****

Simulation Loop

****

Start here!

load main workspace

```
end_sim = 0;
addpath(genpath(pwd));
load_db_params;
conn = database(datasource_name, user_name, password);

% load UAV airframe
uav_sern = 'X001';
octomodel = get_airframe(conn, uav_sern);

% load battery
battery_sern = 'B001';
battery = get_battery(conn, battery_sern);
batterytwin = get_battery(conn, battery_sern);

% load motors
[Motor1, Motor2, Motor3, Motor4, Motor5, Motor6, Motor7, Motor8] = get_motors(conn, octomodel.i
[Motortwin1, Motortwin2, Motortwin3, Motortwin4, Motortwin5, Motortwin6, Motortwin7, Motortwin8

% initial rul estimate, used as baseline in rul updates where the minimum
% value is taken to ensure rul_hat never exceeds this value
rul_init = 18.0;
rul_hat = rul_init;

% minimum rul
rul_threshold = 10.0;

% load base directory
load_base_workspace;

%load_trajectory; % load individually
```

Initialize some variables

```
% for poly fitting
lookback = 6;

% how far into the future to look
horizon = 2;

% number of missions (can be oversized)
n_missions = 100;
```

```
% keep track of delta over time
% number of missions, 3 degradation parameters, 2 coefficients to save
% (slope & intercept)
polys = zeros(n_missions, 3, 2);

% keep track of degradation parameter values for poly fitting
q_deg = zeros(n_missions, 1);
r_deg = zeros(n_missions, 1);
m_deg = zeros(n_missions, 1);

% variance gets tighter over time, a pseudo-hack...
r_var_vals = [.001:-.00001:.0001];
q_var_vals = [.9:-.01:.2];
m_var_vals = [.025:-.00025:.005];

% keep track of rul
ruls = zeros(n_missions, 1);
```

```
temp = m_deg(:);
m_deg = zeros(n_missions, 1);
m_deg(1:length(temp)) = temp;
m_deg
```

Main Loop

```
% loop
% accelerated is 80
% normal is 300
mission_id = table2array(select(conn, 'select id from mission_tb mt order by id desc limit 1;'))
if isempty(mission_id)
    mission_id = 1;
else
    mission_id = mission_id + 1;
end
disp(mission_id)
```

```
   13
```

```
for i = mission_id:n_missions
    if i > 11
        lookback = 8;
        horizon = 3;
    end
    ruls(i) = rul_hat;
    load_trajectory;
    if end_sim == 1
        sprintf("[INFO] no more valid trajectories. ending simulation.")
        break;
    end
    sprintf("[INFO] selecting trajectory: <%d> with path_time: %.2f that meets constraint: path
    sys = "TrueSystem";
    octomodel.sampletime = true_sample_rate;
```

```
sprintf('[INFO] simulating true system on mission: %d', i)
tic
sim('truesystem.slx');
toc
```

update degradation parameters for saving

- assign values from the current run to the arrays for saving

```
q_deg(i) = battery.Q;
r_deg(i) = battery.R0;
m_deg(i) = Motor2.Req;
```

update variance

```
sprintf('[INFO] updating degradation parameter variance on mission: %d', i)
if i <= length(r_var_vals)
   r_var = r_var_vals(i);
else
    r_var = .0001;
end
if i <= length(q_var_vals)
    q_var = q_var_vals(i);
else
    q_var = .25;
end
if i <= length(m_var_vals)
    m_var = m_var_vals(i);
else
    m_var = .005;
end
```

sample the degradation parameters and update

```
sprintf('[INFO] updating degradation parameter values via random sampling on mission: %d',
battery.R0 = max(abs(normrnd(rdeg(i), r_var)), .0001);
battery.Q = min(abs(normrnd(qdeg(i), q_var)), 15.5);
Motor2.Req = max(abs(normrnd(mdeg(i), m_var)), .001);
```

write telemetry data to database

```
distance = calculatedistance([pos_actual.Data(:,1) pos_actual.Data(:,2)]);
start = table2array(select(conn, 'select mt.dt_stop from mission_tb mt order by dt_stop des
if isempty(start)
    start = datetime(now, 'ConvertFrom', 'datenum');
end
start = datetime(start, 'InputFormat', 'yyyy-MM-dd HH:mm:ss');
start = dateshift(start, 'start', 'second');
start = start + hours(1);
stop = start + seconds(flight_time.Data(end, 1)*60);

sprintf("[INFO] mission_id: %d\trul_hat: %.2f\tflight_time: %.2f\tdistance: %.2f\tR0: %.5f\
```

```
    mission_id = i;
    write_mission_data;
    write_battery_data;
    write_flight_data;

    if any(stop_code.Data(:,1)) == 1 && ~any(stop_code.Data(:,3)) == 1
        sprintf('[INFO] true system low soc threshold exceeded on mission %d', i)
        %break;
    end

    if any(stop_code.Data(:,2)) == 1
        sprintf('[INFO] true system position error threshold exceeded on mission %d', i)
        %break;
    end

    if any(stop_code.Data(:,3)) == 1
        sprintf('[INFO] success on mission %d', i)
    end

    clear('trajectory', 'battery_actual', 'battery_observed', 'ctrl_err', 'current', 'current_r
```

define placeholder variables

```
    twin_ctr = 1;
    twin_count = 1;
    times = zeros(1, twin_count);
    vs = zeros(1, twin_count);
    socs = zeros(1, twin_count);
    r0s = zeros(1, twin_count);
    qs = zeros(1, twin_count);
    ms = zeros(1, twin_count);
    dist = zeros(1, twin_count);
    errs = zeros(1, twin_count);
    degs = zeros(3, twin_count);
```

