University College Dublin
SCHOOL OF ELECTRICAL, ELECTRONIC & COMMUNICATION ENG.

EEEN 40350: Rehabilitation Engineering

Fourth year Biomedical engineering – 2019/2020

Assignment 2
creativity in engineering applied to rehabilitation

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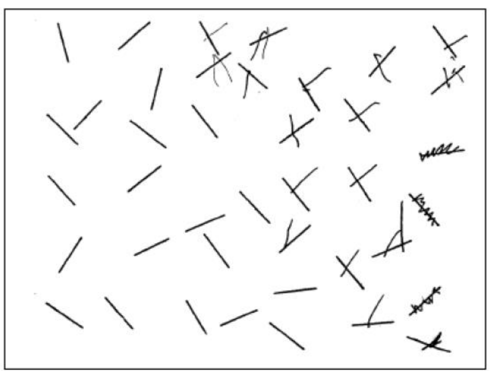
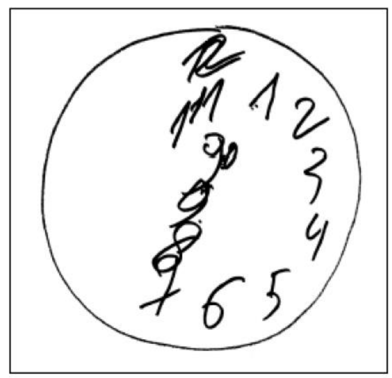
Questions

Part 1

Hemispatial neglect is a symptom often observed in Traumatic Brain Injuries and, sometimes, stroke. It consists in a deficit in attention and awareness in one side of the field of vision. The person can see in that side of the space but has problem "noticing" it. Neglect is most closely related to damage to the temporo-parietal junction and posterior parietal cortex. Design a technology that can help to put in numbers the severity of spatial neglect. Your technology should help deliver a test for neglect that will put the severity of the problem in numbers. Specifically, we are interested in understanding which % of the left visual field is neglected. You can get inspiration from literature, proposing improvements to systems that have been presented in papers.





Part 2

Max is a graphical artist, he prepares his works using software through different interfaces (e.g. mouse, trackpad, tablet). He has been recently diagnosed with Parkinson's disease and has significant postural (static) and kinetic (dynamic) tremor in the hands. The severity of this symptom greatly impairs his ability to carry out his job. Come up with a solution (hardware or software) to limit the impact that tremor has on his work. Provide a brief explanation of the solution you propose (e.g. a design if it is hardware).

Answer – Part 1

Literature review

Hemispatial neglect is one of the very common syndromes post stroke where the patient is unaware and fails to acknowledge the different visual and/or auditory stimuli located in the contralateral side to the brain lesion. These patients have intact sense i.e. their vision is the exact same for both eyes but fail to "recognise" and "process" inputs from the contralateral side of the lesion. [1]

hemispatial neglect is associated with lesions in the right inferior frontal gyrus, precentral gyrus, postcentral gyrus, superior temporal gyrus, middle temporal gyrus, middle occipital gyrus, insula, and surrounding white matter. [2]

Left hemispatial neglect (due to lesions in the right side of the brain) is much more frequent than right hemispacial neglect (due to lesions in the right side of the brain) which is why hemispatial neglect is commonly associated with the left visual field. [4]

Patients with hemispatial neglect fail to "recognise" not just objects on contralateral side to the brain lesion, but also people and their own limbs and face on that side. [3]

Different tests and diagnostic parameters have been used to diagnose patients with hemispatial neglect which is the reason why there's huge variability in the reporting incidences of hemispatial neglect for patients post stroke. [5]

Some of the different diagnostic tests are listed below:

1- **Albert's Test:** In this test, the patient is asked to cross out lines that are placed in random orientations on a piece of paper. Patients fail Albert's test if they do not cross lines in one side of the visual field as shown in figure 1. [6]

