Repeating the previous Surrogate building sage (Chapter 7) but with addition of the anode consumption related data as an extra input variable to the surrogate model.

Note: The anode consumption related varible is not one of p-value or conductivity related parameter so will be dealt in a different way.

Also this experiment uses the experimental results from The Parameter_CAxx_CBxx.mlx files (0,5,10,15). So make sure to undertake those experiments in advance which are similar to 2 parameter estimation using surrogate (Chapter 7)

```
response_data_type = {'voltage', 'normal current density', 'Z_ELECTRIC_FIELD','anode related'};
%response_data_type = {'voltage', 'Z_CURRENT_DENSITY', 'anode related'};
%calibration_data_type = {'voltage'};
%calibration_data_type = {'voltage', 'current density', 'Z_ELECTRIC_FIELD'};

metric = 'nmsq';

IPs_IDs = 32820:32868;

IPs_IDs1 = IPs_IDs(1:2:end);

IDs_current_density = [14390, 7400, 4060, 16000, 19860, 23802, 30002, 23822,21212, 8437];
%IDs_current_density =[27791       27813       27839       27859];
%IDs_current_density = IPs_IDs1;
anode_related_IDs = 1:25:266;

IDs = {py.list(IPs_IDs1), py.list(IDs_current_density),py.list(IPs_IDs1), py.list(anode_relatec
IDs_mat_arr = {IPs_IDs1, IDs_current_density.', IPs_IDs1,anode_related_IDs.'};

%IDs_types = {'Internal Points','Mesh Points', 'Internal Points','CONSUMPTION_FACTOR','ANODE_CU
%IDs_types = {'Internal Points','Mesh Points', 'Internal Points','ANODE_CURRENT'};
IDs_types = {'Internal Points','Mesh Points', 'Internal Points', 'MASS_LOSS_RATE'};
%
%IDs_types = {'Internal Points','Internal Points', 'MASS_LOSS_RATE'};
%py.list(1:2)

parameters_base = {'CA', 'CB'};
```

The average anode consumption for different year time is something the CP model should predict, but this approach deals it as an Inverse problem.

The average anode consumption rate is added for each of the year during data sampling.

```
years = [0, 5,10,15];

all_anode_IDs = 1:266;
```

```
root_folder1 = 'D:\DOE_nd_data_generation\TIme_step\readyToTimeStepUsingV10_B';

average_cons_factor = average_anode_CONSUMPTION_FACTOR(root_folder1, years, all_anode_IDs);
```

```
average_cons_factor
```

```
average_cons_factor = 1×4
         0    0.0754    0.2350    0.4450
```

```
anode_IDs = 1:25:255;

res_folder = 'D:\DOE_nd_data_generation\TIme_step\readyToTimeStepUsingV10_B\year_10\Calibratior

anode_cons_rate = get_anode_data(res_folder, anode_IDs, 'CONSUMPTION_FACTOR');
```

```
%anode_cons_rate
```

```
anode_cons_rate = 11×2
    1.0000    0.2117
  226.0000    0.2365
  101.0000    0.2522
  201.0000    0.2313
   76.0000    0.2707
  176.0000    0.2229
   51.0000    0.2345
  151.0000    0.2417
   26.0000    0.2155
  251.0000    0.2372
      ⋮
```

```
%DOE experiment for 2 varaibles using Central Composite Design
Central_composite_points = ccdesign(2, 'type', 'inscribed', 'center' , 1);

DOE_range1 = [0.005, 0.2; 0.005,  0.15];
DOE_range10 = [0.15, 0.35; 0.100,  0.25];
DOE_range15 = [0.15, 0.275; 0.1100,  0.19];

DOE_sample_points= cell(1, length(years)); snapshots_years = DOE_sample_points;

DOE_sample_points{1} = reverse_normalization(Central_composite_points, DOE_range1);
DOE_sample_points{2} = reverse_normalization(Central_composite_points, DOE_range1);
DOE_sample_points{3} = reverse_normalization(Central_composite_points, DOE_range10);
DOE_sample_points{4} = reverse_normalization(Central_composite_points, DOE_range15);
```

```
for i = 1:length(years)

    source_parameters = {'BARE', 'BARE'};

    if years(i) <10
        parameters = strcat(parameters_base, '0', cellstr(string(years(i))));
    else
```

