')

figure(10)
for i = [13,14,15,16,17,26]
all_gaits(i).plot;
end
lgd = legend('Continuous robot position', 'Actual keyframe positions', ...
                  'Keyframe positions reconstructed from motion primitives','robot orientation
lgd.Orientation = 'horizontal';
lgd.Location = 'northoutside';

a = colorbar('southoutside');
a.Label.String = 'Number of gaits executed';
%E_60_NS_NF_L
title('Gait B sheath')
```

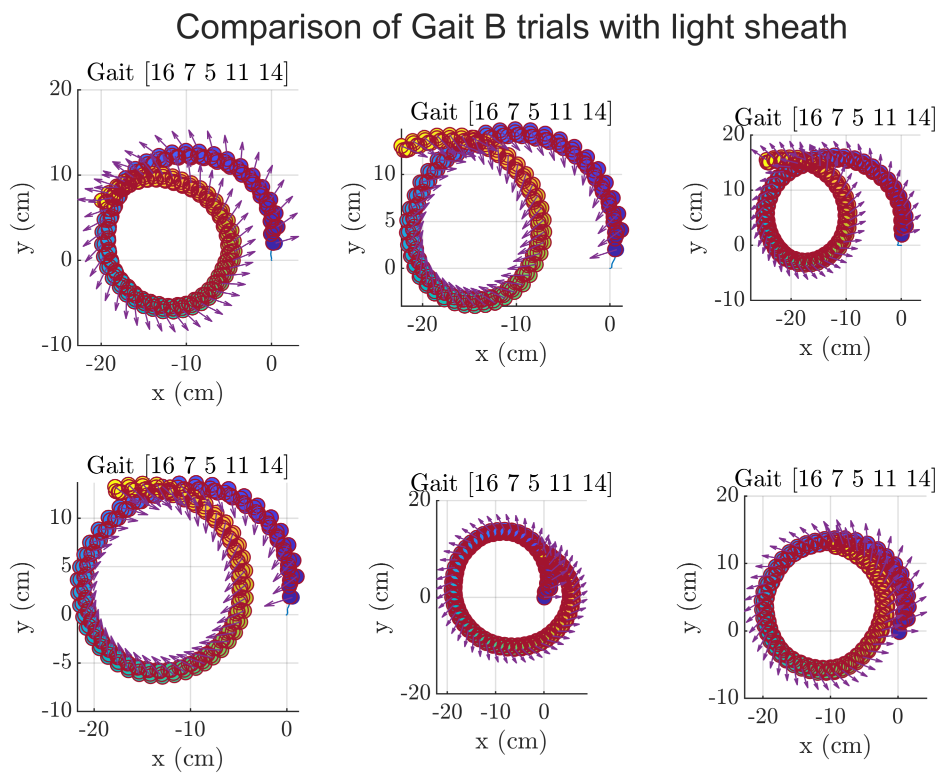