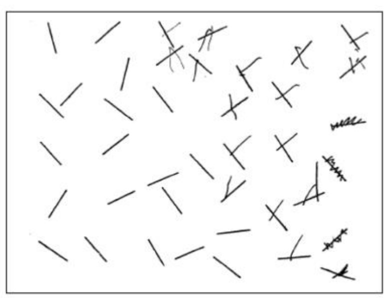


Figure 1 Typical Albert Test Result For Patient WIth Hemispatial Neglect

2- Line bisection test: In this test the patient is asked to bisect several horizontal lines. Patients fail this test if they do not bisect the lines at around their centre point as shown in figure 2. [7]

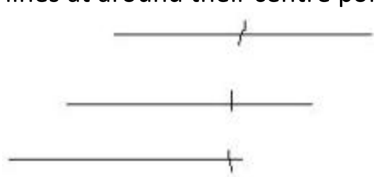


Figure 2 Typical Failed Line Bisection Test Results

3- **Clock test:** In this test, the patient is asked to draw the numbers around a circle representing an analogue watch, starting from number 12. Patients fail the clock test if they don't draw a typical clock as shown in figure 3. [4]

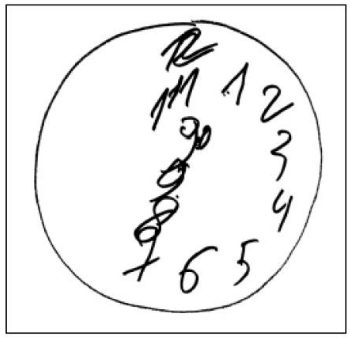


Figure 3 Typical Failed Clock Test Result

4- **Bell test: In this test:** The patient is asked to cross out the bells that are scattered among several different shapes on a sheet of paper. Patients with hemispatial neglect fail to do so as shown in figure 4. [8]

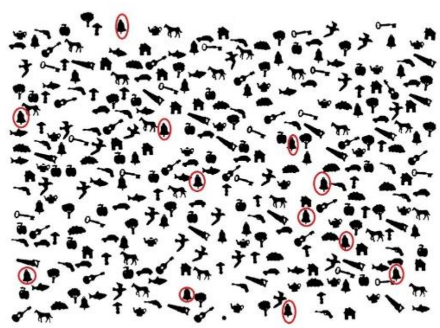


Figure 4 Typical failed bell test results

Needs Statement

For this assignment, we are asked to develop a technology that can help to put in numbers the severity of spatial neglect. This technology should help deliver a test for neglect that will put the severity of the problem in numbers. Specifically, it should be able to determine which % of the left visual field is neglected.

Suggested Solution

I got inspired through reading the article published by The Guardian on the 23 of November 2012, under the title "The man whose brain ignores one half of his world" (https://www.theguardian.com/science/blog/2012/nov/23/man-brain-ignores-half-world) where Dr

Paresh Malhotra confirmed hemispatial neglect in patients if they failed to see his finger which is located in the left visual field of the patient.

The technology I developed is Matlab based that would determine which areas of the visual field the person fails to “recognise” and what is their total percentage.

The Matlab based experiment relies on having the subject sitting in a room and showing him a projector screen (or a PC screen) such that the screen is within the subject’s 60 degrees symbol recognition field as shown in figure 5 [9], thus we will guarantee that whatever is being shown to the subject is actually within his/her visual field i.e. his eyes are able to see it.

