Table of Contents

```matlab
clc; clear all; close all;

%{
Matt Boler
Fundamentals of Nav and Guidance
HW2
%}
```
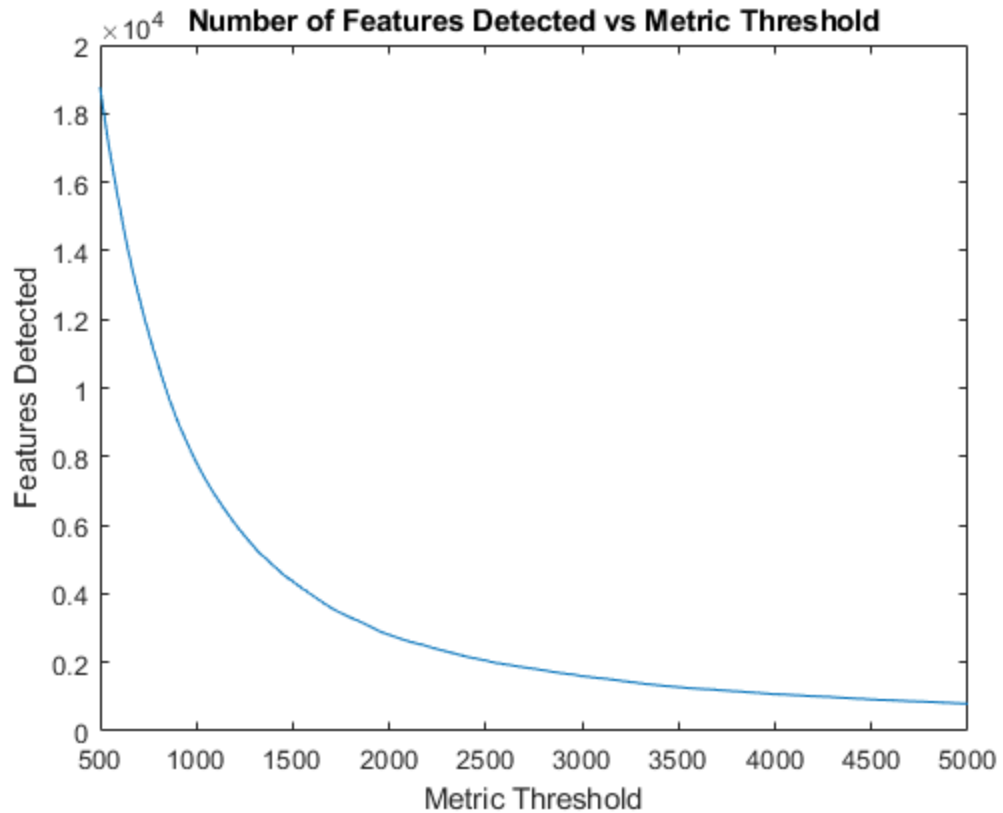
Problem 1

```matlab
p1_image = rgb2gray(imread('test-image.jpg'));
thresholds = linspace(500, 5000);
detections = zeros(size(thresholds));

for i = 1:size(thresholds,2)
    I = detectSURFFeatures(p1_image, 'MetricThreshold',
 thresholds(i));
    detections(1,i) = size(I,1);
    clear I;
end

figure(1)
plot(thresholds, detections);
title("Number of Features Detected vs Metric Threshold");
xlabel("Metric Threshold");
ylabel("Features Detected");
```

Number of Features Detected vs Metric Threshold

Problem 2

```
p2_im1 = rgb2gray(imread('Image_t0.jpg'));
p2_im2 = rgb2gray(imread('Image_t1.jpg'));

pts1 = detectSURFFeatures(p2_im1);
[f1, vpts1] = extractFeatures(p2_im1, pts1);

pts2 = detectSURFFeatures(p2_im2);
[f2, vpts2] = extractFeatures(p2_im2, pts2);

thresholds = linspace(1, 50, 1000);
ratios = linspace(0.01,1);

matches_1 = zeros(size(thresholds));

for i = 1:size(thresholds, 2)
    idxPairs = matchFeatures(f1, f2, 'Unique', true, 'MatchThreshold',
 thresholds(i));
    matches_1(1,i) = size(vpts1(idxPairs(:,1)), 1);
end

figure(2)
plot(thresholds, matches_1);
title("Number of Features Matched vs Match Threshold");
```
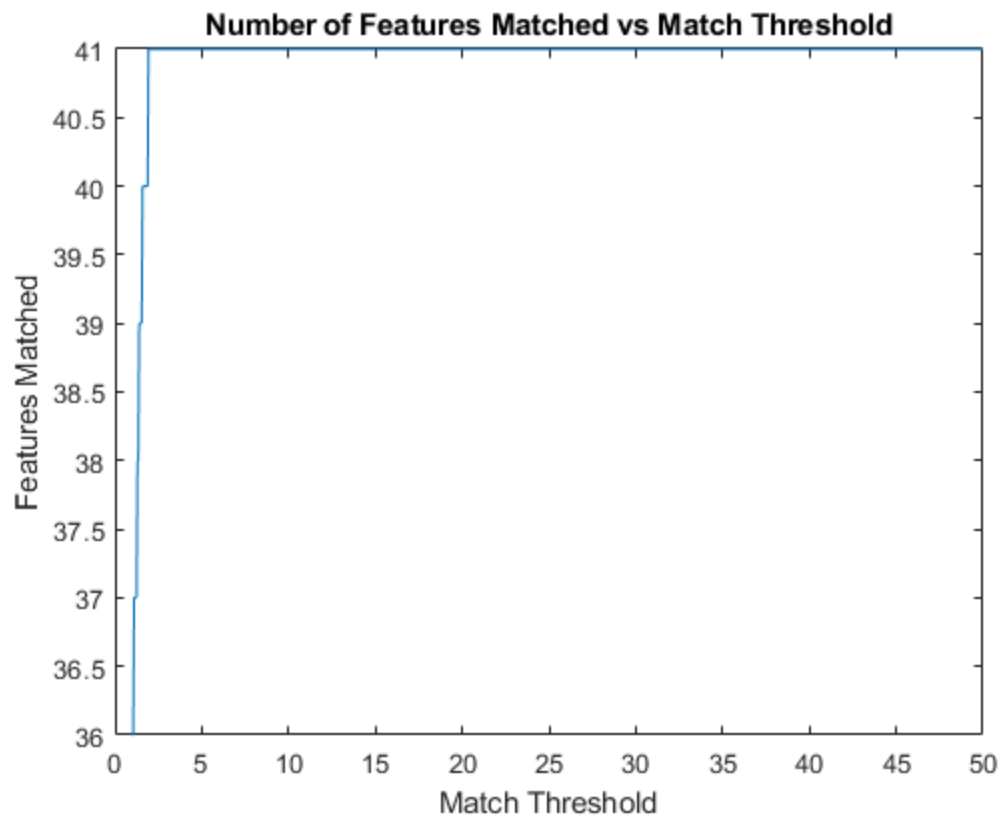
```matlab
xlabel("Match Threshold");
ylabel("Features Matched");

matches_2 = zeros(size(matches_1));

for i = 1:size(ratios, 2)
    idxPairs = matchFeatures(f1, f2, 'Unique', true, 'MaxRatio',
 ratios(i));
    matches_2(1,i) = size(vpts1(idxPairs(:,1)),1);
end

figure(3)
plot(thresholds, matches_2);
title("Number of Features Matched vs Max Ratio");
xlabel("Max Ratio");
ylabel("Features Matched");
```
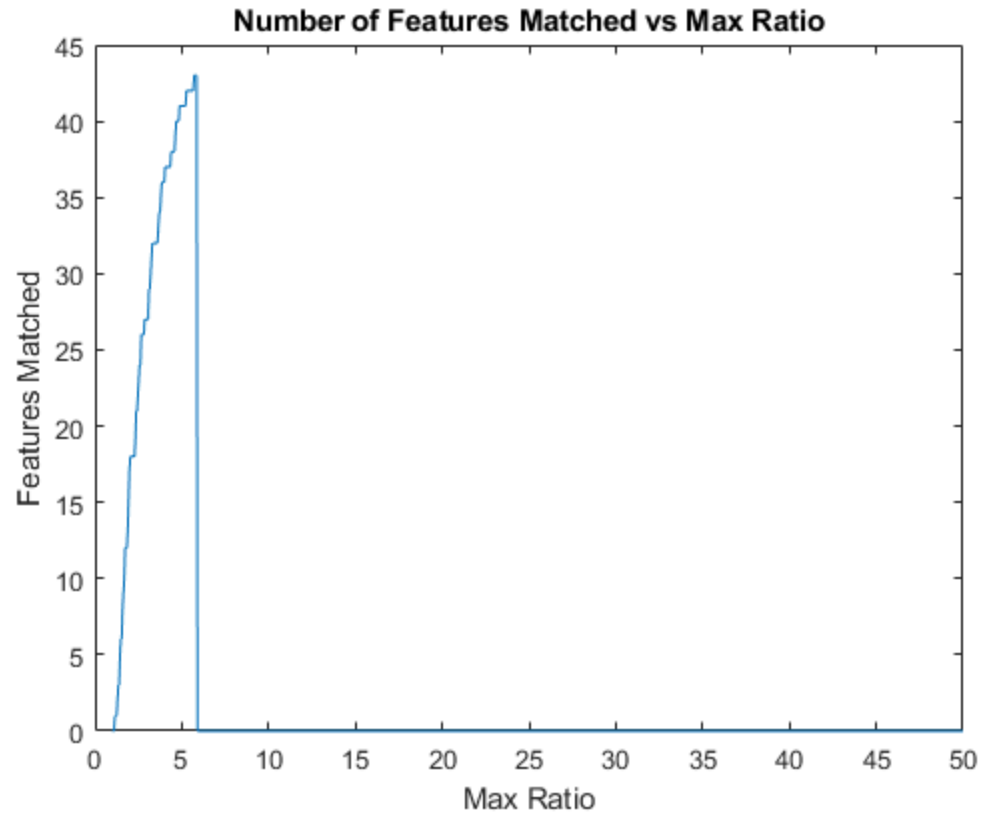
Number of Features Matched vs Max Ratio