```
figure(11)
for i = [18,19,20,21,22,23,25]
all_gaits(i).plot;
end
```

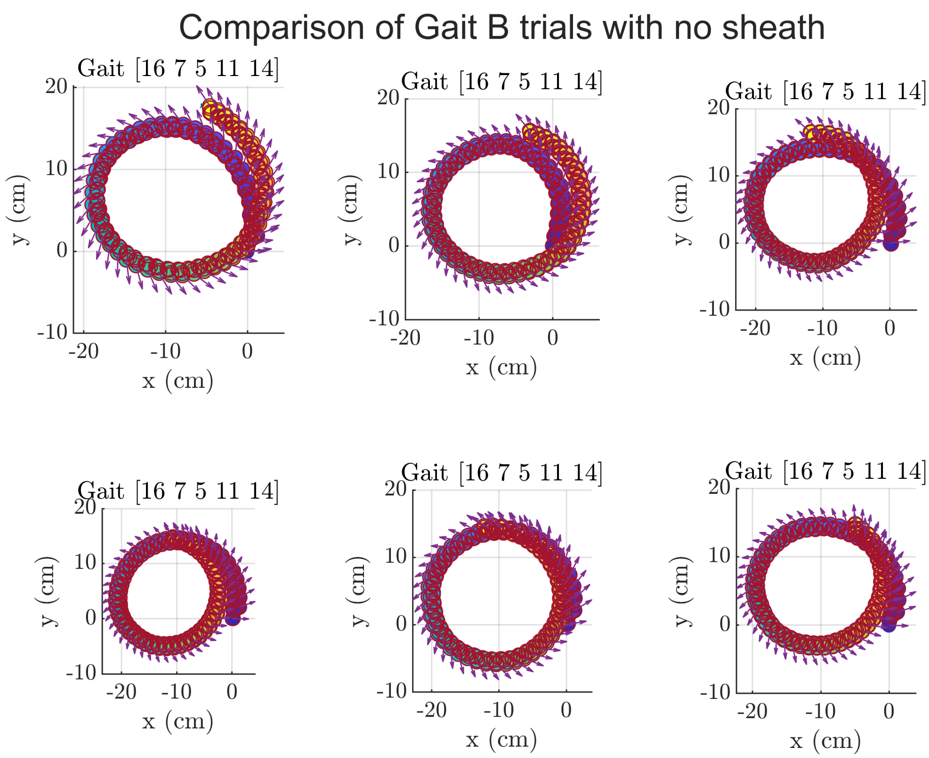
```
lgd = legend('Continuous robot position', 'Actual keyframe positions', ...
                  'Keyframe positions reconstructed from motion primitives','robot orientation
lgd.Orientation = 'horizontal';
lgd.Location = 'northoutside';

a = colorbar('southoutside');
a.Label.String = 'Number of gaits executed';
%E_60_NS_NF_L
title('Gait B no sheath')
```



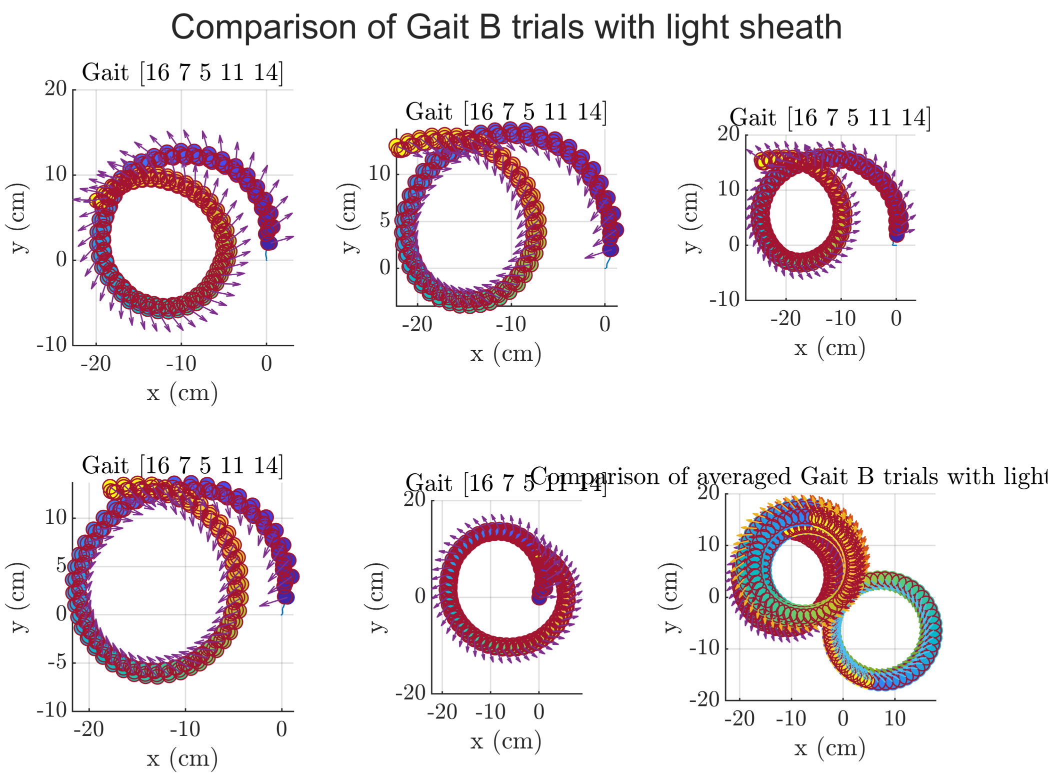

