Sensor Calibration

Data Collection:

Position the ball along the tube by putting a pencil or piece of wire through a hole of the tube and rest the ping pong ball on top of it. Do this for each hole one at a time. Start from the hole nearest to the sensor. Write a MATLAB program in order to:

1--Prompt the user to position the ball. Use the command pause and then press the space bar to continue when ready.

2--Collect N = 3 measurements at each position of ball. There are M = 15 positions.

3--Store the data to an array.

Open port to Pico

```
clear s % closes ports already open
s = serialport('COM4',9600) % Check COM#
```

```
s = 
  Serialport with properties:

                 Port: "COM4"
             BaudRate: 9600
    NumBytesAvailable: 0

  Show all properties, functions
```

```
sensor = zeros(14,3); % initialize empy array for sensor values

% loop through rows in sensor array
for m = 1:size(sensor,1)
    fprintf("Please position the ball to hole: #" + m + "\n") % prompt user to 
position ball
    pause % wait until user keyboard input
    % loop through columns in sensor array
    for n = 1:size(sensor,2)
        s.writeline("read") % write "read" to Pico
        sensor(m,n) = s.readline(); % read ADC value from Pico
        pause(1) % wait 1 second
    end
end
```

```
Please position the ball to hole: #1
Please position the ball to hole: #2
Please position the ball to hole: #3
Please position the ball to hole: #4
Please position the ball to hole: #5
Please position the ball to hole: #6
Please position the ball to hole: #7
```

```
Please position the ball to hole: #8
Please position the ball to hole: #9
Please position the ball to hole: #10
Please position the ball to hole: #11
Please position the ball to hole: #12
Please position the ball to hole: #13
Please position the ball to hole: #14
```

4--Save the collected data in a file called sensor_calibration_DATE.mat

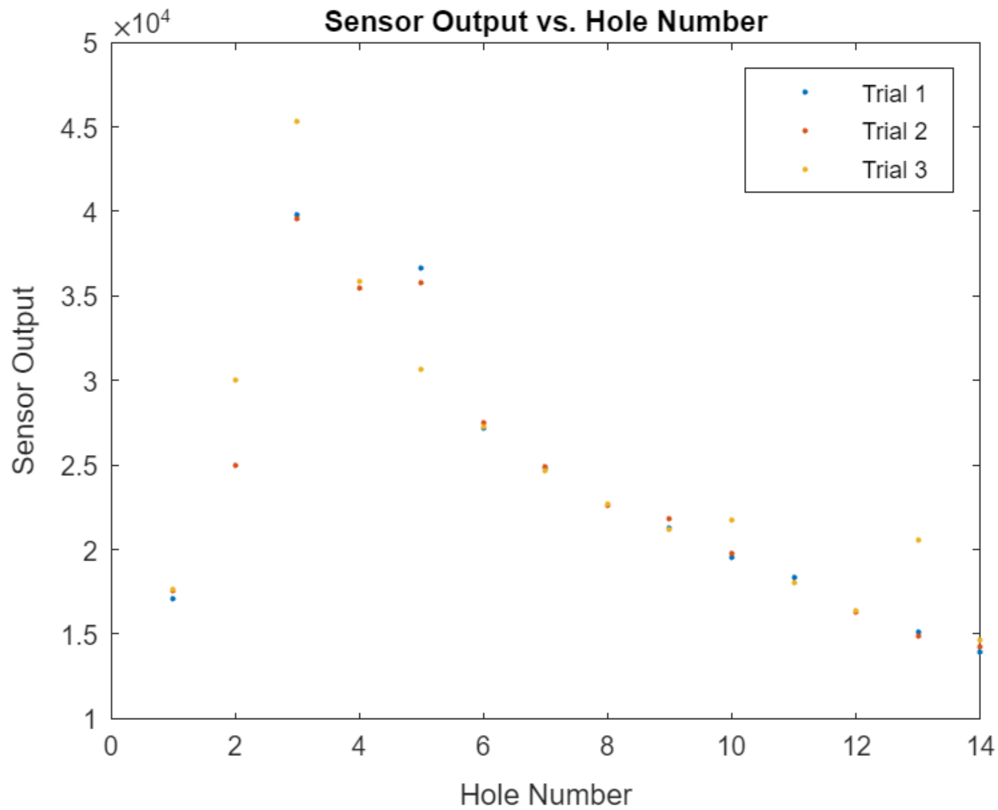
```
save sensor_calibration_03_05_2024.mat sensor
```

```
load sensor_calibration_03_05_2024.mat
sensor
```

```
sensor = 14×3
       17092       17540       17620
       24998       24982       29991
       39785       39561       45355
       35432       35464       35880
       36616       35752       30679
       27158       27494       27238
       24838       24918       24630
       22597       22629       22677
       21285       21797       21221
       19508       19732       21733
      ⋮
```

5--Plot sensor output vs. hole number. Use markers; include axis labels, legend, and title.

```
plot(sensor, ".") % plot sensor data
title("Sensor Output vs. Hole Number")
xlabel("Hole Number")
ylabel("Sensor Output")
legend("Trial 1", "Trial 2", "Trial 3")
```



Discuss the output vs. position contour. Is it linear, parabolic, or other? Are there any outliers in the measurements?