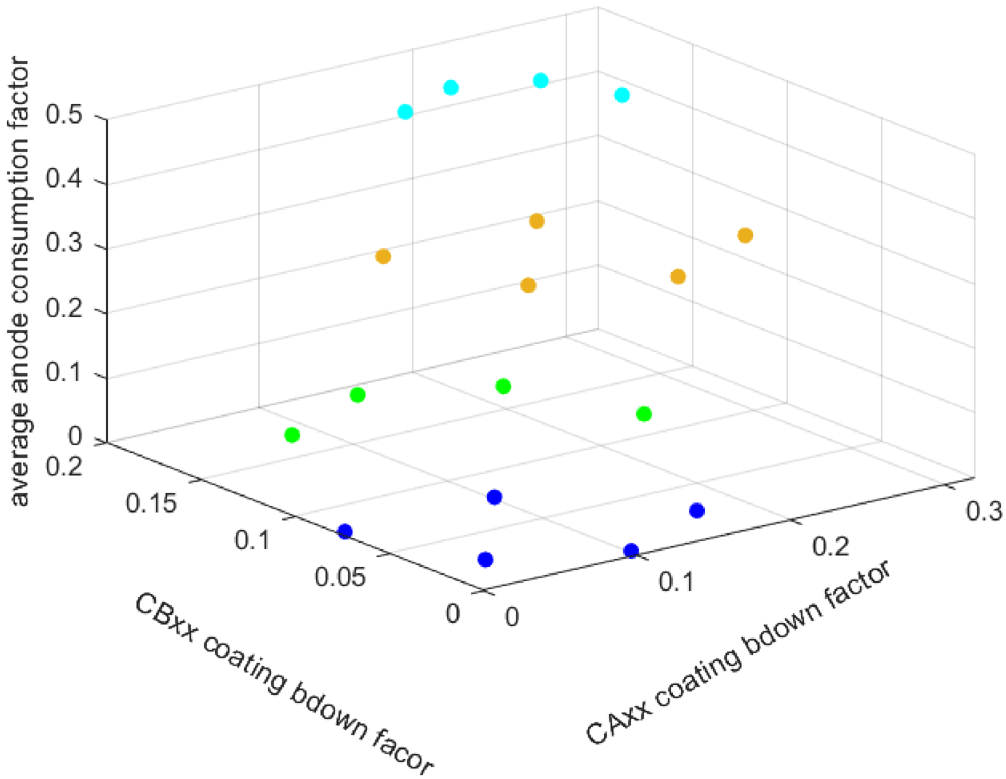
```
        parameters = strcat(parameters_base, cellstr(string(years(i))));
    end

    parameters_np_array1 = convert_arr_to_python_2d_list(DOE_sample_points{i});

    simulation_seed_folder = fullfile(root_folder1,strcat('year_',string(years(i))), 'Initial_f

    collection_dir = fullfile(root_folder1,strcat('year_',string(years(i))), 'Simulation_result

    snapshots_py = py.BEASY_IN_OUT2.snapshots_for_given_parameters_and_IDs(py.list(source_param

    snapshots{i} = double(snapshots_py);
end
```

```
DOE_sample_points1_3d = [DOE_sample_points{1}, average_cons_factor(1)*ones(size(DOE_sample_poin
DOE_sample_points5_3d = [DOE_sample_points{2}, average_cons_factor(2)*ones(size(DOE_sample_poin
DOE_sample_points10_3d = [DOE_sample_points{3}, average_cons_factor(3)*ones(size(DOE_sample_poi
DOE_sample_points15_3d = [DOE_sample_points{4}, average_cons_factor(4)*ones(size(DOE_sample_poi

DOE_sample_points_collected = [DOE_sample_points1_3d(1:2:end,:); DOE_sample_points5_3d(2:2:end,
    DOE_sample_points10_3d(1:2:end,:); DOE_sample_points15_3d(2:2:end,:)];

DOE_sample_points_collected_cells = {DOE_sample_points1_3d(1:2:end,:),
    DOE_sample_points5_3d(2:2:end,:), DOE_sample_points10_3d(1:2:end,:), DOE_sample_points15_3c

snapshots_collected = [snapshots{1}(1:2:end,:); snapshots{2}(2:2:end,:);
    snapshots{3}(1:2:end,:); snapshots{4}(2:2:end,:)];
```

