Robotic Identification of Kinesthetic deficits after stroke - Semrau et al., 2013

Created June 1, 2021

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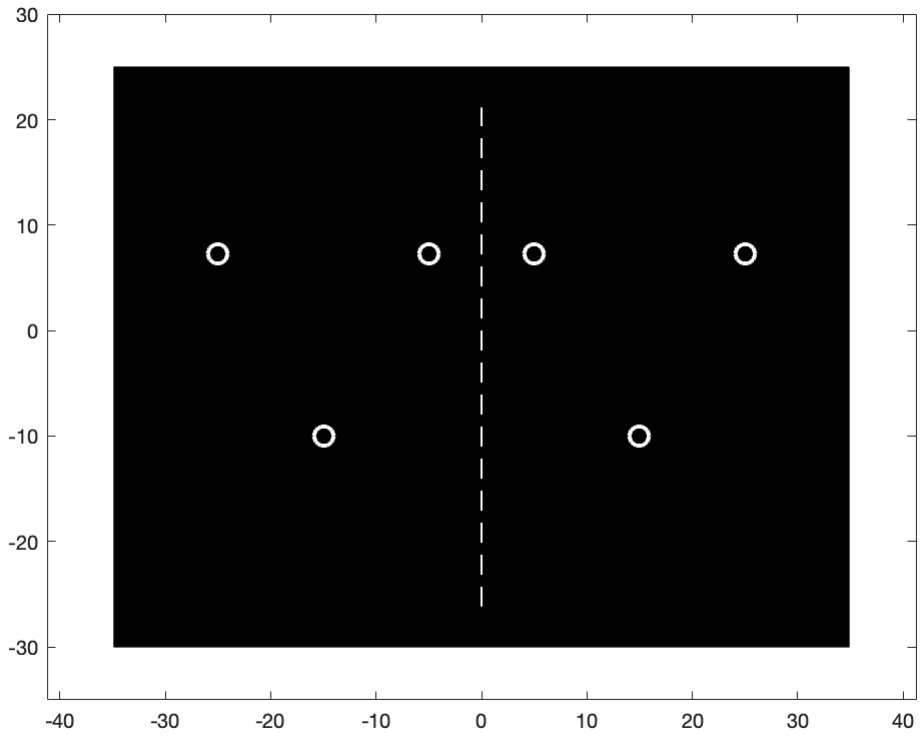
```
clear; clc;
cd('/Users/duncan/OneDrive - University of Delaware - o365/Documents
```

Targets

```
% trig
home = [-10,-10];
dists = 20;
theta = acosd((dists^2 + dists^2 - dists^2) / (2 * dists * dists));
left = [dists * cosd(120) + home(1), dists * sind(120) + home(2)];
right = [dists * cosd(60) + home(1), dists * sind(120) + home(2)];

% combine
ATBA_targs = [home; left; right];
% displace
ATBA_targs(:,1) = ATBA_targs(:,1) - 5;
% mirror
nATBA_targs = [-ATBA_targs(:,1), ATBA_targs(:,2)];

% visual confirmation
figure();
plot(ATBA_targs(:,1), ATBA_targs(:,2), 'o', 'markersize', 10, 'color
hold on
plot(nATBA_targs(:,1), nATBA_targs(:,2), 'o', 'markersize', 10, 'col
axis equal
axis padded
vline(0, 'w', '--', 1);
kBackground(gca);
```




```
rotation_matrix = [nan, 120, 60; 300, nan, 0; 240, 180, nan];
```

Movements

```
robot_peak = 0.28;
duration = round(s_to_ms(dur_calc_KINARM(ATBA_targs(1,:), ATBA_targs
time = 1:1:duration;
[reachX, reachY] = T1reachT2(ATBA_targs(1,:), ATBA_targs(2,:), durat
robot_vel = reachXY2vel(reachX, reachY, time);
```

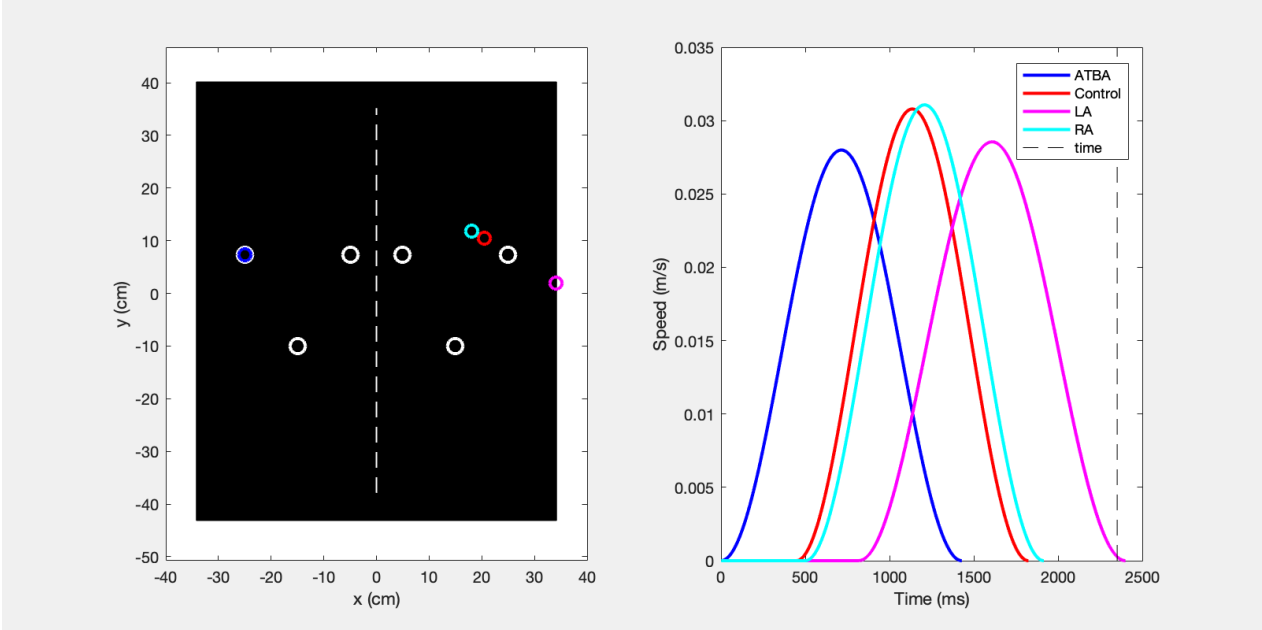
Simulate 1 trial

```
% Set up reaches (spatially and temporally)

% Parameters
% RL
RL_C = 893 / 2;
RL_LA = 817;
RL_RA = 500;
% PSR
PSR_C = (0.8 + 1.4) / 2;
PSR_LA = 1.02;
```

```
PSR_RA = 1.11;
% IDE
IDE_C = 14.8;
IDE_LA = 28;
IDE_RA = 22.1;
% PLR
PLR_C = 1.06;
PLR_LA = 1.13;
PLR_RA = 1.10;

% robot
[robX, robY, time] = reach_wKIN(ATBA_targs(1,:), ATBA_targs(2,:), ro
robot_vel = reachXY2vel(robX, robY, time);

% control
[controlX, controlY, time] = reach_wKIN(ATBA_targs(1,:), ATBA_targs(
control_vel = reachXY2vel(controlX, controlY, time);

% LA
[LAX, LAY, time] = reach_wKIN(ATBA_targs(1,:), ATBA_targs(2,:), robo
LA_vel = reachXY2vel(LAX, LAY, time);

% RA
[RAX, RAY, time] = reach_wKIN(ATBA_targs(1,:), ATBA_targs(2,:), robo
RA_vel = reachXY2vel(RAX, RAY, time);