Problem 3

```matlab
p3_im1 = rgb2gray(imread('reference_map.jpg'));
p3_im2 = rgb2gray(imread('img_132.png'));

max_features_matched = -1;
best_det_thresh = -1;
best_match_thresh = -1;
best_match_ratio = -1;

det_thresholds = linspace(500, 2000, 10);
match_thresholds = linspace(1, 10, 10);
match_ratios = linspace(0.01,1, 10);

for i = 1:size(det_thresholds, 2)
    det_thresh = det_thresholds(i);
    pts1 = detectSURFFeatures(p3_im1, 'MetricThreshold', det_thresh);
    [f1, vpts1] = extractFeatures(p3_im1, pts1);

    pts2 = detectSURFFeatures(p3_im2, 'MetricThreshold', det_thresh);
    [f2, vpts2] = extractFeatures(p3_im2, pts2);

    for j = 1:size(match_thresholds, 2)
        match_thresh = match_thresholds(j);
        for k = 1:size(match_ratios, 2)
```

```matlab
            match_ratio = match_ratios(k);

            % Test parameters
            idxPairs = matchFeatures(f1, f2, 'Unique',
 true, 'MatchThreshold', match_thresh, 'MaxRatio', match_ratio);
            temp_matches = size(vpts1(idxPairs(:,1)), 1);

            if temp_matches > max_features_matched
                max_features_matched  = temp_matches;
                best_det_thresh = det_thresh;
                best_match_thresh = match_thresh;
                best_match_ratio = match_ratio;
            end

        end
    end
end

disp("Best Detection Threshold: ")
disp(best_det_thresh)
disp("Best Matching Threshold: ")
disp(best_match_thresh)
disp("Best Matching Ratio: ")
disp(best_match_ratio)
disp("Features Matched: ")
disp(max_features_matched)
```

Best Detection Threshold:
*   500*

Best Matching Threshold:
*   4*

Best Matching Ratio:
*   1*

Features Matched:
*   472*

Bonus

```matlab
p3_im1 = rgb2gray(imread('Image_t0.jpg'));
p3_im2 = rgb2gray(imread('Image_t1.jpg'));

max_features_matched = -1;
best_det_thresh = -1;
best_match_thresh = -1;
best_match_ratio = -1;

det_thresholds = linspace(500, 2000, 10);
match_thresholds = linspace(1, 10, 10);
match_ratios = linspace(0.01,1, 10);
```

```matlab
for i = 1:size(det_thresholds, 2)
    det_thresh = det_thresholds(i);
    pts1 = detectSURFFeatures(p3_im1, 'MetricThreshold', det_thresh);
    [f1, vpts1] = extractFeatures(p3_im1, pts1);

    pts2 = detectSURFFeatures(p3_im2, 'MetricThreshold', det_thresh);
    [f2, vpts2] = extractFeatures(p3_im2, pts2);

    for j = 1:size(match_thresholds, 2)
        match_thresh = match_thresholds(j);
        for k = 1:size(match_ratios, 2)
            match_ratio = match_ratios(k);

            % Test parameters
            [idxPairs, metric] = matchFeatures(f1, f2, 'Unique', ...
 true, 'MatchThreshold', match_thresh, 'MaxRatio', match_ratio);
            temp_matches = size(vpts1(idxPairs(:,1)), 1);
            temp_avg_metric = sum(metric) / temp_matches

            if temp_matches > max_features_matched
                max_features_matched  = temp_matches;
                best_det_thresh = det_thresh;
                best_match_thresh = match_thresh;
                best_match_ratio = match_ratio;
            end

        end
    end
end

disp("BONUS")

disp("Best Detection Threshold: ")
disp(best_det_thresh)
disp("Best Matching Threshold: ")
disp(best_match_thresh)
disp("Best Matching Ratio: ")
disp(best_match_ratio)
disp("Features Matched: ")
disp(max_features_matched)


temp_avg_metric =

  single

    NaN


temp_avg_metric =

  single
```