Data samples collected at different time-span, now will be used in surrogate-building for the three variables case (PhD Thesis section 8.5.3)

```
figure;

%scatter3( DOE_sample_points3(:,1),  DOE_sample_points3(:,2),DOE_sample_points3(:,3) ,'filled',
%scatter3( DOE_sample_points_collected(:,1),  DOE_sample_points_collected(:,2),DOE_sample_point

sampl_idx = 1;
scatter3( DOE_sample_points_collected_cells{sampl_idx}(:,1),  ...
    DOE_sample_points_collected_cells{sampl_idx}(:,2),DOE_sample_points_collected_cells{sampl_i
hold on;
sampl_idx = 2;
scatter3( DOE_sample_points_collected_cells{sampl_idx}(:,1),  ...
    DOE_sample_points_collected_cells{sampl_idx}(:,2),DOE_sample_points_collected_cells{sampl_i

sampl_idx = 3;
scatter3( DOE_sample_points_collected_cells{sampl_idx}(:,1),  ...
    DOE_sample_points_collected_cells{sampl_idx}(:,2),DOE_sample_points_collected_cells{sampl_i

sampl_idx = 4;
scatter3( DOE_sample_points_collected_cells{sampl_idx}(:,1), ...
    DOE_sample_points_collected_cells{sampl_idx}(:,2),DOE_sample_points_collected_cells{sampl_i
```

```
xlabel('CAxx coating bdown factor', 'Rotation', 30);
ylabel('CBxx coating bdown facor', 'Rotation', -30);
zlabel('average anode consumption factor');
```




```
%csvwrite('Snapshots_3d.csv', snapshots_collected )
%csvwrite('DOE_sample_points_collected_3d.csv', DOE_sample_points_collected )
```

```
%csvwrite('DOE_sample_points_collected_3d.csv', DOE_sample_points_collected )
```

To build the 3 dimensional polynomial fit surrogate, this tool relies upon the MATLAB toolbox *'polyfitn'* .

The toolbox polyfitn need to be downloaded into the system and linked if doesnot exist within the MATLAB.

```
surrogates_3d = response_surface(DOE_sample_points_collected, snapshots_collected,2);
```

```
surrogates_3d
```

```
surrogates_3d = 1×71 cell
```

...

	1	2	3	4	5	6	7	8
1	1×1 struct	1×1 struct	1×1 struct	1×1 struct	1×1 struct	1×1 struct	1×1 struct	1×1 struct

```
surrogates_3d{1}
```

```
ans = struct with fields:
      ModelTerms: [10×3 double]
    Coefficients: [-629.0825 -202.6927 -13.1925 526.6198 662.3681 -464.8554 23.8937 93.4226 28.4219 -1.0791e+03]
     ParameterVar: [2.9296e+04 1.9555e+05 5.4551e+04 2.7400e+03 4.6670e+05 2.8728e+05 1.1682e+04 1.6283e+04 3.5925e+0
     ParameterStd: [171.1604 442.2061 233.5625 52.3451 683.1581 535.9806 108.0826 127.6067 59.9375 4.9720]
              DoF: 8
                p: [0.0063 0.6589 0.9563 8.1140e-06 0.3607 0.4110 0.8306 0.4850 0.6480 2.2735e-16]
               R2: 0.9959
       AdjustedR2: 0.9912
             RMSE: 1.8967
         VarNames: {'X1'  'X2'  'X3'}
```

```
calib_dir = fullfile(root_folder1,'year_20','Calibration_data');
%meas_dir1 = 'C:\Users\msapkota\EXPERIMENT\DOE_nd_data_generation\Model_updated_nonlinear\Param

files_name = 'BU_TimeStepped_01_20';
%meas_dict = py.BEASY_IN_OUT1.get_output_data_for_IDs_from_simulation_folder(meas_dir, files_na

calib_data_IDs = {IPs_IDs1, IDs_current_density};
calib_data_type = response_data_type(1:2);

%meas_data = convert_pydict2data(meas_dict,0);

calib_data_file_err_inc = strcat('data_with_error_',strjoin(response_data_type, '_'), '.xlsx');

%all_position_dict = py.BEASY_IN_OUT2.get_output_data_for_IDs_from_simulation_folder(calib_dir,


if ~isfile(fullfile(calib_dir, calib_data_file_err_inc))
    all_position_dict = py.BEASY_IN_OUT2.get_output_data_for_IDs_from_simulation_folder(calib_d
        files_name, py.list(calib_data_type),  py.list({py.list(IPs_IDs), py.list(IDs_current_d
    all_position_data = convert_pydict2data(all_position_dict,0);
    introduce_error_and_write_file( {IPs_IDs.', IDs_current_density.'},all_position_data, ...
        calib_dir, calib_data_file_err_inc,1);
end
```