% Set up plotting
robot_color = 'b';
control_color = 'r';
LA_color = 'm';
RA_color = 'c';

% visualize
figure("Position",[300, 300 800 400], 'visible', 'on');

% control
subplot(1,2,1); % position
plot(ATBA_targs(:,1), ATBA_targs(:,2), 'o', 'markersize', 10, 'color
hold on
plot(nATBA_targs(:,1), nATBA_targs(:,2), 'o', 'markersize', 10, 'col
plot(nan, nan, 'bo', 'linewidth', 2, 'markersize', 8); % ATBA hand
```

```
% nATBA hand
plot(nan, nan, 'o', 'LineWidth', 2, 'markersize', 8, 'color', contro
plot(nan, nan, 'o', 'LineWidth', 2, 'markersize', 8, 'color', LA_col
plot(nan, nan, 'o', 'LineWidth', 2, 'markersize', 8, 'color', RA_col
axis equal
axis padded
vline(0, 'w', '--', 1);
kBackground(gca);
xlabel('x (cm)'); ylabel('y (cm)');
posG_C = gca();

subplot(1,2,2); % velocity
plot(1:length(robot_vel), robot_vel, 'b-', 'linewidth', 2, 'displayn
hold on
% nATBA velocity
plot(1:length(control_vel), control_vel, '-', 'linewidth', 2, 'color
plot(1:length(LA_vel), LA_vel, '-', 'linewidth', 2, 'color', LA_colo
plot(1:length(RA_vel), RA_vel, '-', 'linewidth', 2, 'color', RA_colo
plot([nan nan], [nan nan], 'k--', 'displayname', 'time'); % time lin
xlabel('Time (ms)'); ylabel('Speed (m/s)')
legend('location', 'best')
velG_C = gca();

max_time = max([length(robot_vel), length(control_vel), length(LA_ve
% visualize
for i = 1:50:max_time

    subplot(1,2,1);
    % ATBA hand (5)
    if i <= length(robX)
        set(posG_C.Children(5), 'XData', robX(i));
        set(posG_C.Children(5), 'YData', robY(i));
    end
    % nATBA hand
    % control (4)
    if i <= length(controlX)
        set(posG_C.Children(4), 'XData', -controlX(i));
        set(posG_C.Children(4), 'YData', controlY(i));
    end
    % LA (3)
    if i <= length(LAX)
```

```
        set(posG_C.Children(3), 'XData', -LAX(i));
        set(posG_C.Children(3), 'YData', LAY(i));
    end
    % RA (2)
    if i <= length(RAX)
        set(posG_C.Children(2), 'XData', -RAX(i));
        set(posG_C.Children(2), 'YData', RAY(i));
    end

    % time slider
    subplot(1,2,2);
    set(velG_C.Children(1), 'XData', [i, i]);