0.0127

temp_avg_metric =

  single

    0.0145

temp_avg_metric =

  single

    0.0159

temp_avg_metric =

  single

    0.0177

temp_avg_metric =

  single

    0.0202

temp_avg_metric =

  single

    0.0214

temp_avg_metric =

  single

    0.0222

temp_avg_metric =

  single

    0.0224

temp_avg_metric =

single

0.0226

temp_avg_metric =

single

NaN

temp_avg_metric =

single

0.0127

temp_avg_metric =

single

0.0158

temp_avg_metric =

single

0.0185

temp_avg_metric =

single

0.0218

temp_avg_metric =

single

0.0253

temp_avg_metric =

single

0.0308

```
temp_avg_metric =

   single

      0.0351


temp_avg_metric =

   single

      0.0391


temp_avg_metric =

   single

      0.0417


temp_avg_metric =

   single

       NaN


temp_avg_metric =

   single

      0.0127


temp_avg_metric =

   single

      0.0158


temp_avg_metric =

   single

      0.0185


temp_avg_metric =

   single

      0.0218
```

```
temp_avg_metric =

  single

    0.0253


temp_avg_metric =

  single

    0.0314


temp_avg_metric =

  single

    0.0361


temp_avg_metric =

  single

    0.0428


temp_avg_metric =

  single

    0.0460


temp_avg_metric =

  single

   NaN


temp_avg_metric =

  single

    0.0127


temp_avg_metric =

  single
```

0.0158

temp_avg_metric =

  single

    0.0185

temp_avg_metric =

  single

    0.0218

temp_avg_metric =

  single

    0.0253

temp_avg_metric =

  single

    0.0323

temp_avg_metric =

  single

    0.0376

temp_avg_metric =

  single

    0.0438

temp_avg_metric =

  single

    0.0469

temp_avg_metric =

```
single

   NaN


temp_avg_metric =

   single

      0.0127


temp_avg_metric =

   single

      0.0158


temp_avg_metric =

   single

      0.0185


temp_avg_metric =

   single

      0.0218


temp_avg_metric =

   single

      0.0253


temp_avg_metric =

   single

      0.0323


temp_avg_metric =

   single

      0.0376
```

```
temp_avg_metric =

  single

    0.0438


temp_avg_metric =

  single

    0.0469


temp_avg_metric =

  single

   NaN


temp_avg_metric =

  single

    0.0127


temp_avg_metric =

  single

    0.0158


temp_avg_metric =

  single

    0.0185


temp_avg_metric =

  single

    0.0218


temp_avg_metric =

  single
```

0.0253

temp_avg_metric =

  single

   0.0323

temp_avg_metric =

  single

   0.0376

temp_avg_metric =

  single

   0.0438

temp_avg_metric =

  single

    0.0469

temp_avg_metric =

  single

   NaN

temp_avg_metric =

  single

    0.0127

temp_avg_metric =

  single

   0.0158

temp_avg_metric =

```
single

  0.0185


temp_avg_metric =

  single

    0.0218


temp_avg_metric =

  single

    0.0253


temp_avg_metric =

  single

    0.0323


temp_avg_metric =

  single

    0.0376


temp_avg_metric =

  single

    0.0438


temp_avg_metric =

  single

    0.0469


temp_avg_metric =

  single

   NaN
```

```
temp_avg_metric =

  single

    0.0127


temp_avg_metric =

  single

    0.0158


temp_avg_metric =

  single

    0.0185


temp_avg_metric =

  single

    0.0218


temp_avg_metric =

  single

    0.0253


temp_avg_metric =

  single

    0.0323


temp_avg_metric =

  single

    0.0376


temp_avg_metric =

  single

    0.0438
```

```
temp_avg_metric =

  single

    0.0469


temp_avg_metric =

  single

   NaN


temp_avg_metric =

  single

    0.0127


temp_avg_metric =

  single

    0.0158


temp_avg_metric =

  single

    0.0185


temp_avg_metric =

  single

    0.0218


temp_avg_metric =

  single

    0.0253


temp_avg_metric =

  single
```

0.0323

temp_avg_metric =

single

0.0376

temp_avg_metric =

single

0.0438

temp_avg_metric =

single

0.0469

temp_avg_metric =

single

NaN

temp_avg_metric =

single

0.0127

temp_avg_metric =

single

0.0158

temp_avg_metric =

single

0.0185

temp_avg_metric =

single

0.0218

temp_avg_metric =

single

0.0253

temp_avg_metric =

single

0.0323

temp_avg_metric =

single

0.0376

temp_avg_metric =

single

0.0438

temp_avg_metric =

single

0.0469

temp_avg_metric =

single

NaN

temp_avg_metric =

single

0.0118

```
temp_avg_metric =

  single

    0.0123


temp_avg_metric =

  single

    0.0156


temp_avg_metric =

  single

    0.0176


temp_avg_metric =

  single

    0.0207


temp_avg_metric =

  single

    0.0219


temp_avg_metric =

  single

    0.0226


temp_avg_metric =

  single

    0.0227


temp_avg_metric =

  single
```

```
     0.0229


temp_avg_metric =

  single

   NaN


temp_avg_metric =

  single

    0.0118


temp_avg_metric =

  single

    0.0123


temp_avg_metric =

  single

    0.0167


temp_avg_metric =

  single

    0.0193


temp_avg_metric =

  single

    0.0229


temp_avg_metric =

  single

    0.0307


temp_avg_metric =
```

single

   0.0356

temp_avg_metric =

  single

   0.0395

temp_avg_metric =

  single

   0.0416

temp_avg_metric =

  single

   NaN

temp_avg_metric =

  single

   0.0118

temp_avg_metric =

  single

   0.0123

temp_avg_metric =

  single

   0.0167

temp_avg_metric =

  single

   0.0193

```
temp_avg_metric =

  single

    0.0229


temp_avg_metric =

  single

    0.0307


temp_avg_metric =

  single

    0.0356


temp_avg_metric =

  single

    0.0421


temp_avg_metric =

  single

    0.0456


temp_avg_metric =

  single

   NaN


temp_avg_metric =

  single

    0.0118


temp_avg_metric =

  single

    0.0123
```

```
temp_avg_metric =

  single

    0.0167


temp_avg_metric =

  single

    0.0193


temp_avg_metric =

  single

    0.0229


temp_avg_metric =

  single

    0.0319


temp_avg_metric =

  single

    0.0366


temp_avg_metric =

  single

    0.0427


temp_avg_metric =

  single

    0.0461


temp_avg_metric =

  single
```

NaN

temp_avg_metric =

  single

    0.0118

temp_avg_metric =

  single

    0.0123

temp_avg_metric =

  single

    0.0167

temp_avg_metric =

  single

    0.0193

temp_avg_metric =

  single

    0.0229

temp_avg_metric =

  single

    0.0319

temp_avg_metric =

  single

    0.0366

temp_avg_metric =

```
single

  0.0427


temp_avg_metric =

  single

    0.0461


temp_avg_metric =

  single

    NaN


temp_avg_metric =

  single

    0.0118


temp_avg_metric =

  single

    0.0123


temp_avg_metric =

  single

    0.0167


temp_avg_metric =

  single

    0.0193


temp_avg_metric =

  single

    0.0229
```

```
temp_avg_metric =

  single

    0.0319


temp_avg_metric =

  single

    0.0366


temp_avg_metric =

  single

    0.0427


temp_avg_metric =

  single

    0.0461


temp_avg_metric =

  single

   NaN


temp_avg_metric =

  single

    0.0118


temp_avg_metric =

  single

    0.0123


temp_avg_metric =

  single
```