Update twin degradation parameters

```
    if i > lookback
        disp('[INFO] forecasting degradation values');
        x = double(((i - (lookback-1)):1:i)');
        r_poly = polyfit(x, smoothdata(r_deg(x), 'rlowess', 5), 1);
        q_poly = polyfit(x, smoothdata(q_deg(x), 'rlowess', 5), 1);
        m_poly = polyfit(x, smoothdata(m_deg(x), 'rlowess', 5), 1);

        polys(i, 1, :) = r_poly;
        polys(i, 2, :) = q_poly;
        polys(i, 3, :) = m_poly;

        r_mu = polyval(r_poly, i + horizon);
        q_mu = polyval(q_poly, i + horizon);
        m_mu = polyval(m_poly, i + horizon);
        batterytwin.R0 = max(abs(normrnd(r_mu, r_var)), .0001);
```

```
        batterytwin.Q = min(abs(normrnd(q_mu, q_var)), 15.5);
        Motortwin2.Req = max(abs(normrnd(m_mu, m_var)), .001);
    else
        batterytwin.R0 = max(abs(normrnd(rdeg(i), r_var)), .0001);
        batterytwin.Q = min(abs(normrnd(qdeg(i), q_var)), 15.5);
        Motortwin2.Req = max(abs(normrnd(mdeg(i), m_var)), .001);
    end
    sprintf("[INFO] digital twin degradation parameters: %.4f\t%.4f\t%.4f", batterytwin.R0, bat
    write_degradation_data;
```

now simulate digital twin

```
    load_trajectory;
    sys = "DigitalTwin";
    octomodel.sampletime = twin_sample_rate;
    for twin_ctr=1:twin_count
        sprintf('[INFO] simulating digital twin on mission: %d', i)
        out = sim('digitaltwin1c.slx');
        %        get the output from each parallel worker
        times(twin_ctr) = flight_time.Data(end);
        vs(twin_ctr) = battery_actual.Data(end, 1);
        socs(twin_ctr) = battery_actual.Data(end, 2);
        r0s(twin_ctr) = battery_actual.Data(end, 3);
        qs(twin_ctr) = battery_actual.Data(end, 6);
        ms(twin_ctr) = motors.Data(end, 1);
        errs(twin_ctr) = mean(euclidean_pos_err);
        dist(twin_ctr) = calculatedistance([pos_actual.Data(:,1) pos_actual.Data(:,2)]);
        degs(:, twin_ctr) = [batterytwin.R0 batterytwin.Q Motortwin2.Req]';

        % resample the degradation parameters if more than one digital twin
        % simulation
%         if twin_count > 1
%            if i > lookback
%                disp('[INFO] using forecast degradation values');
%                batterytwin.R0 = normrnd(r_mu, r_var);
%                batterytwin.Q = normrnd(q_mu, q_var);
%                Motortwin2.Req = normrnd(m_mu, m_var);
%            else
%                batterytwin.R0 = max(abs(normrnd(rdeg(i), r_var)), .00075);
%                batterytwin.Q = min(abs(normrnd(qdeg(i), q_var)), 15.5);
%                Motortwin2.Req = max(abs(normrnd(mdeg(i), m_var)), .001);
%            end
%         end
    end
```