    set(velG_C.Children(1), 'YData', velG_C.YLim);

    pause(ms_to_s(1));
end
```



Simulate multiple trials

```
% Set up
schedule = [1 2 3 2 1];
robotXTotal = [];
robotYTotal = [];
robotVelTotal = [];
controlXTotal = [];
controlYTotal = [];
```

```
controlVelTotal = [];
LAXTotal = [];
LAYTotal = [];
LAVelTotal = [];
RAXTotal = [];
RAYTotal = [];
RAVelTotal = [];

for i = 1:length(schedule)-1

    % where from , where to
    start_targ_idx = schedule(i);
    end_targ_idx = schedule(i+1);

    % robot
    [robX, robY, time] = reach_wKIN(ATBA_targs(start_targ_idx,:), AT
    rob_vel = reachXY2vel(robX, robY, time);

    % control
    [controlX, controlY, time] = reach_wKIN(ATBA_targs(start_targ_id
        rotation_matrix, [start_targ_idx end_targ_idx]);
    control_vel = reachXY2vel(controlX, controlY, time);

    % LA
    [LAX, LAY, time] = reach_wKIN(ATBA_targs(start_targ_idx,:), ATBA
        rotation_matrix, [start_targ_idx end_targ_idx]);
    LA_vel = reachXY2vel(LAX, LAY, time);

    % RA
    [RAX, RAY, time] = reach_wKIN(ATBA_targs(start_targ_idx,:), ATBA
        rotation_matrix, [start_targ_idx end_targ_idx]);
    RA_vel = reachXY2vel(RAX, RAY, time);

    % robot bring back to position
    % robot
    robHomeX = ones([1 750]) * robX(end);
    robHomeY = ones([1 750]) * robY(end);
    robHomeVel = zeros([1 750]);
    % control
    [controlHomeX, controlHomeY] = T1reachT2([controlX(end), control
    controlHomeVel = reachXY2vel(controlHomeX, controlHomeY, 1:1:750
```

```
    % LA
    [LAHomeX, LAHomeY] = T1reachT2([LAX(end), LAY(end)], ATBA_targs(
    LAHomeVel = reachXY2vel(LAHomeX, LAHomeY, 1:1:750);
    % RA
    [RAHomeX, RAHomeY] = T1reachT2([RAX(end), RAY(end)], ATBA_targs(
    RAHomeVel = reachXY2vel(RAHomeX, RAHomeY, 1:1:750);

    % append
    robotXTotal = [robotXTotal, robX, robHomeX];
    robotYTotal = [robotYTotal, robY, robHomeY];
    robotVelTotal = [robotVelTotal, rob_vel, robHomeVel];
    controlXTotal = [controlXTotal, controlX, controlHomeX];
    controlYTotal = [controlYTotal, controlY, controlHomeY];