0.0167

temp_avg_metric =

  single

    0.0193

temp_avg_metric =

  single

    0.0229

temp_avg_metric =

  single

    0.0319

temp_avg_metric =

  single

    0.0366

temp_avg_metric =

  single

    0.0427

temp_avg_metric =

  single

    0.0461

temp_avg_metric =

  single

   NaN

temp_avg_metric =

single

    0.0118

temp_avg_metric =

  single

    0.0123

temp_avg_metric =

  single

    0.0167

temp_avg_metric =

  single

    0.0193

temp_avg_metric =

  single

    0.0229

temp_avg_metric =

  single

    0.0319

temp_avg_metric =

  single

    0.0366

temp_avg_metric =

  single

    0.0427

```
temp_avg_metric =

    single

        0.0461


temp_avg_metric =

    single

        NaN


temp_avg_metric =

    single

        0.0118


temp_avg_metric =

    single

        0.0123


temp_avg_metric =

    single

        0.0167


temp_avg_metric =

    single

        0.0193


temp_avg_metric =

    single

        0.0229


temp_avg_metric =

    single

        0.0319
```

```
temp_avg_metric =

   single

      0.0366


temp_avg_metric =

   single

      0.0427


temp_avg_metric =

   single

      0.0461


temp_avg_metric =

   single

       NaN


temp_avg_metric =

   single

      0.0118


temp_avg_metric =

   single

      0.0123


temp_avg_metric =

   single

      0.0167


temp_avg_metric =

   single
```

0.0193

temp_avg_metric =

  single

    0.0229

temp_avg_metric =

  single

    0.0319

temp_avg_metric =

  single

    0.0366

temp_avg_metric =

  single

    0.0427

temp_avg_metric =

  single

    0.0461

temp_avg_metric =

  single

    NaN

temp_avg_metric =

  single

    0.0132

temp_avg_metric =

single

   0.0130

temp_avg_metric =

   single

   0.0174

temp_avg_metric =

   single

   0.0185

temp_avg_metric =

   single

   0.0218

temp_avg_metric =

   single

   0.0228

temp_avg_metric =

   single

   0.0237

temp_avg_metric =

   single

   0.0237

temp_avg_metric =

   single

   0.0240

```
temp_avg_metric =

  single

    NaN


temp_avg_metric =

  single

    0.0132


temp_avg_metric =

  single

    0.0130


temp_avg_metric =

  single

    0.0187


temp_avg_metric =

  single

    0.0215


temp_avg_metric =

  single

    0.0263


temp_avg_metric =

  single

    0.0335


temp_avg_metric =

  single
```

0.0375

temp_avg_metric =

  single

    0.0422

temp_avg_metric =

  single

    0.0435

temp_avg_metric =

  single

    NaN

temp_avg_metric =

  single

    0.0132

temp_avg_metric =

  single

    0.0130

temp_avg_metric =

  single

    0.0187

temp_avg_metric =

  single

    0.0215

temp_avg_metric =

single

   0.0263

temp_avg_metric =

  single

   0.0335

temp_avg_metric =

  single

   0.0375

temp_avg_metric =

  single

   0.0441

temp_avg_metric =

  single

   0.0483

temp_avg_metric =

  single

   NaN

temp_avg_metric =

  single

   0.0132

temp_avg_metric =

  single

   0.0130

```
temp_avg_metric =

  single

    0.0187


temp_avg_metric =

  single

    0.0215


temp_avg_metric =

  single

    0.0263


temp_avg_metric =

  single

    0.0350


temp_avg_metric =

  single

    0.0387


temp_avg_metric =

  single

    0.0449


temp_avg_metric =

  single

    0.0489


temp_avg_metric =

  single

   NaN
```

```
temp_avg_metric =

   single

      0.0132


temp_avg_metric =

   single

      0.0130


temp_avg_metric =

   single

      0.0187


temp_avg_metric =

   single

      0.0215


temp_avg_metric =

   single

      0.0263


temp_avg_metric =

   single

      0.0350


temp_avg_metric =

   single

      0.0387


temp_avg_metric =

   single
```

0.0449

temp_avg_metric =

  single

   0.0489

temp_avg_metric =

  single

  NaN

temp_avg_metric =

  single

   0.0132

temp_avg_metric =

  single

   0.0130

temp_avg_metric =

  single

   0.0187

temp_avg_metric =

  single

   0.0215

temp_avg_metric =

  single

   0.0263

temp_avg_metric =

```
     single

       0.0350


temp_avg_metric =

   single

     0.0387


temp_avg_metric =

   single

     0.0449


temp_avg_metric =

   single

       0.0489


temp_avg_metric =

   single

    NaN


temp_avg_metric =

   single

       0.0132


temp_avg_metric =

   single

     0.0130


temp_avg_metric =

   single

     0.0187
```

```
temp_avg_metric =

  single

    0.0215


temp_avg_metric =

  single

    0.0263


temp_avg_metric =

  single

    0.0350


temp_avg_metric =

  single

    0.0387


temp_avg_metric =

  single

    0.0449


temp_avg_metric =

  single

    0.0489


temp_avg_metric =

  single

   NaN


temp_avg_metric =

  single
```

0.0132

temp_avg_metric =

single

0.0130

temp_avg_metric =

single

0.0187

temp_avg_metric =

single

0.0215

temp_avg_metric =

single

0.0263

temp_avg_metric =

single

0.0350

temp_avg_metric =

single

0.0387

temp_avg_metric =

single

0.0449

temp_avg_metric =

single

    0.0489

temp_avg_metric =

  single

   NaN

temp_avg_metric =

  single

    0.0132

temp_avg_metric =

  single

    0.0130

temp_avg_metric =

  single

    0.0187

temp_avg_metric =

  single

    0.0215

temp_avg_metric =

  single

    0.0263

temp_avg_metric =

  single

    0.0350

```
temp_avg_metric =

  single

    0.0387


temp_avg_metric =

  single

    0.0449


temp_avg_metric =

  single

    0.0489


temp_avg_metric =

  single

   NaN


temp_avg_metric =

  single

    0.0132


temp_avg_metric =

  single

    0.0130


temp_avg_metric =

  single

    0.0187


temp_avg_metric =

  single

    0.0215
```

```
temp_avg_metric =

  single

    0.0263


temp_avg_metric =

  single

    0.0350


temp_avg_metric =

  single

    0.0387


temp_avg_metric =

  single

    0.0449


temp_avg_metric =

  single

    0.0489


temp_avg_metric =

  single

   NaN


temp_avg_metric =

  single

    0.0123


temp_avg_metric =

  single
```

0.0135

temp_avg_metric =

  single

    0.0171

temp_avg_metric =

  single

    0.0185

temp_avg_metric =

  single

    0.0207

temp_avg_metric =

  single

    0.0216

temp_avg_metric =

  single

    0.0227

temp_avg_metric =

  single

    0.0228

temp_avg_metric =

  single

    0.0231

temp_avg_metric =

```
single

  NaN


temp_avg_metric =

  single

    0.0123


temp_avg_metric =

  single

    0.0135


temp_avg_metric =

  single

    0.0186


temp_avg_metric =

  single

    0.0210


temp_avg_metric =

  single

    0.0242


temp_avg_metric =

  single

    0.0316


temp_avg_metric =

  single

    0.0369
```

```
temp_avg_metric =

    single

        0.0414


temp_avg_metric =

    single

        0.0431


temp_avg_metric =

    single

        NaN


temp_avg_metric =

    single

        0.0123


temp_avg_metric =

    single

        0.0135


temp_avg_metric =

    single

        0.0186


temp_avg_metric =

    single

        0.0210


temp_avg_metric =

    single
```