do some checks on when to stop the simulation

```
    if any(stop_code.Data(:,1)) == 1
        sprintf('[INFO] digital twin low soc threshold exceeded on mission %d', i)
        rul_hat = min(mean(times(:)) - 1, rul_init); % rul is now 1 minute less than the digita
    end

    if any(stop_code.Data(:,2)) == 1
```

```
        sprintf('[INFO] digital twin position error threshold exceeded on mission %d', i)
        rul_hat = min(mean(times(:)) - 1, rul_init); % rul is now 1 minute less than the digita
    end

    if any(stop_code.Data(:,3)) == 1 && ~any(stop_code.Data(:,1)) == 1 && ~any(stop_code.Data(:
        sprintf('[INFO] digital twin mission success on %d, rul_hat: %.2f remains effective', i
    end


    % otherwise, end of life was never reached so the current rul estimate
    % is the best estimate

    if rul_hat <= rul_threshold
        sprintf('[INFO] digital twin rul_hat: %.2f does not meet the threshold: %.2f on mission
        break;
    end
        clear('trajectory', 'battery_actual', 'battery_observed', 'ctrl_err', 'current', 'curre
end
```

```
ans =
"[INFO] selecting trajectory: <3> with path_time: 17.83 that meets constraint: path_time < 18.00"
ans =
'[INFO] simulating true system on mission: 13'
Elapsed time is 223.882887 seconds.
ans =
'[INFO] updating degradation parameter variance on mission: 13'
ans =
'[INFO] updating degradation parameter values via random sampling on mission: 13'
ans =
"[INFO] mission_id: 13 rul_hat: 18.00 flight_time: 17.84 distance: 1302.17 R0: 0.00176 Q: 15.50 Req: 0.27356"
ans =
'[INFO] success on mission 13'
[INFO] forecasting degradation values
ans =
'[INFO] simulating digital twin on mission: 13'
ans =
'[INFO] digital twin mission success on 13, rul_hat: 18.00 remains effective'
ans =
"[INFO] selecting trajectory: <3> with path_time: 17.83 that meets constraint: path_time < 18.00"
ans =
'[INFO] simulating true system on mission: 14'
Elapsed time is 219.796029 seconds.
ans =
'[INFO] updating degradation parameter variance on mission: 14'
ans =
'[INFO] updating degradation parameter values via random sampling on mission: 14'
ans =
"[INFO] mission_id: 14 rul_hat: 18.00 flight_time: 17.84 distance: 1302.21 R0: 0.00215 Q: 14.10 Req: 0.27374"
ans =
'[INFO] success on mission 14'
[INFO] forecasting degradation values
ans =
'[INFO] simulating digital twin on mission: 14'
ans =
'[INFO] digital twin mission success on 14, rul_hat: 18.00 remains effective'
ans =
"[INFO] selecting trajectory: <15> with path_time: 17.63 that meets constraint: path_time < 18.00"
ans =
'[INFO] simulating true system on mission: 15'
Elapsed time is 232.343326 seconds.
ans =
```

```
'[INFO] updating degradation parameter variance on mission: 15'
ans =
'[INFO] updating degradation parameter values via random sampling on mission: 15'
ans =
"[INFO] mission_id: 15 rul_hat: 18.00 flight_time: 17.63 distance: 1283.91 R0: 0.00104 Q: 14.23 Req: 0.29558"
ans =
'[INFO] success on mission 15'
[INFO] forecasting degradation values
ans =
'[INFO] simulating digital twin on mission: 15'
ans =
'[INFO] digital twin mission success on 15, rul_hat: 18.00 remains effective'
ans =
"[INFO] selecting trajectory: <3> with path_time: 17.83 that meets constraint: path_time < 18.00"
ans =
'[INFO] simulating true system on mission: 16'
Elapsed time is 218.396023 seconds.
ans =
'[INFO] updating degradation parameter variance on mission: 16'
ans =
'[INFO] updating degradation parameter values via random sampling on mission: 16'
ans =
"[INFO] mission_id: 16 rul_hat: 18.00 flight_time: 17.84 distance: 1302.31 R0: 0.00178 Q: 13.41 Req: 0.27865"
ans =
'[INFO] success on mission 16'
[INFO] forecasting degradation values
ans =
'[INFO] simulating digital twin on mission: 16'
ans =
'[INFO] digital twin mission success on 16, rul_hat: 18.00 remains effective'
ans =
"[INFO] selecting trajectory: <11> with path_time: 16.38 that meets constraint: path_time < 18.00"
ans =
'[INFO] simulating true system on mission: 17'
Elapsed time is 218.257373 seconds.
ans =
'[INFO] updating degradation parameter variance on mission: 17'
ans =
'[INFO] updating degradation parameter values via random sampling on mission: 17'
ans =
"[INFO] mission_id: 17 rul_hat: 18.00 flight_time: 16.36 distance: 1218.91 R0: 0.00315 Q: 15.31 Req: 0.26654"
ans =
'[INFO] success on mission 17'
[INFO] forecasting degradation values
ans =
'[INFO] simulating digital twin on mission: 17'
ans =
'[INFO] digital twin mission success on 17, rul_hat: 18.00 remains effective'
ans =
"[INFO] selecting trajectory: <3> with path_time: 17.83 that meets constraint: path_time < 18.00"
ans =
'[INFO] simulating true system on mission: 18'
Elapsed time is 219.810809 seconds.
ans =
'[INFO] updating degradation parameter variance on mission: 18'
ans =
'[INFO] updating degradation parameter values via random sampling on mission: 18'
ans =
"[INFO] mission_id: 18 rul_hat: 18.00 flight_time: 17.84 distance: 1302.13 R0: 0.00374 Q: 13.86 Req: 0.28062"