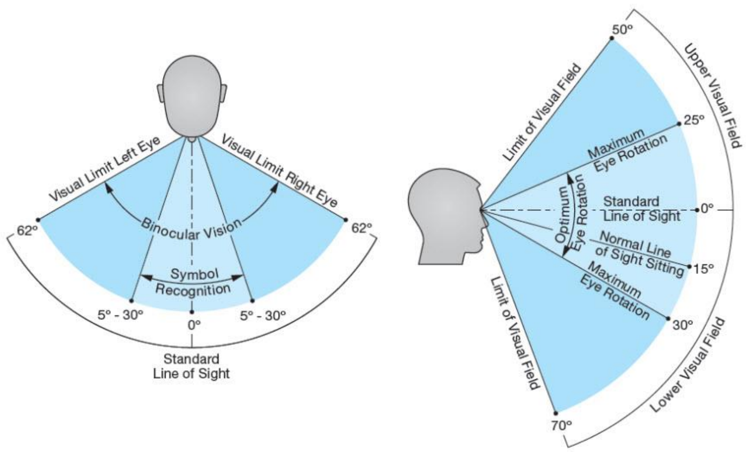


Figure 5 Symbol Recognition Visual Field

The experiment relies on segmenting the visual field into tiny squares (whose side length can be determined by the person running the experiment; the smaller the side length the more accurate the results are but the longer the experiment is going to be). In each trial only one of these squares is dark whereas the others are white. The subject is asked after each trial if he sees the black square. The software keeps track of the different squares that are unseen by the patient. At the end of the experiment, the whole “unrecognized” visual field is marked in black and its percentage is calculated. Thus, giving a quantitative measure and a precise diagnostic of the disease.

In the following section, we will discuss, stepwise, exactly how this experiment is carried out exactly.

(Kindly run the code attached with this report to carry out this experiment on yourself!)

1- Determine the dimensions of the used screen (in number of pixels). (my own screen, on which this experiment was tested has dimensions of 1701x960 pixels)

2- Define the side length of the squares into which the screen is going to be segmented. By default, it is set to 150 (pixels)

3- Determine the number of rows (rows) and columns (columns) into which the visual field is going to be segmented. The number of rows and columns is defined as the largest integer multiple of the squares side lengths that is less than or equal to the dimensions of the screen used.

4- Create a (rows)x(column) matrix representing the different squares in the visual field. Each cell in this matrix will have a random value between 1 and (r)x(c), such that each number is unique. These numbers will represent the order in which the black squares are shown to the subject.

5- Carry out (rows)x(column) different trials, in each there is only one square that is black, and the rest are white. The subject is asked (using a pop up dialog box) after each trial if he was able to see the single black box in the screen or not.