0.0242

temp_avg_metric =

single

0.0328

temp_avg_metric =

single

0.0377

temp_avg_metric =

single

0.0438

temp_avg_metric =

single

0.0475

temp_avg_metric =

single

NaN

temp_avg_metric =

single

0.0123

temp_avg_metric =

single

0.0135

temp_avg_metric =

single

   0.0186

temp_avg_metric =

   single

   0.0210

temp_avg_metric =

   single

   0.0242

temp_avg_metric =

   single

   0.0348

temp_avg_metric =

   single

   0.0391

temp_avg_metric =

   single

   0.0448

temp_avg_metric =

   single

   0.0483

temp_avg_metric =

   single

   NaN

```
temp_avg_metric =

   single

     0.0123


temp_avg_metric =

   single

     0.0135


temp_avg_metric =

   single

     0.0186


temp_avg_metric =

   single

     0.0210


temp_avg_metric =

   single

     0.0242


temp_avg_metric =

   single

     0.0348


temp_avg_metric =

   single

     0.0391


temp_avg_metric =

   single

     0.0448
```

```
temp_avg_metric =

  single

    0.0483


temp_avg_metric =

  single

   NaN


temp_avg_metric =

  single

    0.0123


temp_avg_metric =

  single

    0.0135


temp_avg_metric =

  single

    0.0186


temp_avg_metric =

  single

    0.0210


temp_avg_metric =

  single

    0.0242


temp_avg_metric =

  single
```

0.0348

temp_avg_metric =

  single

    0.0391

temp_avg_metric =

  single

    0.0448

temp_avg_metric =

  single

    0.0483

temp_avg_metric =

  single

    NaN

temp_avg_metric =

  single

    0.0123

temp_avg_metric =

  single

    0.0135

temp_avg_metric =

  single

    0.0186

temp_avg_metric =

single

    0.0210

temp_avg_metric =

  single

    0.0242

temp_avg_metric =

  single

    0.0348

temp_avg_metric =

  single

    0.0391

temp_avg_metric =

  single

    0.0448

temp_avg_metric =

  single

    0.0483

temp_avg_metric =

  single

   NaN

temp_avg_metric =

  single

    0.0123

```
temp_avg_metric =

  single

    0.0135


temp_avg_metric =

  single

    0.0186


temp_avg_metric =

  single

    0.0210


temp_avg_metric =

  single

    0.0242


temp_avg_metric =

  single

    0.0348


temp_avg_metric =

  single

    0.0391


temp_avg_metric =

  single

    0.0448


temp_avg_metric =

  single
```

```
    0.0483


temp_avg_metric =

  single

    NaN


temp_avg_metric =

  single

    0.0123


temp_avg_metric =

  single

    0.0135


temp_avg_metric =

  single

    0.0186


temp_avg_metric =

  single

    0.0210


temp_avg_metric =

  single

    0.0242


temp_avg_metric =

  single

    0.0348


temp_avg_metric =
```

single

   0.0391

temp_avg_metric =

   single

   0.0448

temp_avg_metric =

   single

   0.0483

temp_avg_metric =

   single

   NaN

temp_avg_metric =

   single

   0.0123

temp_avg_metric =

   single

   0.0135

temp_avg_metric =

   single

   0.0186

temp_avg_metric =

   single

   0.0210

```
temp_avg_metric =

  single

    0.0242


temp_avg_metric =

  single

    0.0348


temp_avg_metric =

  single

    0.0391


temp_avg_metric =

  single

    0.0448


temp_avg_metric =

  single

    0.0483


temp_avg_metric =

  single

    NaN


temp_avg_metric =

  single

    0.0162


temp_avg_metric =

  single

    0.0147
```

```
temp_avg_metric =

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    0.0180


temp_avg_metric =

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    0.0183


temp_avg_metric =

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    0.0195


temp_avg_metric =

  single

    0.0215


temp_avg_metric =

  single

    0.0219


temp_avg_metric =

  single

    0.0216


temp_avg_metric =

  single

    0.0220


temp_avg_metric =

  single
```

NaN

temp_avg_metric =

  single

    0.0162

temp_avg_metric =

  single

    0.0170

temp_avg_metric =

  single

    0.0221

temp_avg_metric =

  single

    0.0235

temp_avg_metric =

  single

    0.0252

temp_avg_metric =

  single

    0.0325

temp_avg_metric =

  single

    0.0368

temp_avg_metric =

single

   0.0415

temp_avg_metric =

  single

   0.0434

temp_avg_metric =

  single

  NaN

temp_avg_metric =

  single

   0.0162

temp_avg_metric =

  single

   0.0170

temp_avg_metric =

  single

   0.0221

temp_avg_metric =

  single

   0.0235

temp_avg_metric =

  single

   0.0252

```
temp_avg_metric =

  single

    0.0325


temp_avg_metric =

  single

    0.0368


temp_avg_metric =

  single

    0.0430


temp_avg_metric =

  single

    0.0500


temp_avg_metric =

  single

    NaN


temp_avg_metric =

  single

    0.0162


temp_avg_metric =

  single

    0.0170


temp_avg_metric =

  single
```

0.0221

temp_avg_metric =

  single

    0.0235

temp_avg_metric =

  single

    0.0252

temp_avg_metric =

  single

    0.0325

temp_avg_metric =

  single

    0.0368

temp_avg_metric =

  single

    0.0430

temp_avg_metric =

  single

    0.0500

temp_avg_metric =

  single

   NaN

temp_avg_metric =

single

    0.0162

temp_avg_metric =

  single

    0.0170

temp_avg_metric =

  single

    0.0221

temp_avg_metric =

  single

    0.0235

temp_avg_metric =

  single

    0.0252

temp_avg_metric =

  single

    0.0325

temp_avg_metric =

  single

    0.0368

temp_avg_metric =

  single

    0.0430

```
temp_avg_metric =

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      0.0500


temp_avg_metric =

    single

      NaN


temp_avg_metric =

    single

      0.0162


temp_avg_metric =

    single

      0.0170


temp_avg_metric =

    single

      0.0221


temp_avg_metric =

    single

      0.0235


temp_avg_metric =

    single

      0.0252


temp_avg_metric =

    single

      0.0325
```

```
temp_avg_metric =

  single

    0.0368


temp_avg_metric =

  single

    0.0430


temp_avg_metric =

  single

    0.0500


temp_avg_metric =

  single

   NaN


temp_avg_metric =

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    0.0162


temp_avg_metric =

  single

    0.0170


temp_avg_metric =

  single

    0.0221


temp_avg_metric =

  single
```