ans =
'[INFO] success on mission 18'
[INFO] forecasting degradation values
ans =
'[INFO] simulating digital twin on mission: 18'
ans =
```

```
'[INFO] digital twin mission success on 18, rul_hat: 18.00 remains effective'
ans =
"[INFO] selecting trajectory: <11> with path_time: 16.38 that meets constraint: path_time < 18.00"
ans =
'[INFO] simulating true system on mission: 19'
Elapsed time is 218.391024 seconds.
ans =
'[INFO] updating degradation parameter variance on mission: 19'
ans =
'[INFO] updating degradation parameter values via random sampling on mission: 19'
ans =
"[INFO] mission_id: 19 rul_hat: 18.00 flight_time: 16.36 distance: 1218.83 R0: 0.00158 Q: 14.23 Req: 0.28147"
ans =
'[INFO] success on mission 19'
[INFO] forecasting degradation values
ans =
'[INFO] simulating digital twin on mission: 19'
ans =
'[INFO] digital twin mission success on 19, rul_hat: 18.00 remains effective'
ans =
"[INFO] selecting trajectory: <3> with path_time: 17.83 that meets constraint: path_time < 18.00"
ans =
'[INFO] simulating true system on mission: 20'
Elapsed time is 217.828128 seconds.
ans =
'[INFO] updating degradation parameter variance on mission: 20'
ans =
'[INFO] updating degradation parameter values via random sampling on mission: 20'
ans =
"[INFO] mission_id: 20 rul_hat: 18.00 flight_time: 17.84 distance: 1302.29 R0: 0.00162 Q: 14.54 Req: 0.31470"
ans =
'[INFO] success on mission 20'
[INFO] forecasting degradation values
ans =
'[INFO] simulating digital twin on mission: 20'
ans =
'[INFO] digital twin mission success on 20, rul_hat: 18.00 remains effective'
ans =
"[INFO] selecting trajectory: <15> with path_time: 17.63 that meets constraint: path_time < 18.00"
ans =
'[INFO] simulating true system on mission: 21'
Elapsed time is 217.762219 seconds.
ans =
'[INFO] updating degradation parameter variance on mission: 21'
ans =
'[INFO] updating degradation parameter values via random sampling on mission: 21'
ans =
"[INFO] mission_id: 21 rul_hat: 18.00 flight_time: 17.64 distance: 1284.10 R0: 0.00135 Q: 14.70 Req: 0.28286"
ans =
'[INFO] success on mission 21'
[INFO] forecasting degradation values
ans =
'[INFO] simulating digital twin on mission: 21'
ans =
'[INFO] digital twin mission success on 21, rul_hat: 18.00 remains effective'
ans =
"[INFO] selecting trajectory: <11> with path_time: 16.38 that meets constraint: path_time < 18.00"
ans =
'[INFO] simulating true system on mission: 22'
Elapsed time is 218.329365 seconds.
ans =
'[INFO] updating degradation parameter variance on mission: 22'
ans =
'[INFO] updating degradation parameter values via random sampling on mission: 22'
ans =
```

```
"[INFO] mission_id: 22 rul_hat: 18.00 flight_time: 16.36 distance: 1218.81 R0: 0.00348 Q: 15.45 Req: 0.30527"
ans =
'[INFO] success on mission 22'
[INFO] forecasting degradation values
ans =
'[INFO] simulating digital twin on mission: 22'
ans =
'[INFO] digital twin mission success on 22, rul_hat: 18.00 remains effective'
ans =
"[INFO] selecting trajectory: <15> with path_time: 17.63 that meets constraint: path_time < 18.00"
ans =
'[INFO] simulating true system on mission: 23'
Elapsed time is 217.487528 seconds.
ans =
'[INFO] updating degradation parameter variance on mission: 23'
ans =
'[INFO] updating degradation parameter values via random sampling on mission: 23'
ans =
"[INFO] mission_id: 23 rul_hat: 18.00 flight_time: 17.64 distance: 1284.06 R0: 0.00256 Q: 15.19 Req: 0.29259"
ans =
'[INFO] success on mission 23'
[INFO] forecasting degradation values
ans =
'[INFO] simulating digital twin on mission: 23'
ans =
'[INFO] digital twin mission success on 23, rul_hat: 18.00 remains effective'
ans =
"[INFO] selecting trajectory: <3> with path_time: 17.83 that meets constraint: path_time < 18.00"
ans =
'[INFO] simulating true system on mission: 24'
Elapsed time is 217.912645 seconds.
ans =
'[INFO] updating degradation parameter variance on mission: 24'
ans =
'[INFO] updating degradation parameter values via random sampling on mission: 24'
ans =
"[INFO] mission_id: 24 rul_hat: 18.00 flight_time: 17.84 distance: 1302.32 R0: 0.00377 Q: 14.47 Req: 0.33638"
ans =
'[INFO] success on mission 24'
[INFO] forecasting degradation values
ans =
'[INFO] simulating digital twin on mission: 24'
ans =
'[INFO] digital twin mission success on 24, rul_hat: 18.00 remains effective'
ans =
"[INFO] selecting trajectory: <11> with path_time: 16.38 that meets constraint: path_time < 18.00"
ans =
'[INFO] simulating true system on mission: 25'
Elapsed time is 199.889365 seconds.
ans =
'[INFO] updating degradation parameter variance on mission: 25'
ans =
'[INFO] updating degradation parameter values via random sampling on mission: 25'
ans =
"[INFO] mission_id: 25 rul_hat: 18.00 flight_time: 16.37 distance: 1219.09 R0: 0.00389 Q: 14.68 Req: 0.32273"
ans =
'[INFO] success on mission 25'
[INFO] forecasting degradation values
ans =