Figure 6 shows a typical trial of a test experiment that I ran on my computer

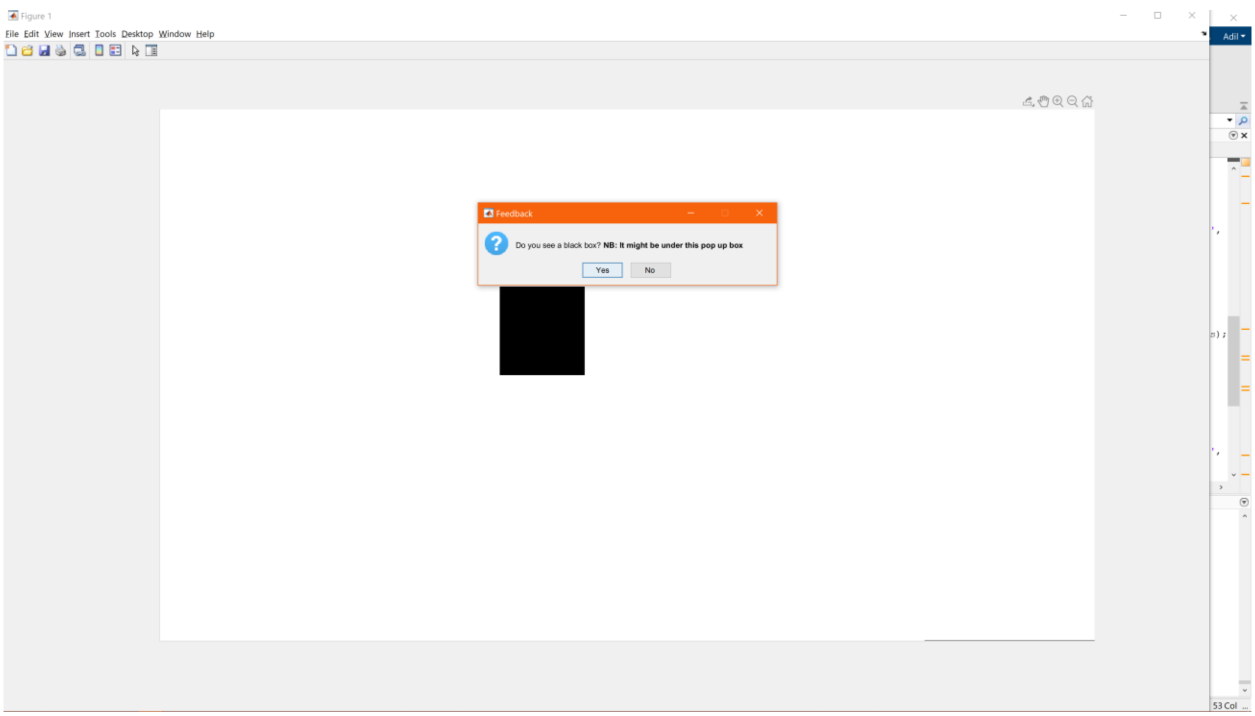


Figure 6 Typical Experiment Trial

1- Figure 6 is a screenshot of my whole screen. Note how the figure is actually slightly smaller than my screen, this is because I set the dimensions of the figure to be the largest integer multiple of the squares side lengths that is less than or equal to the dimensions of the screen used.
Ideally, the pop-up message would show above or underneath the figure. I tried doing that but I didn't manage to do so. To go around that problem, the pop up message is shown 0.5s after showing the figure and there's a notice message alerting the subject that the black box might be under the dialog box.

2- At the end of the experiment, the visual field that the subject wasn't able to see is shown along with the calculated percentage it represents off the whole visual field and the tolerance in this result. The tolerance is calculated as the percentage of the area of a single square over the whole visual field area.