```
% Instantiate objects for gait B sheath.
figure
t1 = tiledlayout(2,3);
for i = [13,14,15,16,17,26]
    all_gaits(i) = offlineanalysis.GaitTest(stab_exp(i).raw_data, ...
                                            [16,7,5,11,14], ...
                                            stab_exp(i).params);
    nexttile;
    all_gaits(i).plot;
end
title(t1,'Comparison of Gait B trials with light sheath')
```



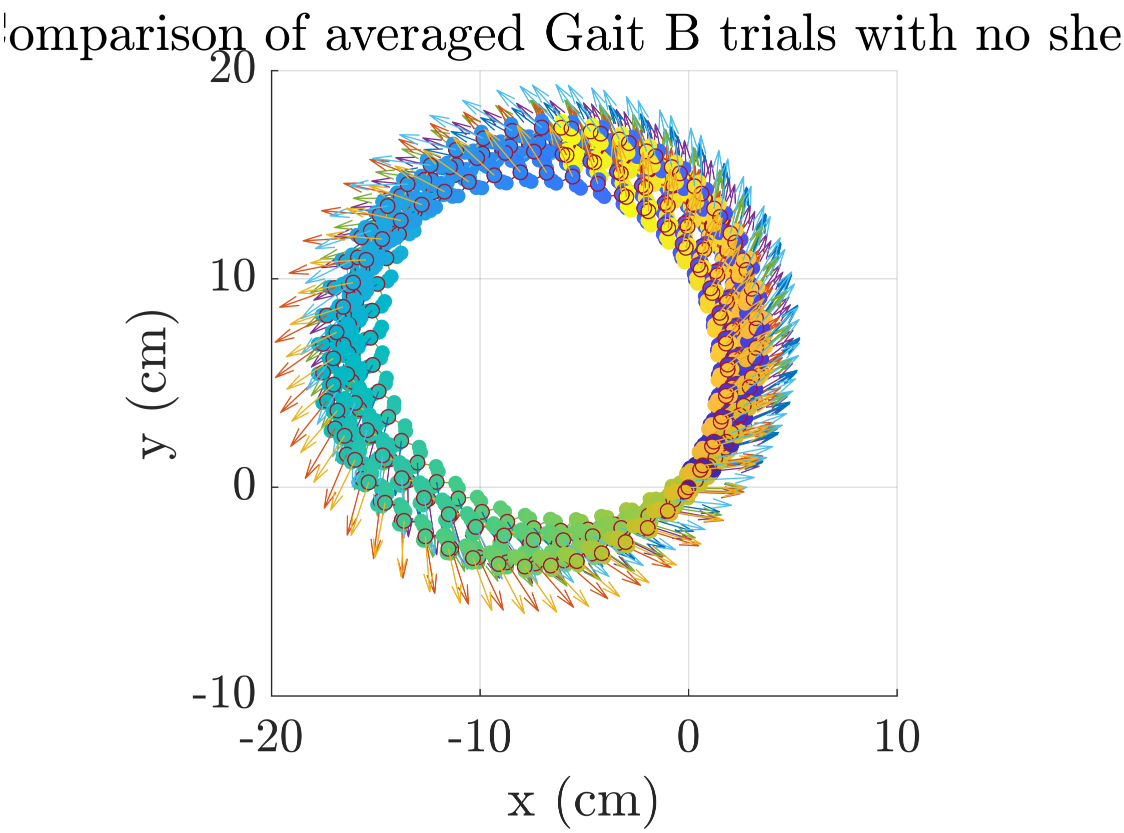