'[INFO] simulating digital twin on mission: 25'
ans =
'[INFO] digital twin mission success on 25, rul_hat: 18.00 remains effective'
ans =
"[INFO] selecting trajectory: <11> with path_time: 16.38 that meets constraint: path_time < 18.00"
ans =
```

```
'[INFO] simulating true system on mission: 26'
Elapsed time is 201.615867 seconds.
ans =
'[INFO] updating degradation parameter variance on mission: 26'
ans =
'[INFO] updating degradation parameter values via random sampling on mission: 26'
ans =
"[INFO] mission_id: 26 rul_hat: 18.00 flight_time: 16.37 distance: 1219.08 R0: 0.00508 Q: 15.21 Req: 0.32779"
ans =
'[INFO] success on mission 26'
[INFO] forecasting degradation values
ans =
'[INFO] simulating digital twin on mission: 26'
ans =
'[INFO] digital twin mission success on 26, rul_hat: 18.00 remains effective'
ans =
"[INFO] selecting trajectory: <15> with path_time: 17.63 that meets constraint: path_time < 18.00"
ans =
'[INFO] simulating true system on mission: 27'
Elapsed time is 214.748752 seconds.
ans =
'[INFO] updating degradation parameter variance on mission: 27'
ans =
'[INFO] updating degradation parameter values via random sampling on mission: 27'
ans =
"[INFO] mission_id: 27 rul_hat: 18.00 flight_time: 17.64 distance: 1284.12 R0: 0.00645 Q: 14.17 Req: 0.34114"
ans =
'[INFO] success on mission 27'
[INFO] forecasting degradation values
ans =
'[INFO] simulating digital twin on mission: 27'
ans =
'[INFO] digital twin mission success on 27, rul_hat: 18.00 remains effective'
ans =
"[INFO] selecting trajectory: <11> with path_time: 16.38 that meets constraint: path_time < 18.00"
ans =
'[INFO] simulating true system on mission: 28'
Elapsed time is 199.417263 seconds.
ans =
'[INFO] updating degradation parameter variance on mission: 28'
ans =
'[INFO] updating degradation parameter values via random sampling on mission: 28'
ans =
"[INFO] mission_id: 28 rul_hat: 18.00 flight_time: 16.37 distance: 1219.06 R0: 0.00636 Q: 13.66 Req: 0.34412"
ans =
'[INFO] success on mission 28'
[INFO] forecasting degradation values
ans =
'[INFO] simulating digital twin on mission: 28'
ans =
'[INFO] digital twin mission success on 28, rul_hat: 18.00 remains effective'
ans =
"[INFO] selecting trajectory: <3> with path_time: 17.83 that meets constraint: path_time < 18.00"
ans =
'[INFO] simulating true system on mission: 29'
Elapsed time is 216.227244 seconds.
ans =
'[INFO] updating degradation parameter variance on mission: 29'
ans =
'[INFO] updating degradation parameter values via random sampling on mission: 29'
ans =
"[INFO] mission_id: 29 rul_hat: 18.00 flight_time: 17.84 distance: 1302.54 R0: 0.00633 Q: 14.22 Req: 0.37938"
ans =
'[INFO] success on mission 29'
[INFO] forecasting degradation values
```

```
ans =
'[INFO] simulating digital twin on mission: 29'
ans =
'[INFO] digital twin mission success on 29, rul_hat: 18.00 remains effective'
ans =
"[INFO] selecting trajectory: <11> with path_time: 16.38 that meets constraint: path_time < 18.00"
ans =
'[INFO] simulating true system on mission: 30'
Elapsed time is 200.197007 seconds.
ans =
'[INFO] updating degradation parameter variance on mission: 30'
ans =
'[INFO] updating degradation parameter values via random sampling on mission: 30'
ans =
"[INFO] mission_id: 30 rul_hat: 18.00 flight_time: 16.38 distance: 1219.48 R0: 0.00860 Q: 14.37 Req: 0.34582"
ans =
'[INFO] success on mission 30'
[INFO] forecasting degradation values
ans =
'[INFO] simulating digital twin on mission: 30'
ans =
'[INFO] digital twin mission success on 30, rul_hat: 18.00 remains effective'
ans =
"[INFO] selecting trajectory: <11> with path_time: 16.38 that meets constraint: path_time < 18.00"
ans =
'[INFO] simulating true system on mission: 31'
Elapsed time is 199.411438 seconds.
ans =
'[INFO] updating degradation parameter variance on mission: 31'
ans =
'[INFO] updating degradation parameter values via random sampling on mission: 31'
ans =
"[INFO] mission_id: 31 rul_hat: 18.00 flight_time: 16.37 distance: 1219.19 R0: 0.00864 Q: 14.26 Req: 0.35501"
ans =
'[INFO] success on mission 31'
[INFO] forecasting degradation values
ans =
'[INFO] simulating digital twin on mission: 31'
ans =
'[INFO] digital twin mission success on 31, rul_hat: 18.00 remains effective'
ans =
"[INFO] selecting trajectory: <3> with path_time: 17.83 that meets constraint: path_time < 18.00"
ans =
'[INFO] simulating true system on mission: 32'
Elapsed time is 216.982114 seconds.
ans =
'[INFO] updating degradation parameter variance on mission: 32'
ans =
'[INFO] updating degradation parameter values via random sampling on mission: 32'
ans =
"[INFO] mission_id: 32 rul_hat: 18.00 flight_time: 17.84 distance: 1302.54 R0: 0.00867 Q: 13.66 Req: 0.35884"
ans =
'[INFO] success on mission 32'
[INFO] forecasting degradation values
ans =
'[INFO] simulating digital twin on mission: 32'
ans =
'[INFO] digital twin mission success on 32, rul_hat: 18.00 remains effective'