Figure 7 shows a typical trial of a test experiment that I ran on my computer

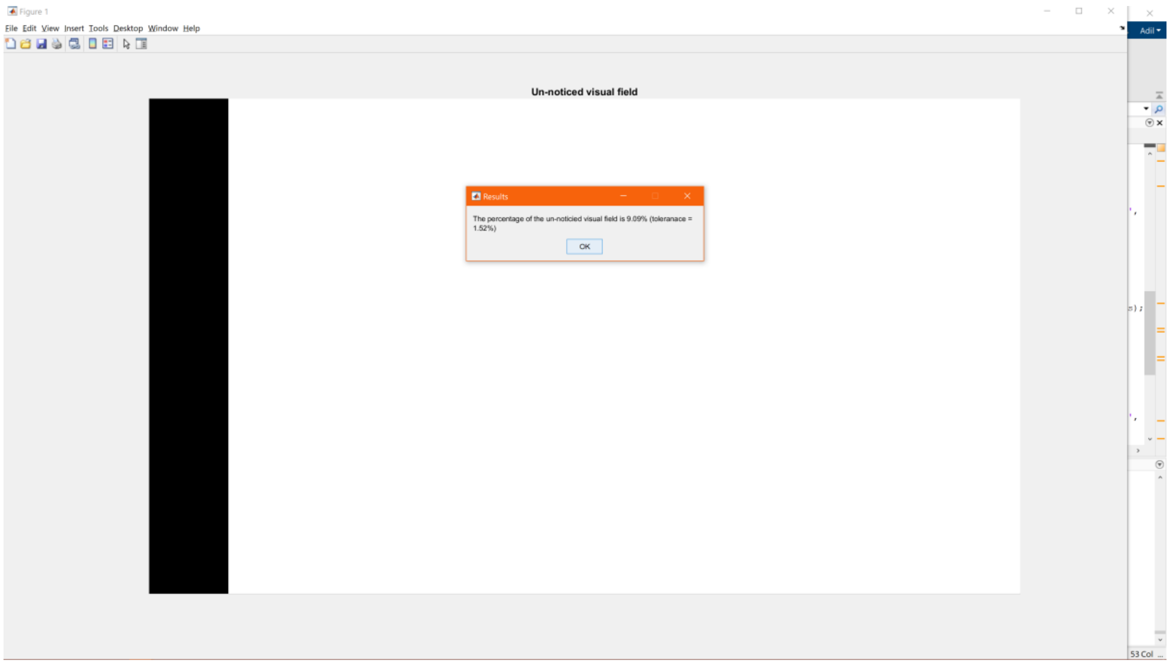


Figure 7 Typical Experiment Trial

Kindly find attached in the appendix the code for this experiment.

Answer – Part 2

Literature review

Parkinson's disease (PD) is a neurodegenerative disorder caused by the death of dopaminergic cell death in the substantia nigra pars compacta (SNpc), which leads to the decreased striatal inhibition to the cortico-basal-ganglia network that is hypothesized to cause the motor symptoms associated with PD [10].

There are four cardinal motor symptoms associated with PD: tremor, rigidity, bradykinesia, and postural instability (or freezing of gait). Typically, Parkinsonian tremor is a type of rest tremor that occurs when the affected limb is at rest (at frequencies from 2-7 Hz [11]). PD patients may also exhibit postural tremor arising when one is trying to maintain limb posture in a certain position (as when reaching out to shake someone's hand) and also kinetic tremor being present when performing a visually guided movement (such as eating or writing) to varying degrees. Rigidity and bradykinesia describe slowness of movement and difficulty performing repetitive movements. Postural instability and freezing of gait is often more difficult to characterize as symptomatic episodes are generally more intermittent and context-dependent (walking indoors or outdoors).Neurologists assess PD symptom severity using the United Parkinson's Disease Rating Scale (UPDRS) [12]

Needs Statement

For this assignment, we are asked to develop a solution to limit the impact that tremor has on Max who is a graphical artist diagnosed with Parkinson's disease.

Suggested Solution

Since Max uses softwares that run on electronic devices, the solution I came up with is a software solution rather than a mechanical hardware one. Since tremor is Parkinson's disease patients is in the range between 2 and 7 Hz [11], I decided to develop a solution that relies on low pass filtering the coordinates of the mouse cursor such that the hand tremor is cancelled out.

In developing this solution, I was inspired by the famous "Liftware" spoon/fork, shown in figure 8, developed in 2014 for patients with Parkinson's disease. This product relied on having two actuators that cancel out oscillations of frequencies above 2Hz, using what's called "Active Cancellation of Tremor". [13] Instead of developing a hardware version, since Max is using electronic software's I decided to develop an equivalent software model.

Figure 8 "Liftware" spoon

My solution is very simple, all it relies on is low pass filtering the cursor coordinates by a 4th order Butterworth filter of cut off frequency equal to 2Hz.

I tested this idea in Matlab. To do so, I had to define a timer using `timer` function, which collected the cursor x and y coordinates 3000 times, every 0.001s using `get(0,'PointerLocation')` function. I was the subject moving the mouse and I tried as much as possible to create Parkinson like tremor in my hand. After collecting the data, I low pass filtered the x and y coordinates separately as described above. Finally, I plotted the cursor trace using the original unfiltered coordinates and using the low pass filtered coordinates getting the two traces shown in figure 9.