    controlVelTotal = [controlVelTotal, control_vel, controlHomeVel]
    LAXTotal = [LAXTotal, LAX, LAHomeX];
    LAYTotal = [LAYTotal, LAY, LAHomeY];
    LAVelTotal = [LAVelTotal, LA_vel, LAHomeVel];
    RAXTotal = [RAXTotal, RAX, RAHomeX];
    RAYTotal = [RAYTotal, RAY, RAHomeY];
    RAVelTotal = [RAVelTotal, RA_vel, RAHomeVel];

    fprintf('iteration %d \n', i)

end
```

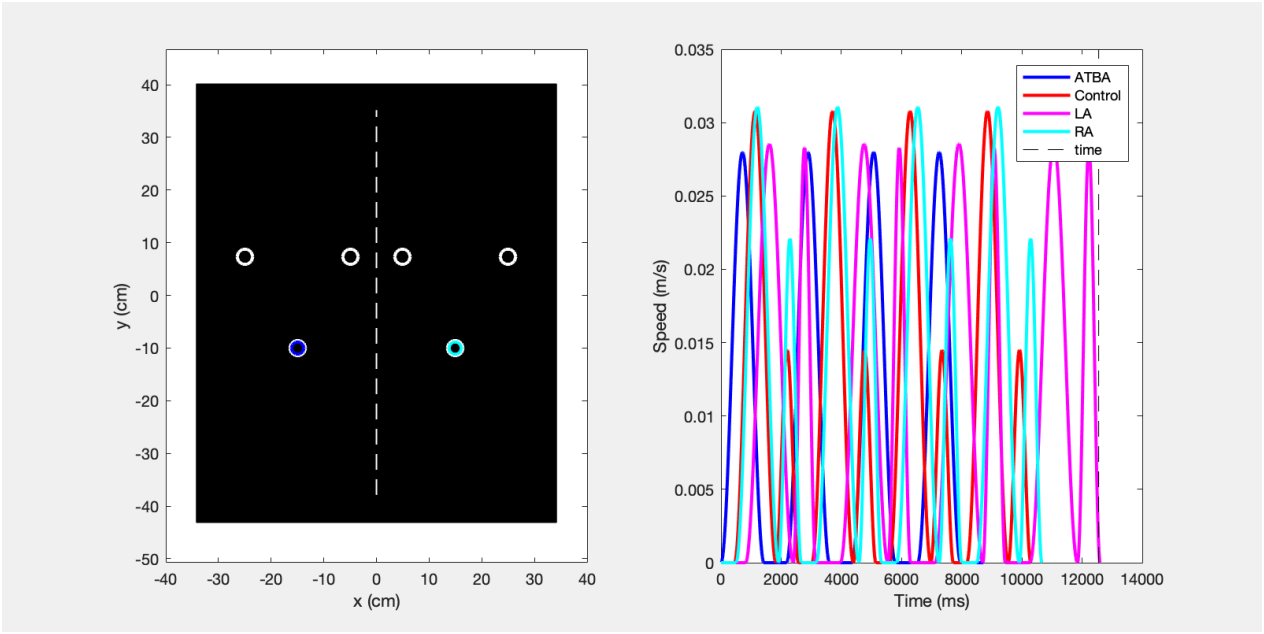
```
iteration 1
iteration 2
iteration 3
iteration 4
```

Visualize multiple trials

```
% visualize
figure("Position",[300, 300 800 400], 'visible', 'on');

% control
subplot(1,2,1); % position
plot(ATBA_targs(:,1), ATBA_targs(:,2), 'o', 'markersize', 10, 'color
hold on
plot(nATBA_targs(:,1), nATBA_targs(:,2), 'o', 'markersize', 10, 'col
plot(nan, nan, 'bo', 'linewidth', 2, 'markersize', 8); % ATBA hand
% nATBA hand
```

```
plot(nan, nan, 'o', 'LineWidth', 2, 'markersize', 8, 'color', contro
plot(nan, nan, 'o', 'LineWidth', 2, 'markersize', 8, 'color', LA_col
plot(nan, nan, 'o', 'LineWidth', 2, 'markersize', 8, 'color', RA_col
axis equal
axis padded
vline(0, 'w', '--', 1);
kBackground(gca);
xlabel('x (cm)'); ylabel('y (cm)');
posG_C = gca();

subplot(1,2,2); % velocity
plot(1:length(robotVelTotal), robotVelTotal, 'b-', 'linewidth', 2, '
hold on
% nATBA velocity
plot(1:length(controlVelTotal), controlVelTotal, '-', 'linewidth', 2
plot(1:length(LAVelTotal), LAVelTotal, '-', 'linewidth', 2, 'color',
plot(1:length(RAVelTotal), RAVelTotal, '-', 'linewidth', 2, 'color',
plot([nan nan], [nan nan], 'k--', 'displayname', 'time'); % time lin
xlabel('Time (ms)'); ylabel('Speed (m/s)')
legend('location', 'best')
velG_C = gca();

max_time = max([length(robotVelTotal), length(controlVelTotal), leng
% visualize
for i = 1:50:max_time

    subplot(1,2,1);
    % ATBA hand (5)
    if i <= length(robotXTotal)
        set(posG_C.Children(5), 'XData', robotXTotal(i));
        set(posG_C.Children(5), 'YData', robotYTotal(i));
    end
    % nATBA hand
    % control (4)
    if i <= length(controlXTotal)
        set(posG_C.Children(4), 'XData', -controlXTotal(i));