ans =
"[INFO] selecting trajectory: <3> with path_time: 17.83 that meets constraint: path_time < 18.00"
ans =
'[INFO] simulating true system on mission: 33'
Elapsed time is 217.673982 seconds.
ans =
'[INFO] updating degradation parameter variance on mission: 33'
```

```
ans =
'[INFO] updating degradation parameter values via random sampling on mission: 33'
ans =
"[INFO] mission_id: 33 rul_hat: 18.00 flight_time: 17.85 distance: 1302.80 R0: 0.00919 Q: 13.93 Req: 0.35851"
ans =
'[INFO] success on mission 33'
[INFO] forecasting degradation values
ans =
'[INFO] simulating digital twin on mission: 33'
ans =
'[INFO] digital twin mission success on 33, rul_hat: 18.00 remains effective'
ans =
"[INFO] selecting trajectory: <3> with path_time: 17.83 that meets constraint: path_time < 18.00"
ans =
'[INFO] simulating true system on mission: 34'
Elapsed time is 216.863823 seconds.
ans =
'[INFO] updating degradation parameter variance on mission: 34'
ans =
'[INFO] updating degradation parameter values via random sampling on mission: 34'
ans =
"[INFO] mission_id: 34 rul_hat: 18.00 flight_time: 17.85 distance: 1302.79 R0: 0.01122 Q: 13.32 Req: 0.39496"
ans =
'[INFO] success on mission 34'
[INFO] forecasting degradation values
ans =
'[INFO] simulating digital twin on mission: 34'
ans =
'[INFO] digital twin mission success on 34, rul_hat: 18.00 remains effective'
ans =
"[INFO] selecting trajectory: <15> with path_time: 17.63 that meets constraint: path_time < 18.00"
ans =
'[INFO] simulating true system on mission: 35'
Elapsed time is 214.177196 seconds.
ans =
'[INFO] updating degradation parameter variance on mission: 35'
ans =
'[INFO] updating degradation parameter values via random sampling on mission: 35'
ans =
"[INFO] mission_id: 35 rul_hat: 18.00 flight_time: 17.64 distance: 1284.76 R0: 0.01220 Q: 13.13 Req: 0.38996"
ans =
'[INFO] success on mission 35'
[INFO] forecasting degradation values
ans =
'[INFO] simulating digital twin on mission: 35'
ans =
'[INFO] digital twin mission success on 35, rul_hat: 18.00 remains effective'
ans =
"[INFO] selecting trajectory: <3> with path_time: 17.83 that meets constraint: path_time < 18.00"
ans =
'[INFO] simulating true system on mission: 36'
Elapsed time is 216.430316 seconds.
ans =
'[INFO] updating degradation parameter variance on mission: 36'
ans =
'[INFO] updating degradation parameter values via random sampling on mission: 36'
ans =
"[INFO] mission_id: 36 rul_hat: 18.00 flight_time: 17.85 distance: 1302.81 R0: 0.01348 Q: 14.45 Req: 0.40564"
ans =
'[INFO] success on mission 36'
[INFO] forecasting degradation values
ans =
'[INFO] simulating digital twin on mission: 36'
ans =
'[INFO] digital twin mission success on 36, rul_hat: 18.00 remains effective'
```

```
ans =
"[INFO] selecting trajectory: <3> with path_time: 17.83 that meets constraint: path_time < 18.00"
ans =
'[INFO] simulating true system on mission: 37'
Elapsed time is 217.019936 seconds.
ans =
'[INFO] updating degradation parameter variance on mission: 37'
ans =
'[INFO] updating degradation parameter values via random sampling on mission: 37'
ans =
"[INFO] mission_id: 37 rul_hat: 18.00 flight_time: 17.85 distance: 1303.10 R0: 0.01551 Q: 14.03 Req: 0.42768"
ans =
'[INFO] success on mission 37'
[INFO] forecasting degradation values
ans =
'[INFO] simulating digital twin on mission: 37'
ans =
'[INFO] digital twin mission success on 37, rul_hat: 18.00 remains effective'
ans =
"[INFO] selecting trajectory: <11> with path_time: 16.38 that meets constraint: path_time < 18.00"
ans =
'[INFO] simulating true system on mission: 38'
Elapsed time is 199.070152 seconds.
ans =
'[INFO] updating degradation parameter variance on mission: 38'
ans =
'[INFO] updating degradation parameter values via random sampling on mission: 38'
ans =
"[INFO] mission_id: 38 rul_hat: 18.00 flight_time: 16.39 distance: 1220.09 R0: 0.01751 Q: 14.34 Req: 0.44650"
ans =
'[INFO] success on mission 38'
[INFO] forecasting degradation values
ans =
'[INFO] simulating digital twin on mission: 38'
ans =
'[INFO] digital twin mission success on 38, rul_hat: 18.00 remains effective'
ans =
"[INFO] selecting trajectory: <11> with path_time: 16.38 that meets constraint: path_time < 18.00"
ans =
'[INFO] simulating true system on mission: 39'
Elapsed time is 198.914201 seconds.
ans =
'[INFO] updating degradation parameter variance on mission: 39'
ans =
'[INFO] updating degradation parameter values via random sampling on mission: 39'
ans =
"[INFO] mission_id: 39 rul_hat: 18.00 flight_time: 16.39 distance: 1220.34 R0: 0.01880 Q: 13.40 Req: 0.44782"
ans =
'[INFO] success on mission 39'
[INFO] forecasting degradation values
ans =
'[INFO] simulating digital twin on mission: 39'
ans =
'[INFO] digital twin mission success on 39, rul_hat: 18.00 remains effective'
ans =
"[INFO] selecting trajectory: <3> with path_time: 17.83 that meets constraint: path_time < 18.00"
ans =