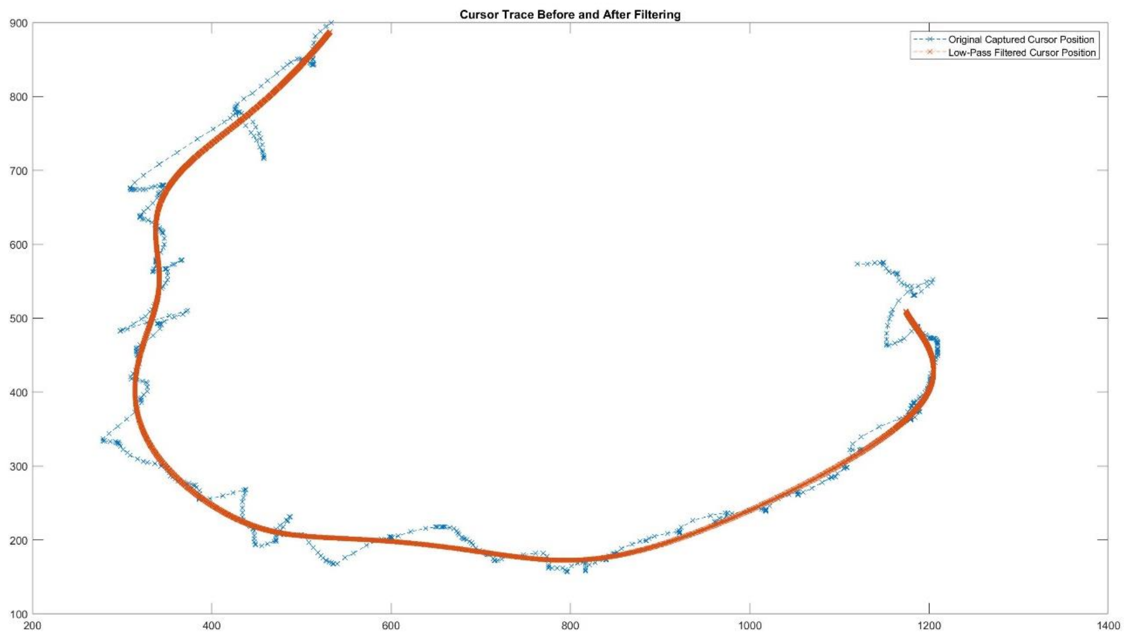


Figure 9 Cursor Trace Before and After Filtering

We can see that the developed algorithm performs quit well as we were able to get rid of all the tremor like oscillations. Thus, hopefully Max will be able to carry out his job perfectly.

Kindly refer to the code attached in the appendix or run the associated .m file

Appendix

Code for answer 1

```
% Store the dimensions of the screen in vector dim
dim=get(0, 'Screensize')

% Define the side length of the squares in the visual field to consider (in pixesl)
square_side=150;

% Determine the largest dimensions smaller than or equal to dim, that are
% divisable by square_side
dim=(square_side*floor(dim/square_side))

% Divide the visual field into rows and columns
% Determine the number of rows in the visual field to consider
rows=dim(4)/square_side;

% Determine the number of columns in the visual field to consider
columns=dim(3)/square_side;

% Define the number of squares in the visual field to consider
squares_num=rows*columns;

% Create a matrix that will represent the visual field of dimensions
% equal to (rows x columns) where each element of it has a number
% between 0 and (rows x columns - 1)
% The visual field cells will be examined
% incrementally based on the number stored in them
visual_field=reshape(randperm(squares_num, squares_num), rows, columns)-1;

% Create a vector to hold the values of the cells in
% the visual_field matrix that are unseen by the subject
unknown=[];                 %(unknow is initially empty)

% Create a figure of dimensions equal to dim
figure
set(gcf, 'Position', dim);
xlim([0 dim(3)]);
ylim([0 dim(4)]);
set(gca,'XTick',[], 'YTick', [])

% Loop through the different squares inside the visual field
for i=0:squares_num-1
    % Find the coordinates of the square in the visual field to consider
    [r,c]=find(visual_field==i)

    % Plot the associated square
    rectangle('Position',[(c-1)*square_side,(r-
1)*square_side,square_side,square_side],'FaceColor',[0 0 0], 'EdgeColor', 'none')

    pause(1);
```

```
    opts.Interpreter = 'tex'
    opts.Default = 'Yes'

    % Check if the subject was able to notice the sqaure or not
    answer = questdlg('Do you see a black box? \bf{NB:} It might be under this pop up
box','Feedback','Yes','No ', opts);

    % If the subject didn't recoginise the visua
    % field then record its number
    if (answer=='No ')
        unknown=[unknown visual_field(r, c)];
    end

    % Remove the drawn visual field box in order to draw the following one
    rectangle('Position',[(c-1)*square_side,(r-
1)*square_side,square_side,square_side],'FaceColor',[1 1 1], 'EdgeColor', 'none')
end

% Calculate the percentage of the un-noticed visual field
percentage=length(unknown)/squares_num*100;

% Calculate the associated tolerance
tolerance=square_side*square_side/(dim(4)*dim(3))*100;

% Plot the unnoticed visual field
title('Un-noticed visual field');
    % Loop through the different un-noticed squares and plot each of them
    for i=1:length(unknown)
         [r,c]=find(visual_field==unknown(i))
         rectangle('Position',[(c-1)*square_side,(r-
1)*square_side,square_side,square_side],'FaceColor',[0 0 0], 'EdgeColor', 'none')
    end

% Show a pop up message with the percentage of the un-noticed visual field
str = sprintf('The percentage of the un-noticied visual field is %.2f%% (toleranace = %.2f%%) ',
percentage, tolerance)
f = msgbox(str, 'Results');
```