        set(posG_C.Children(4), 'YData', controlYTotal(i));
    end
    % LA (3)
    if i <= length(LAXTotal)
        set(posG_C.Children(3), 'XData', -LAXTotal(i));
```

```
        set(posG_C.Children(3), 'YData', LAYTotal(i));
    end
    % RA (2)
    if i <= length(RAXTotal)
        set(posG_C.Children(2), 'XData', -RAXTotal(i));
        set(posG_C.Children(2), 'YData', RAYTotal(i));
    end

    % time slider
    subplot(1,2,2);
    set(velG_C.Children(1), 'XData', [i, i]);
    set(velG_C.Children(1), 'YData', velG_C.YLim);

    pause(ms_to_s(1));
end
```



Multiple trials, one at a time

```
schedule = [1 2 1 3 1 3 2 3 2];
% Set up reaches (spatially and temporally)

% Parameters
% RL
RL_C = 893 / 2;
RL_LA = 817;
RL_RA = 500;
```

```
% PSR
PSR_C = (0.8 + 1.4) / 2;
PSR_LA = 1.02;
PSR_RA = 1.11;
% IDE
IDE_C = 14.8;
IDE_LA = 28;
IDE_RA = 22.1;
% PLR
PLR_C = 1.06;
PLR_LA = 1.13;
PLR_RA = 1.10;

for i = 1:length(schedule)-1

    filename = sprintf('T%d_T%d_ex.gif', schedule(i), schedule(i+1))

    % robot
    [robX, robY, time] = reach_wKIN(ATBA_targs(schedule(i),:), ATBA_
    robot_vel = reachXY2vel(robX, robY, time);

    % control
    [controlX, controlY, time] = reach_wKIN(ATBA_targs(schedule(i),:
        rotation_matrix, [schedule(i) schedule(i+1)]);
    control_vel = reachXY2vel(controlX, controlY, time);

    % LA
    [LAX, LAY, time] = reach_wKIN(ATBA_targs(schedule(i),:), ATBA_ta
        rotation_matrix, [schedule(i) schedule(i+1)]);
    LA_vel = reachXY2vel(LAX, LAY, time);

    % RA
    [RAX, RAY, time] = reach_wKIN(ATBA_targs(schedule(i),:), ATBA_ta
        rotation_matrix, [schedule(i) schedule(i+1)]);
    RA_vel = reachXY2vel(RAX, RAY, time);

    % Set up plotting
    robot_color = 'b';
    control_color = 'r';
    LA_color = 'm';
    RA_color = 'c';
```

```
% visualize
figure("Position",[300, 300 800 400], 'visible', 'on');

% control
subplot(1,2,1); % position
plot(ATBA_targs(:,1), ATBA_targs(:,2), 'o', 'markersize', 10, 'c
hold on
plot(nATBA_targs(:,1), nATBA_targs(:,2), 'o', 'markersize', 10,
plot(nan, nan, 'bo', 'linewidth', 2, 'markersize', 8); % ATBA ha