'[INFO] simulating true system on mission: 40'
Elapsed time is 216.723776 seconds.
ans =
'[INFO] updating degradation parameter variance on mission: 40'
ans =
'[INFO] updating degradation parameter values via random sampling on mission: 40'
ans =
"[INFO] mission_id: 40 rul_hat: 18.00 flight_time: 17.85 distance: 1303.34 R0: 0.02237 Q: 12.88 Req: 0.43324"
```

```
ans =
'[INFO] success on mission 40'
[INFO] forecasting degradation values
ans =
'[INFO] simulating digital twin on mission: 40'
ans =
'[INFO] digital twin mission success on 40, rul_hat: 18.00 remains effective'
ans =
"[INFO] selecting trajectory: <11> with path_time: 16.38 that meets constraint: path_time < 18.00"
ans =
'[INFO] simulating true system on mission: 41'
Elapsed time is 199.149350 seconds.
ans =
'[INFO] updating degradation parameter variance on mission: 41'
ans =
'[INFO] updating degradation parameter values via random sampling on mission: 41'
ans =
"[INFO] mission_id: 41 rul_hat: 18.00 flight_time: 16.39 distance: 1220.25 R0: 0.02493 Q: 12.41 Req: 0.47947"
ans =
'[INFO] success on mission 41'
[INFO] forecasting degradation values
ans =
'[INFO] simulating digital twin on mission: 41'
ans =
'[INFO] digital twin mission success on 41, rul_hat: 18.00 remains effective'
ans =
"[INFO] selecting trajectory: <11> with path_time: 16.38 that meets constraint: path_time < 18.00"
ans =
'[INFO] simulating true system on mission: 42'
Elapsed time is 199.341523 seconds.
ans =
'[INFO] updating degradation parameter variance on mission: 42'
ans =
'[INFO] updating degradation parameter values via random sampling on mission: 42'
ans =
"[INFO] mission_id: 42 rul_hat: 18.00 flight_time: 16.41 distance: 1220.86 R0: 0.02709 Q: 14.25 Req: 0.48491"
ans =
'[INFO] success on mission 42'
[INFO] forecasting degradation values
ans =
'[INFO] simulating digital twin on mission: 42'
ans =
'[INFO] digital twin mission success on 42, rul_hat: 18.00 remains effective'
ans =
"[INFO] selecting trajectory: <3> with path_time: 17.83 that meets constraint: path_time < 18.00"
ans =
'[INFO] simulating true system on mission: 43'
Bumping sigmax
Elapsed time is 216.213047 seconds.
ans =
'[INFO] updating degradation parameter variance on mission: 43'
ans =
'[INFO] updating degradation parameter values via random sampling on mission: 43'
ans =
"[INFO] mission_id: 43 rul_hat: 18.00 flight_time: 17.86 distance: 1303.88 R0: 0.02873 Q: 13.17 Req: 0.46986"
ans =
'[INFO] success on mission 43'
[INFO] forecasting degradation values
ans =
'[INFO] simulating digital twin on mission: 43'
ans =
'[INFO] digital twin mission success on 43, rul_hat: 18.00 remains effective'
ans =
"[INFO] selecting trajectory: <11> with path_time: 16.38 that meets constraint: path_time < 18.00"
ans =
```

```
'[INFO] simulating true system on mission: 44'
Bumping sigmax
Elapsed time is 199.344466 seconds.
ans =
'[INFO] updating degradation parameter variance on mission: 44'
ans =
'[INFO] updating degradation parameter values via random sampling on mission: 44'
ans =
"[INFO] mission_id: 44 rul_hat: 18.00 flight_time: 16.40 distance: 1220.46 R0: 0.03184 Q: 13.10 Req: 0.49816"
ans =
'[INFO] success on mission 44'
[INFO] forecasting degradation values
ans =
'[INFO] simulating digital twin on mission: 44'
ans =
'[INFO] digital twin mission success on 44, rul_hat: 18.00 remains effective'
ans =
"[INFO] selecting trajectory: <15> with path_time: 17.63 that meets constraint: path_time < 18.00"
ans =
'[INFO] simulating true system on mission: 45'
Bumping sigmax
Elapsed time is 133.133339 seconds.
ans =
'[INFO] updating degradation parameter variance on mission: 45'
ans =
'[INFO] updating degradation parameter values via random sampling on mission: 45'
ans =
"[INFO] mission_id: 45 rul_hat: 18.00 flight_time: 10.83 distance: 763.21 R0: 0.03588 Q: 12.06 Req: 0.52166"
ans =
'[INFO] true system position error threshold exceeded on mission 45'
[INFO] forecasting degradation values
ans =
'[INFO] simulating digital twin on mission: 45'
ans =
'[INFO] digital twin mission success on 45, rul_hat: 18.00 remains effective'
ans =
"[INFO] selecting trajectory: <15> with path_time: 17.63 that meets constraint: path_time < 18.00"
ans =
'[INFO] simulating true system on mission: 46'
Bumping sigmax
Elapsed time is 4.040007 seconds.
ans =
'[INFO] updating degradation parameter variance on mission: 46'
ans =
'[INFO] updating degradation parameter values via random sampling on mission: 46'
ans =
"[INFO] mission_id: 46 rul_hat: 18.00 flight_time: 0.05 distance: 3.38 R0: 0.03836 Q: 13.49 Req: 0.55192"
ans =
'[INFO] true system position error threshold exceeded on mission 46'
[INFO] forecasting degradation values
ans =
'[INFO] simulating digital twin on mission: 46'
ans =
'[INFO] digital twin mission success on 46, rul_hat: 18.00 remains effective'
ans =
"[INFO] selecting trajectory: <11> with path_time: 16.38 that meets constraint: path_time < 18.00"
ans =