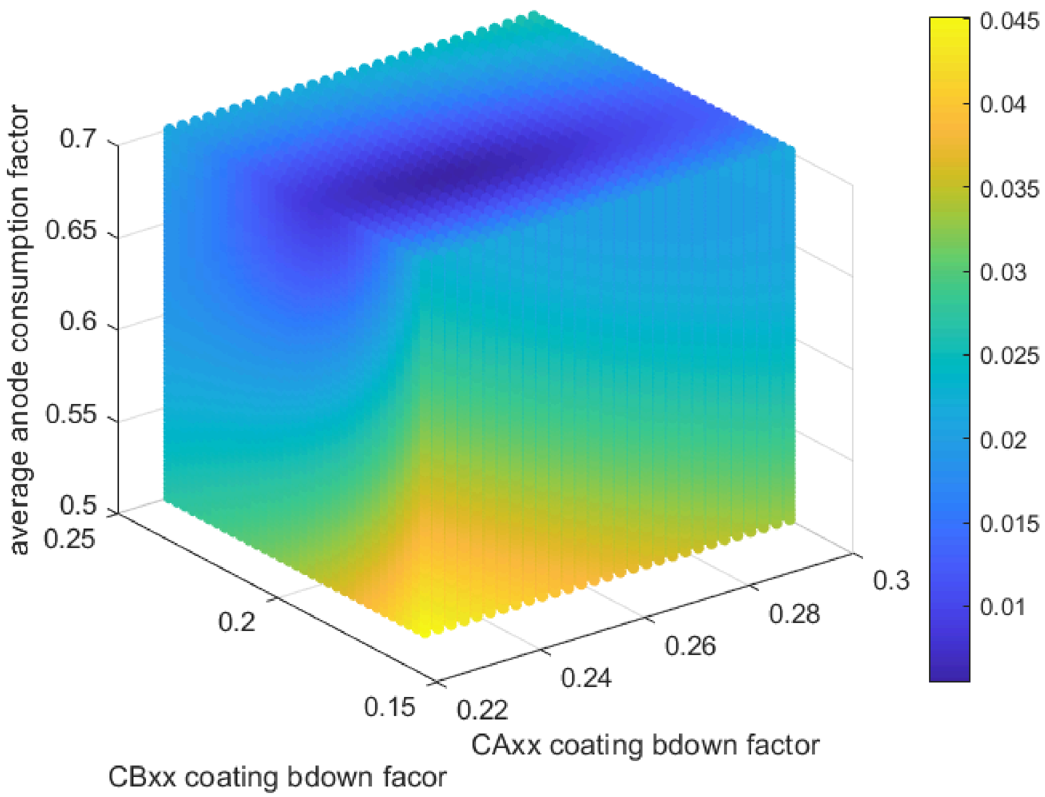
```
Warning: Added specified worksheet.
```

```
%model_out = output_from_surrogates([2.0, 3.0], surrogates, [17,6]);

calib_data_inc_error = data_from_tables(fullfile(calib_dir, calib_data_file_err_inc), calib_dat
```

```
%if we know one of the value we can fix it
figure;

ax = gca;

DOE_range20 = [0.23 0.3; 0.17 0.25; 0.5,0.7];

[plot_data,min_value, min_out_pos20] = plot_objective_with_surrogates(ax, ...
    DOE_range20, surrogates_3d, calib_data_inc_error, 'nmsq', calib_data_type, ...
    cellfun('length',IDs_mat_arr),[1,0.5,0,0], [0.0025,0.0025, 0.0025]);
```

```
    14     14     74
```

```
sol_output_from_surrogate = output_from_surrogates(min_out_pos20, surrogates_3d,cellfun('length
    IDs_mat_arr));

xlabel('CAxx coating bdown factor');
ylabel('CBxx coating bdown facor');
zlabel('average anode consumption factor');
```




```
min_out_pos20
```