0.0235

temp_avg_metric =

  single

   0.0252

temp_avg_metric =

  single

   0.0325

temp_avg_metric =

  single

   0.0368

temp_avg_metric =

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   0.0430

temp_avg_metric =

  single

   0.0500

temp_avg_metric =

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  NaN

temp_avg_metric =

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   0.0162

temp_avg_metric =

single

   0.0170

temp_avg_metric =

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   0.0221

temp_avg_metric =

   single

   0.0235

temp_avg_metric =

   single

   0.0252

temp_avg_metric =

   single

   0.0325

temp_avg_metric =

   single

   0.0368

temp_avg_metric =

   single

   0.0430

temp_avg_metric =

   single

   0.0500

```
temp_avg_metric =

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    NaN


temp_avg_metric =

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    0.0162


temp_avg_metric =

  single

    0.0170


temp_avg_metric =

  single

    0.0221


temp_avg_metric =

  single

    0.0235


temp_avg_metric =

  single

    0.0252


temp_avg_metric =

  single

    0.0325


temp_avg_metric =

  single
```

0.0368

temp_avg_metric =

single

0.0430

temp_avg_metric =

single

0.0500

temp_avg_metric =

single

NaN

temp_avg_metric =

single

0.0162

temp_avg_metric =

single

0.0170

temp_avg_metric =

single

0.0221

temp_avg_metric =

single

0.0235

temp_avg_metric =

single

   0.0252

temp_avg_metric =

   single

      0.0325

temp_avg_metric =

   single

      0.0368

temp_avg_metric =

   single

      0.0430

temp_avg_metric =

   single

      0.0500

temp_avg_metric =

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      NaN

temp_avg_metric =

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      0.0162

temp_avg_metric =

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      0.0150

```
temp_avg_metric =

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    0.0185


temp_avg_metric =

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    0.0187


temp_avg_metric =

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    0.0199


temp_avg_metric =

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    0.0206


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    0.0212


temp_avg_metric =

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    0.0208


temp_avg_metric =

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    0.0214


temp_avg_metric =

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    NaN
```

```
temp_avg_metric =

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    0.0162


temp_avg_metric =

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    0.0175


temp_avg_metric =

  single

    0.0226


temp_avg_metric =

  single

    0.0225


temp_avg_metric =

  single

    0.0258


temp_avg_metric =

  single

    0.0315


temp_avg_metric =

  single

    0.0356


temp_avg_metric =

  single
```

```
      0.0403


temp_avg_metric =

  single

    0.0431


temp_avg_metric =

  single

   NaN


temp_avg_metric =

  single

    0.0162


temp_avg_metric =

  single

    0.0175


temp_avg_metric =

  single

    0.0226


temp_avg_metric =

  single

    0.0225


temp_avg_metric =

  single

    0.0258


temp_avg_metric =
```

single

   0.0315

temp_avg_metric =

  single

   0.0356

temp_avg_metric =

  single

   0.0430

temp_avg_metric =

  single

   0.0489

temp_avg_metric =

  single

   NaN

temp_avg_metric =

  single

   0.0162

temp_avg_metric =

  single

   0.0175

temp_avg_metric =

  single

   0.0226

```
temp_avg_metric =

  single

    0.0225


temp_avg_metric =

  single

    0.0258


temp_avg_metric =

  single

    0.0315


temp_avg_metric =

  single

    0.0356


temp_avg_metric =

  single

    0.0430


temp_avg_metric =

  single

    0.0489


temp_avg_metric =

  single

   NaN


temp_avg_metric =

  single
```

0.0162

temp_avg_metric =

single

0.0175

temp_avg_metric =

single

0.0226

temp_avg_metric =

single

0.0225

temp_avg_metric =

single

0.0258

temp_avg_metric =

single

0.0315

temp_avg_metric =

single

0.0356

temp_avg_metric =

single

0.0430

temp_avg_metric =

single

    0.0489

temp_avg_metric =

  single

   NaN

temp_avg_metric =

  single

    0.0162

temp_avg_metric =

  single

    0.0175

temp_avg_metric =

  single

    0.0226

temp_avg_metric =

  single

    0.0225

temp_avg_metric =

  single

    0.0258

temp_avg_metric =

  single

    0.0315

```
temp_avg_metric =

    single

      0.0356


temp_avg_metric =

    single

      0.0430


temp_avg_metric =

    single

      0.0489


temp_avg_metric =

    single

      NaN


temp_avg_metric =

    single

      0.0162


temp_avg_metric =

    single

      0.0175


temp_avg_metric =

    single

      0.0226


temp_avg_metric =

    single

      0.0225
```

```
temp_avg_metric =

  single

    0.0258


temp_avg_metric =

  single

    0.0315


temp_avg_metric =

  single

    0.0356


temp_avg_metric =

  single

    0.0430


temp_avg_metric =

  single

    0.0489


temp_avg_metric =

  single

   NaN


temp_avg_metric =

  single

    0.0162


temp_avg_metric =

  single
```

0.0175

temp_avg_metric =

  single

    0.0226

temp_avg_metric =

  single

    0.0225

temp_avg_metric =

  single

    0.0258

temp_avg_metric =

  single

    0.0315

temp_avg_metric =

  single

    0.0356

temp_avg_metric =

  single

    0.0430

temp_avg_metric =

  single

    0.0489

temp_avg_metric =

```
    single

      NaN


temp_avg_metric =

    single

      0.0162


temp_avg_metric =

    single

      0.0175


temp_avg_metric =

    single

      0.0226


temp_avg_metric =

    single

      0.0225


temp_avg_metric =

    single

      0.0258


temp_avg_metric =

    single

      0.0315


temp_avg_metric =

    single

      0.0356
```

```
temp_avg_metric =

  single

    0.0430


temp_avg_metric =

  single

    0.0489


temp_avg_metric =

  single

   NaN


temp_avg_metric =

  single

    0.0162


temp_avg_metric =

  single

    0.0175


temp_avg_metric =

  single

    0.0226


temp_avg_metric =

  single

    0.0225


temp_avg_metric =

  single
```

0.0258

temp_avg_metric =

  single

    0.0315

temp_avg_metric =

  single

    0.0356

temp_avg_metric =

  single

    0.0430

temp_avg_metric =

  single

    0.0489

temp_avg_metric =

  single

   NaN

temp_avg_metric =

  single

    0.0152

temp_avg_metric =

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    0.0145

temp_avg_metric =

```
    single

      0.0187


temp_avg_metric =

  single

    0.0189


temp_avg_metric =

  single

    0.0197


temp_avg_metric =

  single

    0.0206


temp_avg_metric =

  single

    0.0206


temp_avg_metric =

  single

    0.0202


temp_avg_metric =

  single

    0.0209


temp_avg_metric =

  single

   NaN
```

```
temp_avg_metric =

  single

    0.0152


temp_avg_metric =

  single

    0.0176


temp_avg_metric =

  single

    0.0223


temp_avg_metric =

  single

    0.0221


temp_avg_metric =

  single

    0.0227


temp_avg_metric =

  single

    0.0319


temp_avg_metric =

  single

    0.0350


temp_avg_metric =

  single

    0.0389
```

```
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    0.0424


temp_avg_metric =

  single

   NaN


temp_avg_metric =

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    0.0152


temp_avg_metric =

  single

    0.0176


temp_avg_metric =

  single

    0.0223


temp_avg_metric =

  single

    0.0221


temp_avg_metric =

  single

    0.0227


temp_avg_metric =

  single
```