'[INFO] simulating true system on mission: 47'
Bumping sigmax
Elapsed time is 83.239875 seconds.
ans =
'[INFO] updating degradation parameter variance on mission: 47'
ans =
'[INFO] updating degradation parameter values via random sampling on mission: 47'
ans =
```

```
"[INFO] mission_id: 47 rul_hat: 18.00 flight_time: 6.68 distance: 507.56 R0: 0.04222 Q: 12.53 Req: 0.56683"
ans =
'[INFO] true system position error threshold exceeded on mission 47'
[INFO] forecasting degradation values
ans =
'[INFO] simulating digital twin on mission: 47'
ans =
'[INFO] digital twin mission success on 47, rul_hat: 18.00 remains effective'
ans =
"[INFO] selecting trajectory: <11> with path_time: 16.38 that meets constraint: path_time < 18.00"
ans =
'[INFO] simulating true system on mission: 48'
Bumping sigmax
Elapsed time is 66.246839 seconds.
ans =
'[INFO] updating degradation parameter variance on mission: 48'
ans =
'[INFO] updating degradation parameter values via random sampling on mission: 48'
ans =
"[INFO] mission_id: 48 rul_hat: 18.00 flight_time: 5.15 distance: 447.96 R0: 0.04577 Q: 12.64 Req: 0.55832"
ans =
'[INFO] true system position error threshold exceeded on mission 48'
[INFO] forecasting degradation values
ans =
'[INFO] simulating digital twin on mission: 48'
ans =
'[INFO] digital twin mission success on 48, rul_hat: 18.00 remains effective'
ans =
"[INFO] selecting trajectory: <11> with path_time: 16.38 that meets constraint: path_time < 18.00"
ans =
'[INFO] simulating true system on mission: 49'
Bumping sigmax
Elapsed time is 63.005512 seconds.
ans =
'[INFO] updating degradation parameter variance on mission: 49'
ans =
'[INFO] updating degradation parameter values via random sampling on mission: 49'
ans =
"[INFO] mission_id: 49 rul_hat: 18.00 flight_time: 4.91 distance: 418.67 R0: 0.04862 Q: 12.29 Req: 0.56395"
ans =
'[INFO] true system position error threshold exceeded on mission 49'
[INFO] forecasting degradation values
ans =
'[INFO] simulating digital twin on mission: 49'
ans =
'[INFO] digital twin mission success on 49, rul_hat: 18.00 remains effective'
ans =
"[INFO] selecting trajectory: <11> with path_time: 16.38 that meets constraint: path_time < 18.00"
ans =
'[INFO] simulating true system on mission: 50'
Bumping sigmax
Elapsed time is 26.171033 seconds.
ans =
'[INFO] updating degradation parameter variance on mission: 50'
ans =
'[INFO] updating degradation parameter values via random sampling on mission: 50'
ans =
"[INFO] mission_id: 50 rul_hat: 18.00 flight_time: 1.87 distance: 157.20 R0: 0.05319 Q: 12.88 Req: 0.57842"
ans =
'[INFO] true system position error threshold exceeded on mission 50'
[INFO] forecasting degradation values
ans =
'[INFO] simulating digital twin on mission: 50'
ans =
'[INFO] digital twin mission success on 50, rul_hat: 18.00 remains effective'
```

```
ans =
"[INFO] selecting trajectory: <11> with path_time: 16.38 that meets constraint: path_time < 18.00"
ans =
'[INFO] simulating true system on mission: 51'
Bumping sigmax
Elapsed time is 4.237479 seconds.
ans =
'[INFO] updating degradation parameter variance on mission: 51'
ans =
'[INFO] updating degradation parameter values via random sampling on mission: 51'
ans =
"[INFO] mission_id: 51 rul_hat: 18.00 flight_time: 0.06 distance: 5.27 R0: 0.05824 Q: 13.51 Req: 0.60627"
ans =
'[INFO] true system position error threshold exceeded on mission 51'
[INFO] forecasting degradation values
ans =
'[INFO] simulating digital twin on mission: 51'
ans =
'[INFO] digital twin mission success on 51, rul_hat: 18.00 remains effective'
ans =
"[INFO] selecting trajectory: <15> with path_time: 17.63 that meets constraint: path_time < 18.00"
ans =
'[INFO] simulating true system on mission: 52'
Bumping sigmax
Elapsed time is 3.944267 seconds.
ans =
'[INFO] updating degradation parameter variance on mission: 52'
ans =
'[INFO] updating degradation parameter values via random sampling on mission: 52'
ans =
"[INFO] mission_id: 52 rul_hat: 18.00 flight_time: 0.03 distance: 4.10 R0: 0.06315 Q: 12.45 Req: 0.61681"
ans =
'[INFO] true system position error threshold exceeded on mission 52'
[INFO] forecasting degradation values
ans =
'[INFO] simulating digital twin on mission: 52'
ans =
'[INFO] digital twin position error threshold exceeded on mission 52'
ans =
'[INFO] digital twin rul_hat: 4.87 does not meet the threshold: 10.00 on mission 52'
```

********** end of simulation code

test sim digital twin (for testing)

```
i = 1;
sys = "DigitalTwin";
octomodel.sampletime = true_sample_rate;
sprintf('[INFO] simulating digital twin on mission: %d', i);
tic
sim('digitaltwin1c.slx');
toc
```

```
clear('trajectory', 'battery_actual', 'battery_observed', 'ctrl_err', 'current', 'current_rs',
```

test sim true system (for testing)

```
i = 1;
sys = "TrueSystem";
octomodel.sampletime = true_sample_rate;
sprintf('[INFO] simulating true system on mission: %d', i);
tic
sim('truesystem.slx');
toc
```