% nATBA hand
plot(nan, nan, 'o', 'LineWidth', 2, 'markersize', 8, 'color', co
plot(nan, nan, 'o', 'LineWidth', 2, 'markersize', 8, 'color', LA
plot(nan, nan, 'o', 'LineWidth', 2, 'markersize', 8, 'color', RA
axis equal
axis padded
vline(0, 'w', '--', 1);
kBackground(gca);
xlabel('x (cm)'); ylabel('y (cm)');
posG_C = gca();

subplot(1,2,2); % velocity
plot(1:length(robot_vel), robot_vel, 'b-', 'linewidth', 2, 'disp
hold on
% nATBA velocity
plot(1:length(control_vel), control_vel, '-', 'linewidth', 2, 'c
plot(1:length(LA_vel), LA_vel, '-', 'linewidth', 2, 'color', LA_
plot(1:length(RA_vel), RA_vel, '-', 'linewidth', 2, 'color', RA_
plot([nan nan], [nan nan], 'k--', 'displayname', 'time'); % time
xlabel('Time (ms)'); ylabel('Speed (m/s)')
legend('location', 'best')
velG_C = gca();

max_time = max([length(robot_vel), length(control_vel), length(L
% visualize
for i = 1:50:max_time

    subplot(1,2,1);
    % ATBA hand (5)
    if i <= length(robX)
        set(posG_C.Children(5), 'XData', robX(i));
```

```
            set(posG_C.Children(5), 'YData', robY(i));
        end
        % nATBA hand
        % control (4)
        if i <= length(controlX)
            set(posG_C.Children(4), 'XData', -controlX(i));
            set(posG_C.Children(4), 'YData', controlY(i));
        end
        % LA (3)
        if i <= length(LAX)
            set(posG_C.Children(3), 'XData', -LAX(i));
            set(posG_C.Children(3), 'YData', LAY(i));
        end
        % RA (2)
        if i <= length(RAX)
            set(posG_C.Children(2), 'XData', -RAX(i));
            set(posG_C.Children(2), 'YData', RAY(i));
        end

        % time slider
        subplot(1,2,2);
        set(velG_C.Children(1), 'XData', [i, i]);
        set(velG_C.Children(1), 'YData', velG_C.YLim);

        writeGif(filename, i, 0.001)

%         pause(ms_to_s(1));
    end
    close(gcf);
end
```

```
function hand_vel = reachXY2vel(reachX, reachY, time)
XVel = derivative(reachX) ./ derivative(time);
YVel = derivative(reachY) ./ derivative(time);
hand_vel = sqrt(XVel.^2 + YVel.^2);
end
```