0.0336

temp_avg_metric =

  single

   0.0364

temp_avg_metric =

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   0.0421

temp_avg_metric =

  single

   0.0493

temp_avg_metric =

  single

   NaN

temp_avg_metric =

  single

   0.0152

temp_avg_metric =

  single

   0.0176

temp_avg_metric =

  single

   0.0223

temp_avg_metric =

single

   0.0221

temp_avg_metric =

  single

   0.0227

temp_avg_metric =

  single

   0.0336

temp_avg_metric =

  single

   0.0364

temp_avg_metric =

  single

   0.0421

temp_avg_metric =

  single

   0.0507

temp_avg_metric =

  single

   NaN

temp_avg_metric =

  single

   0.0152

```
temp_avg_metric =

  single

    0.0176


temp_avg_metric =

  single

    0.0223


temp_avg_metric =

  single

    0.0221


temp_avg_metric =

  single

    0.0227


temp_avg_metric =

  single

    0.0336


temp_avg_metric =

  single

    0.0364


temp_avg_metric =

  single

    0.0421


temp_avg_metric =

  single
```

0.0507

temp_avg_metric =

   single

   NaN

temp_avg_metric =

   single

   0.0152

temp_avg_metric =

   single

   0.0176

temp_avg_metric =

   single

   0.0223

temp_avg_metric =

   single

   0.0221

temp_avg_metric =

   single

   0.0227

temp_avg_metric =

   single

   0.0336

temp_avg_metric =

single

0.0364

temp_avg_metric =

single

0.0421

temp_avg_metric =

single

0.0507

temp_avg_metric =

single

NaN

temp_avg_metric =

single

0.0152

temp_avg_metric =

single

0.0176

temp_avg_metric =

single

0.0223

temp_avg_metric =

single

0.0221

```
temp_avg_metric =

   single

      0.0227


temp_avg_metric =

   single

      0.0336


temp_avg_metric =

   single

      0.0364


temp_avg_metric =

   single

      0.0421


temp_avg_metric =

   single

      0.0507


temp_avg_metric =

   single

      NaN


temp_avg_metric =

   single

      0.0152


temp_avg_metric =

   single

      0.0176
```

```
temp_avg_metric =

  single

    0.0223


temp_avg_metric =

  single

    0.0221


temp_avg_metric =

  single

    0.0227


temp_avg_metric =

  single

    0.0336


temp_avg_metric =

  single

    0.0364


temp_avg_metric =

  single

    0.0421


temp_avg_metric =

  single

    0.0507


temp_avg_metric =

  single
```

```
   NaN

temp_avg_metric =

  single

    0.0152


temp_avg_metric =

  single

    0.0176


temp_avg_metric =

  single

    0.0223


temp_avg_metric =

  single

    0.0221


temp_avg_metric =

  single

    0.0227


temp_avg_metric =

  single

    0.0336


temp_avg_metric =

  single

    0.0364


temp_avg_metric =
```

single

  0.0421

temp_avg_metric =

  single

   0.0507

temp_avg_metric =

  single

  NaN

temp_avg_metric =

  single

   0.0152

temp_avg_metric =

  single

   0.0176

temp_avg_metric =

  single

   0.0223

temp_avg_metric =

  single

   0.0221

temp_avg_metric =

  single

   0.0227

```
temp_avg_metric =

  single

    0.0336


temp_avg_metric =

  single

    0.0364


temp_avg_metric =

  single

    0.0421


temp_avg_metric =

  single

    0.0507


temp_avg_metric =

  single

   NaN


temp_avg_metric =

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    0.0134


temp_avg_metric =

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    0.0141


temp_avg_metric =

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```

```
        0.0187


temp_avg_metric =

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        0.0180


temp_avg_metric =

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        0.0197


temp_avg_metric =

    single

        0.0202


temp_avg_metric =

    single

        0.0202


temp_avg_metric =

    single

        0.0198


temp_avg_metric =

    single

        0.0206


temp_avg_metric =

    single

      NaN


temp_avg_metric =
```

single

   0.0134

temp_avg_metric =

   single

      0.0141

temp_avg_metric =

   single

      0.0187

temp_avg_metric =

   single

      0.0180

temp_avg_metric =

   single

      0.0226

temp_avg_metric =

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      0.0327

temp_avg_metric =

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      0.0360

temp_avg_metric =

   single

      0.0386

```
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    0.0418


temp_avg_metric =

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    NaN


temp_avg_metric =

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    0.0134


temp_avg_metric =

  single

    0.0201


temp_avg_metric =

  single

    0.0228


temp_avg_metric =

  single

    0.0219


temp_avg_metric =

  single

    0.0256


temp_avg_metric =

  single

    0.0344
```

```
temp_avg_metric =

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    0.0374


temp_avg_metric =

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    0.0448


temp_avg_metric =

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    0.0526


temp_avg_metric =

  single

   NaN


temp_avg_metric =

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    0.0134


temp_avg_metric =

  single

    0.0201


temp_avg_metric =

  single

    0.0228


temp_avg_metric =

  single
```

```
    0.0219


temp_avg_metric =

  single

    0.0256


temp_avg_metric =

  single

    0.0344


temp_avg_metric =

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    0.0374


temp_avg_metric =

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    0.0470


temp_avg_metric =

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    0.0542


temp_avg_metric =

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   NaN


temp_avg_metric =

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    0.0134


temp_avg_metric =
```

single

   0.0201

temp_avg_metric =

  single

   0.0228

temp_avg_metric =

  single

   0.0219

temp_avg_metric =

  single

   0.0256

temp_avg_metric =

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   0.0344

temp_avg_metric =

  single

   0.0374

temp_avg_metric =

  single

   0.0470

temp_avg_metric =

  single

   0.0542

```
temp_avg_metric =

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    NaN


temp_avg_metric =

  single

    0.0134


temp_avg_metric =

  single

    0.0201


temp_avg_metric =

  single

    0.0228


temp_avg_metric =

  single

    0.0219


temp_avg_metric =

  single

    0.0256


temp_avg_metric =

  single

    0.0344


temp_avg_metric =

  single
```

0.0374

temp_avg_metric =

  single

    0.0470

temp_avg_metric =

  single

    0.0542

temp_avg_metric =

  single

    NaN

temp_avg_metric =

  single

    0.0134

temp_avg_metric =

  single

    0.0201

temp_avg_metric =

  single

    0.0228

temp_avg_metric =

  single

    0.0219

temp_avg_metric =

single

    0.0256

temp_avg_metric =

  single

    0.0344

temp_avg_metric =

  single

    0.0374

temp_avg_metric =

  single

    0.0470

temp_avg_metric =

  single

    0.0542

temp_avg_metric =

  single

   NaN

temp_avg_metric =

  single

    0.0134

temp_avg_metric =

  single

    0.0201