```
% Instantiate objects for gait B no sheath.
figure
t2 = tiledlayout(2,3);
for i = [18,19,20,21,22,25]
    all_gaits(i) = offlineanalysis.GaitTest(stab_exp(i).raw_data, ...
                                             [16,7,5,11,14], ...
                                             stab_exp(i).params);
    nexttile;
    all_gaits(i).plot;

end
title(t2,'Comparison of Gait B trials with no sheath')
```




```
figure(1)
hold on;
j = 1;
for i = [13,14,15,16,17,26]
    gait_library_S(j) = gaitdef.Gait(all_gaits(i), stab_exp(i).params);
    gait_library_S(j).gait_name = num2str(i);
    gait_library_S(j).plot(60)
    j = j+1;
end
title('Comparison of averaged Gait B trials with light sheath')
```




```
figure
hold on;
j =1;
for i = [18,19,20,21,22,25]
    gait_library_NS(j) = gaitdef.Gait(all_gaits(i), stab_exp(i).params);
    gait_library_NS(j).gait_name = num2str(i);

    gait_library_NS(j).plot(60)
    j = j+1;
end
title('Comparison of averaged Gait B trials with no sheath')
```




```
if show_markers
    figure
    tiledlayout(5,6)
    for i = 1:n_gaits

    pic_name = gait_names{i};
    pic_name(end-3:end) = [];
    % Plot first image of experiment video.
    file_name = ['data/visualtracking/firstframe_', pic_name, '.jpg'];
    pic = imread(file_name);
    nexttile;
    imshow(pic)
    hold on

    % Plot labeled (i.e., numbered) markers on top of image.
    markers_x(i, :) = stab_exp(i).raw_data(1, 1:3:stab_exp(i).params.n_markers*3-2);
    markers_y(i, :) = stab_exp(i).raw_data(1, 2:3:stab_exp(i).params.n_markers*3-1);
%     if iTrial ~=5
    for m = 1:stab_exp(i).params.n_markers
        text(markers_x(i, m), 1080-markers_y(i, m), num2str(m),'Color','white','FontSize',14);
%     end
    end

    % Adjust size.
     xlim([min(markers_x(i, :))-200, max(markers_x(i, :))+200]);
```

```
    ylim([min(1080 - markers_y(i, :)) - 200, max(1080 - markers_y(i, :))+200]);


end
end
```

```
function twists_plot = plot_twists(twists, global_theta, trial_nums, trial_labels, ylims)

    twists_plot = tiledlayout(3,2);
    ylabels = {'$v_x$ (cm/s)', '$v_y$ (cm/s)', '$\omega$ (deg/s)'};

    % Plot twist components vs number of gait cycles.
    for i = 1:3
        nexttile(2*i - 1);
        hold on;
        for j = 1:length(trial_nums)
            plot(twists{trial_nums(j)}(i,:))
        end
        ylabel(ylabels{i})
        if ~isempty(ylims)
            ylim(ylims(i,:))
        end
    end
    xlabel('Number of Gait Cycles')

    % Plot twist components vs global robot orientation.
    for i = 1:3
        nexttile(2*i);
        hold on;
        for j = 1:length(trial_nums)
            scatter(rad2deg(global_theta{trial_nums(j)}(1,:)),twists{trial_nums(j)}(i,:))
        end
        xlim([-180 180])
        ylabel(ylabels{i})
        if ~isempty(ylims)
            ylim(ylims(3+i,:))
        end
    end
    xlabel('Global robot orientation $\theta_G$ (deg)')

    if length(trial_labels) > 1
        lgd = legend(trial_labels);
        lgd.Orientation = 'horizontal';
        lgd.Layout.Tile = 'north';
    else
        plot_title = ['Twist (body velocity) for', trial_labels];
        title(twists_plot,plot_title, 'FontSize',22)
    end
```

```
end
```