Code for answer 2

```
% Define the number of samples to consider (iterations)
samples = 3000;

% Define the period between iterations
sampling_period = 0.001;

% assign output variable from callback function
C = [];

% crete a timer object and set its properties
t_obj = timer;
```

```
set(t_obj, 'Period', sampling_period);
set(t_obj, 'TasksToExecute', samples);
set(t_obj, 'ExecutionMode', 'fixedRate');
set(t_obj, 'UserData', C);
set(t_obj, 'TimerFcn',{@swap_fcn});

% start timer loop
start(t_obj);

% Pause for 10s to collect data
pause(10);

% Determine the collected cursor coordinates
C=t_obj.UserData;

% Define the sampling frequency
fs=1/sampling_period;

% Define Nyquest frequency
nyq=fs/2;

% Define cut off frequency to be 2Hz
fc=2;

% Define normalized cut off frequency
Wn=fc/nyq;

% Define the coefficients of the low pass 4th order filter of cut off
% frequency equal to 2Hz
[b,a] = butter(4,Wn,'low');

% Filter the x and y coordinates of the cursor
C1_filtered=filtfilt(b, a , C(:,1));
C2_filtered=filtfilt(b, a , C(:,2));

% Open a screen size figure whose x and y axis are the screen's pixels
figure;
set(gcf, 'Position', dim);
dim=get(0, 'Screensize')
xlim([0 dim(3)]);
ylim([0 dim(4)]);
% Plot collected cursor position data
plot(C(:,1), C(:,2), '--x')
% Plot the filtered coordinates
hold on;
plot(C1_filtered, C2_filtered, '--x');
% Add legend to the figure
legend('Original Captured Cursor Position', 'Low-Pass Filtered Cursor Position');
% Add title
title('Cursor Trace Before and After Filtering');

% Define callback function
function [C] = swap_fcn(obj, event)
        % get current user data
```

```
        C = get(obj, 'UserData');
        c=get(0, 'PointerLocation')
        % update any changes
        C=[C;c];
        set(obj,'UserData',C);
end
```

References

[1] Heilman, K. M., and Valenstein, E. (1979). Mechanism underlying hemispatial neglect. *Ann.Neurol.* 5, 166–170.doi:10.1002/ana. 410050210

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[13] Pathak, A., Redmond, J. A., Allen, M., & Chou, K. L. (2014). A noninvasive handheld assistive device to accommodate essential tremor: a pilot study. *Movement Disorders*, *29*(6), 838-842.