```
temp_avg_metric =

  single

    0.0228


temp_avg_metric =

  single

    0.0219


temp_avg_metric =

  single

    0.0256


temp_avg_metric =

  single

    0.0344


temp_avg_metric =

  single

    0.0374


temp_avg_metric =

  single

    0.0470


temp_avg_metric =

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    0.0542


temp_avg_metric =

  single

   NaN
```

```
temp_avg_metric =

  single

    0.0134


temp_avg_metric =

  single

    0.0201


temp_avg_metric =

  single

    0.0228


temp_avg_metric =

  single

    0.0219


temp_avg_metric =

  single

    0.0256


temp_avg_metric =

  single

    0.0344


temp_avg_metric =

  single

    0.0374


temp_avg_metric =

  single
```

```
   0.0470


temp_avg_metric =

  single

    0.0542


temp_avg_metric =

  single

   NaN


temp_avg_metric =

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    0.0134


temp_avg_metric =

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    0.0201


temp_avg_metric =

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    0.0228


temp_avg_metric =

  single

    0.0219


temp_avg_metric =

  single

    0.0256


temp_avg_metric =
```

single

0.0344

temp_avg_metric =

single

0.0374

temp_avg_metric =

single

0.0470

temp_avg_metric =

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0.0542

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single

0.0145

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single

0.0180

```
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    0.0199


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    0.0199


temp_avg_metric =

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    0.0194


temp_avg_metric =

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    0.0203


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    NaN


temp_avg_metric =

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```

0.0134

temp_avg_metric =

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    0.0145

temp_avg_metric =

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    0.0173

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    0.0270

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    0.0340

temp_avg_metric =

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    0.0374

temp_avg_metric =

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    0.0384

temp_avg_metric =

single

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temp_avg_metric =

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      NaN

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temp_avg_metric =

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   0.0205

temp_avg_metric =

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temp_avg_metric =

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temp_avg_metric =

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   0.0328

temp_avg_metric =

   single

   0.0395

```
temp_avg_metric =

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temp_avg_metric =

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      0.0478


temp_avg_metric =

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      0.0561


temp_avg_metric =

   single

       NaN


temp_avg_metric =

   single

      0.0134


temp_avg_metric =

   single

      0.0205


temp_avg_metric =

   single

      0.0228


temp_avg_metric =

   single

      0.0218
```

```
temp_avg_metric =

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    0.0328


temp_avg_metric =

  single

    0.0395


temp_avg_metric =

  single

    0.0456


temp_avg_metric =

  single

    0.0500


temp_avg_metric =

  single

    0.0576


temp_avg_metric =

  single

   NaN


temp_avg_metric =

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    0.0134


temp_avg_metric =

  single
```

0.0205

temp_avg_metric =

   single

      0.0228

temp_avg_metric =

   single

      0.0218

temp_avg_metric =

   single

      0.0328

temp_avg_metric =

   single

      0.0395

temp_avg_metric =

   single

      0.0456

temp_avg_metric =

   single

      0.0500

temp_avg_metric =

   single

      0.0576

temp_avg_metric =

```
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    0.0205

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temp_avg_metric =

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    0.0218

temp_avg_metric =

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    0.0328

temp_avg_metric =

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    0.0395

temp_avg_metric =

  single

    0.0456
```

```
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temp_avg_metric =

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    0.0205


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    0.0218


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```

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    0.0395

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    0.0456

temp_avg_metric =

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    0.0500

temp_avg_metric =

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    0.0576

temp_avg_metric =

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    NaN

temp_avg_metric =

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    0.0134

temp_avg_metric =

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    0.0205

temp_avg_metric =

single

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temp_avg_metric =

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   0.0218

temp_avg_metric =

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   0.0328

temp_avg_metric =

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   0.0395

temp_avg_metric =

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temp_avg_metric =

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temp_avg_metric =

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   NaN

```
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temp_avg_metric =

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temp_avg_metric =

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temp_avg_metric =

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temp_avg_metric =

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```

```
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temp_avg_metric =

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    0.0205


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    0.0228


temp_avg_metric =

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    0.0218


temp_avg_metric =

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    0.0328


temp_avg_metric =

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```

0.0395

temp_avg_metric =

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    0.0500

temp_avg_metric =

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    0.0576

temp_avg_metric =

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    NaN

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0.0181

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0.0204

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single

NaN

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```
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temp_avg_metric =

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    0.0191


temp_avg_metric =

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    0.0181


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    0.0288


temp_avg_metric =

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    0.0359


temp_avg_metric =

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    0.0393


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    0.0402


temp_avg_metric =

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```

0.0418

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temp_avg_metric =

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   0.0149

temp_avg_metric =

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   0.0191

temp_avg_metric =

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temp_avg_metric =

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   0.0334

temp_avg_metric =

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temp_avg_metric =

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   0.0191

temp_avg_metric =

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   0.0181

```
temp_avg_metric =

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temp_avg_metric =

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temp_avg_metric =

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temp_avg_metric =

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     0.0509


temp_avg_metric =

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     0.0584


temp_avg_metric =

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     NaN


temp_avg_metric =

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     0.0152


temp_avg_metric =

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     0.0149
```

```
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temp_avg_metric =

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    0.0181


temp_avg_metric =

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    0.0334


temp_avg_metric =

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    0.0443


temp_avg_metric =

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    0.0461


temp_avg_metric =

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    0.0509


temp_avg_metric =

  single

    0.0584


temp_avg_metric =

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```

NaN

temp_avg_metric =

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temp_avg_metric =

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    0.0149

temp_avg_metric =

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    0.0191

temp_avg_metric =

  single

    0.0181

temp_avg_metric =

  single

    0.0334

temp_avg_metric =

  single

    0.0443

temp_avg_metric =

  single

    0.0461

temp_avg_metric =

single

   0.0509

temp_avg_metric =

  single

   0.0584

temp_avg_metric =

  single

   NaN

temp_avg_metric =

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temp_avg_metric =

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   0.0149

temp_avg_metric =

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   0.0191

temp_avg_metric =

  single

   0.0181

temp_avg_metric =

  single

   0.0334

```
temp_avg_metric =

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    0.0443


temp_avg_metric =

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    0.0461


temp_avg_metric =

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    0.0509


temp_avg_metric =

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    0.0584


temp_avg_metric =

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   NaN


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    0.0152


temp_avg_metric =

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    0.0149


temp_avg_metric =

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```

0.0191

temp_avg_metric =

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    0.0181

temp_avg_metric =

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    0.0334

temp_avg_metric =

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    0.0443

temp_avg_metric =

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    0.0461

temp_avg_metric =

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    0.0509

temp_avg_metric =

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    0.0584

temp_avg_metric =

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   NaN

temp_avg_metric =

single

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temp_avg_metric =

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   0.0149

temp_avg_metric =

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   0.0191

temp_avg_metric =

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   0.0181

temp_avg_metric =

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   0.0334

temp_avg_metric =

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   0.0443

temp_avg_metric =

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   0.0461

temp_avg_metric =

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   0.0509

```
temp_avg_metric =

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temp_avg_metric =

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    NaN


temp_avg_metric =

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temp_avg_metric =

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    0.0149


temp_avg_metric =

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    0.0191


temp_avg_metric =

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    0.0181


temp_avg_metric =

  single

    0.0334


temp_avg_metric =

  single

    0.0443
```

```
temp_avg_metric =

  single

    0.0461


temp_avg_metric =

  single

    0.0509


temp_avg_metric =

  single

    0.0584

BONUS
Best Detection Threshold:
   500

Best Matching Threshold:
     4

Best Matching Ratio:
     1

Features Matched:
   217
```

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