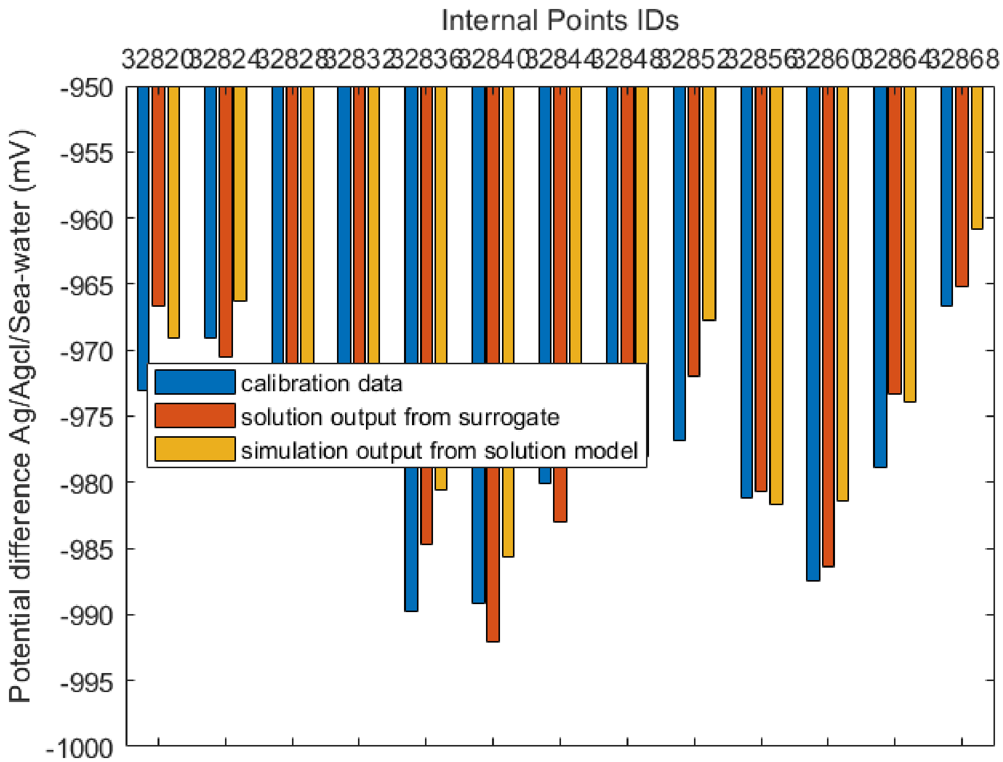
```
min_out_pos20 = 1×3
    0.2625    0.2025    0.6825
```

```
%min_out_pos20 = [0.2575    0.2000    0.6925]
testing_par_value = min_out_pos20;

sol_output_from_surrogate = output_from_surrogates(testing_par_value, ...
    surrogates_3d,cellfun('length',IDs_mat_arr));

testing_par_value = min_out_pos20(1:2);
root_folder = 'D:\DOE_nd_data_generation\TIme_step\readyToTimeStepUsingV10_B\year_20';
files_name = 'BU_TimeStepped_01_20';
```

```
parameters= {'CA20','CB20'};

simulation_seed_folder = fullfile(root_folder, 'Initial_files');

solution_folder = '';
for i = 1:length(parameters)
    solution_folder =   strcat(solution_folder, parameters{i},'_', num2str(testing_par_value(i)
        '%.4f'));
    if i~=length(parameters)
        solution_folder = strcat(solution_folder, '_');
    end
end
solution_colection_dir = fullfile(root_folder,'Solution_results');

solution_dir = fullfile(solution_colection_dir, solution_folder);

if ~isfolder(solution_dir)
    solution_dict = py.BEASY_IN_OUT2.get_response_data_for_IDs_and_input_parameters(py.list(sou
        py.list(parameters), testing_par_value, simulation_seed_folder, solution_colection_dir,
    solution_data = convert_pydict2data(solution_dict,1);
else

    solution_dict = py.BEASY_IN_OUT2.get_output_data_for_IDs_from_simulation_folder(solution_di
        files_name, py.list(response_data_type),  py.list(IDs), py.list(IDs_types));
    solution_data = convert_pydict2data(solution_dict,0);
end
```

```
('running_simulation in:', 'D:\\DOE_nd_data_generation\\TIme_step\\readyToTimeStepUsingV10_B\\year_20\\Solution_resu
```

```
figure;
ax = gca;
%difference_in_bar_chart(ax,simulation_data{1}(1:4:end,:), out_frm_nnet{1}(1:4:end,:),{'simuati

%legend_cell = strcat('Data from Simulation on year', strsplit(num2str(time_period)));
legend_cell = {'calibration data', 'solution output from surrogate',
    'simulation output from solution model'};
data_ID = 1;

response_in_bar_chart(ax, solution_data{data_ID}(1:2:end,:) , ...
    {calib_data_inc_error{data_ID}(1:2:end,:), sol_output_from_surrogate{data_ID}(1:2:end,:), .