It's linear up to a point. When it gets really close to the sensor, the sensor output drops drastically. There are a few outliers in the measurements amongnst the multipule trials.

Sensor Calibration:

Having collected the data this step performs sensor calibration. A mathematical relationship between ADC output voltage, V, and ball position, D, is sought. The simplest relationship is linear:

$V = a \cdot D + b$

Based on the theory developed in Lecture Notes #2, identify a range on the horizontal where the markers seem to follow a linear trend (e.g., form holes #6 to #15). In MATLAB, do the following:

1--For each position in the selected range find the mean value of the N = 3 measurements taken.

```
average = trimmean(sensor,50,2); % take a 50% trimmed mean to remove bias from
outliers
hole_range = (7:14); % index for range of holes to find linear trend
```

```
V = average(hole_range) % index average array using range of holes
```

```
V = 8×1
       24838
       22629
       21285
       19732
       18068
       16307
       15123
       14227
```

2--Use the pseudo-inverse method to solve for the parameters a and b of the best line fit to all points in the selected interval.

```
D_2 = ones(size(V)); % create a column vector of ones with size of V
D = [hole_range' D_2] % create D matrix [D_1 1]
```

```
D = 8×2
     7     1
     8     1
     9     1
    10     1
    11     1
    12     1
    13     1
    14     1
```

```
P = inv(D'*D) * D' * V; % pseudo-inverse to solve for the parameters
a = P(1)
```

```
a =
   -1.528630952380952e+03
```

```
b = P(2)
```

```
b =
    3.507675000000007e+04
```

3--Using the calculated values for parameters a and b plot the best line fit inside the selected range and overlay the markers of the experimental measurements.

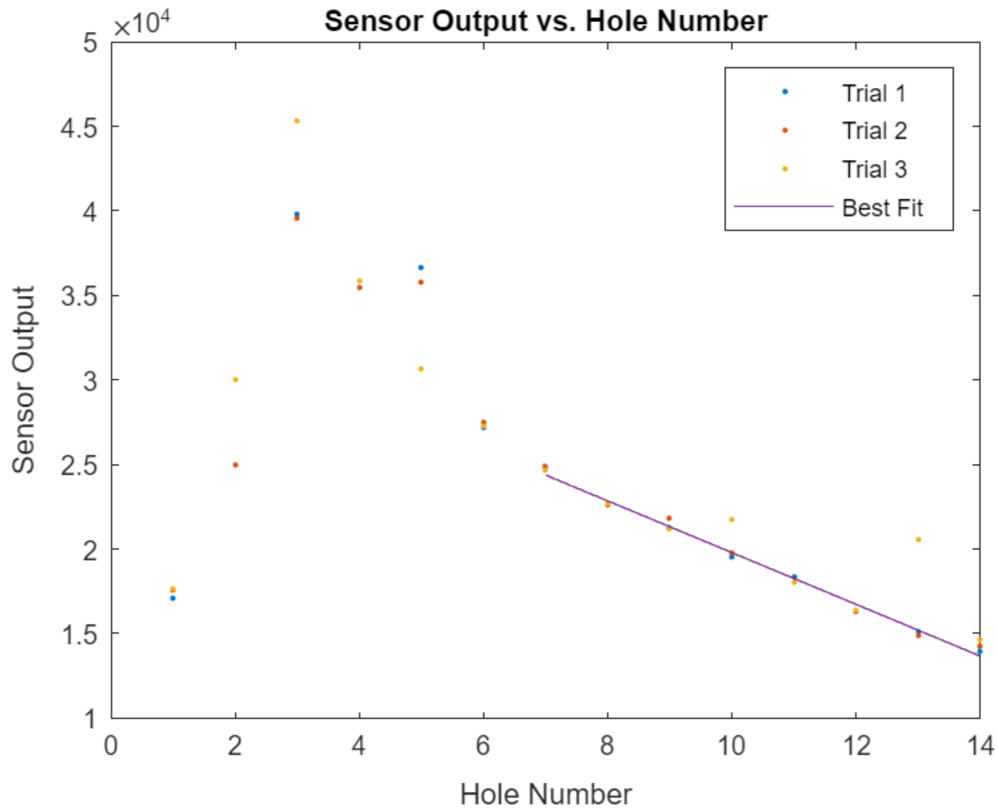
```
x = hole_range; % x axis range is same as hole_range
y = a*x + b; % calculate line using calculated parameters

plot(sensor, ".") % plot sensor data

hold on
plot(x,y) % plot best fit line
hold off

title("Sensor Output vs. Hole Number")
xlabel("Hole Number")
ylabel("Sensor Output")
```

```
legend("Trial 1", "Trial 2", "Trial 3", "Best Fit")
```



Discuss whether the line passes closely from the markers inside the selected interval.

The line passes very closely with the markers inside the selected interval!

Inverse Linear Relationship:

For the purpose of closed-loop ball levitation, the position of the ball corresponding to

the sensor output is needed. Find the parameters c and e of the inverse linear relationship:

$D = c \cdot V + e$

```
format long % formatted to long for best accuracy
% caluculate inverse linear relationship parameters using algebra
c = 1/a
```

```
c =
    -6.541801331723846e-04
```

```
e = -b/a
```

```
e =
  22.946512986254490
```