    solution_data{data_ID}(1:2:end,:)}, legend_cell);

xlabel('Internal Points IDs');
%xlabel('Mesh Points IDs');
%xlabel('Data Positional IDs', 'Rotation', 30);
%ylabel('consumption rate (kg/yr)')
%ylabel('Z electric field (micro-V/m)');
%ylabel('Normal current density (mAmp/Sq.m)');
ylim([-1000 -950]);
```




```
%ylim([15 22]);
%ylabel('anode Current');
%ylim([1200 2000]);
```

```
function average_CONSUMPTION_FACTOR  = average_anode_CONSUMPTION_FACTOR(root_folder_address, ye


average_CONSUMPTION_FACTOR = zeros(1, length(years_time));

for i = 1:length(years_time)

    year_t = years_time(i);

    response_folder = fullfile(root_folder_address, strcat('year_', string(year_t)), 'Calibrati

    simulation_files = dir(response_folder);
    files_name = simulation_files(end-3).name;
    files_name = strsplit(files_name, '.');
    files_name = files_name{1};

    %anode_file = fullfile(response_folder,strcat(files_name, '.cp_anode_decay'));

    initial_anode_data = py.BEASY_IN_OUT2.get_output_data_for_IDs_from_simulation_folder(respon

    initial_anode_data = convert_pydict2data(initial_anode_data,0);

    initial_anode_data = initial_anode_data{1};
```

```
    average_CONSUMPTION_FACTOR(i) = mean(initial_anode_data(:,2));

end

end



function anode_data = get_anode_data(response_folder,  anode_IDs, data_type)

    simulation_files = dir(response_folder);
    files_name = simulation_files(end-2).name;
    files_name = strsplit(files_name, '.');
    files_name = files_name{1};

    anode_file = fullfile(response_folder,strcat(files_name, '.cp_anode_decay'));

    anode_data = py.BEASY_IN_OUT2.get_output_data_for_IDs_from_simulation_folder(response_folde


    anode_data = convert_pydict2data(anode_data,0);

    anode_data = anode_data{1};

end

function de_normaised_data = reverse_normalization(normalised_data, value_ranges)

de_normaised_data = zeros(size(normalised_data));

for i = 1:size(normalised_data, 2)

    de_normaised_data(:,i) = value_ranges(i,1)+ diff(value_ranges(i,:))/2 * (normalised_data(:,

end
end
```