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%% Digit recognition from spoken recordings using DTW
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% Generate vector 'utterances': 300 cells of Mx13 matrixes
paths = 'Final_digits/Final_digits/';
utterances = cell(1,300);
files = dir([paths,'*.mat']);

% Get the 300 test utterances
for spokenDigits = 1 : 300
    T = load([paths, files(spokenDigits).name ]); % Test Utterance
    % M X 13 matrix, T
    % M = number of frames that utterance has and 13 is dimension of each frame.
    T = squeeze(T.feat);
    % Save out 62x13 matrix
    utterances(spokenDigits) = {T};
end
clearvars T path spokenDigits
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% For each T (columns), you will have 299 costs (rows)
allignment_costs= zeros(299,300);

for spokenDigits = 1 : 300
    T = cell2mat(utterances(:, spokenDigits));
    M = size(T,1);
    for ref_utterances = 1 : 299
        if spokenDigits ~= ref_utterances
            % Calculate allignment cost between T and R (one number):
            R = cell2mat(utterances(:, ref_utterances));
            N = size(R,1);

            % Dissimilarity Matrix
            S = pdist2(T,R);

            % Compute accumulated DTW matrix (D) from the above dissimilarity matrix
            D = zeros(size(S));
            all_paths = cell(size(D));
            for row = 1 : M
                for col = 1 : N
                    % cumulative value D(m,n) = S(m,n) + min( D(m-1,n), D(m,n-1), D(m-1
                    if row>1 && col>1
                        above = D(row-1, col);
                        left = D(row, col-1);
                        diag = D(row-1, col-1);
                        [MIN, IDX] = min([above, left, diag]);
                        if IDX==1
                            % came from ABOVE: cell(row-1, col)
                            all_paths{row,col} = [row-1, col];
                            D(row,col) = S(row,col) + MIN;
                        elseif IDX==2
                            all_paths{row,col} = [row, col-1];
                            D(row,col) = S(row,col) + MIN;
                        else
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                            all_paths{row,col} = [row-1, col-1];
                            D(row,col) = S(row,col) + MIN;
                        end

                    elseif row==1 && col>1
                        % came from LEFT: cell(row, col-1)
                        all_paths{row,col} = [row, col-1];
                        D(row,col) = S(row,col);

                    elseif row>1 && col==1
                        % came from ABOVE: cell(row-1, col)
                        all_paths{row,col} = [row-1, col];
                        D(row,col) = S(row,col);

                    else
                        D(row,col) = S(row,col);
                        all_paths{row,col} = [0,0];
                    end
                end
            end

            % follow optimal path and calculate min_cost
            x=M; y=N;
            min_cost = 0;
            opt_path = {};
            count = 0;
            while x>1 || y>1
                min_cost = min_cost + S(x,y);
                % update x and y to min path
                x = all_paths{x,y}(1);
                y = all_paths{x,y}(2);
                opt_path{count+1} = [x,y];
                count = count + 1;
            end
            % normalized cost
            allignment_costs(ref_utterances,spokenDigits) = min_cost / count;

        else
            continue
        end

    end
end
```

```
% So for each utterance T (column in 'allignments'), theres 299 "cost allignment" value
% Sort them and take least 29 values (because you have 29 utterances of same digit).
[sorted,IDXs] = mink(allignment_costs, 30);
crop_sort = sorted(2:30, :);
crop_IDXs = IDXs(2:30, :);
```

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% Now, check if the utterances corresponding to those 29 values are of same digit
% and note down number of comparisons that yielded the same digit as T.
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```
acc = zeros(29,300);
for Ts = 1 : 300
    T_digit = str2double(files(Ts).name(1));
    for Ns = 1 : 29
        N_digit = str2double(files(crop_IDXs(Ns,Ts)).name(1));
        if T_digit == N_digit
            acc(Ns,Ts) = 1;
        else
            acc(Ns,Ts) = 0;
        end
    end
end
```

```
% Compute accuracy for each digit.
digit_acc = zeros(1,10);
count = 1;
for digit = 1:30:300 % ends at 271
    digit_acc(count) = sum(acc(:, digit : digit+29), 'all') / (29*30);
    dig = count-1;
    disp("Accuracy for digit '" + dig + "' is " + digit_acc(count));
    count = count + 1;
end
```

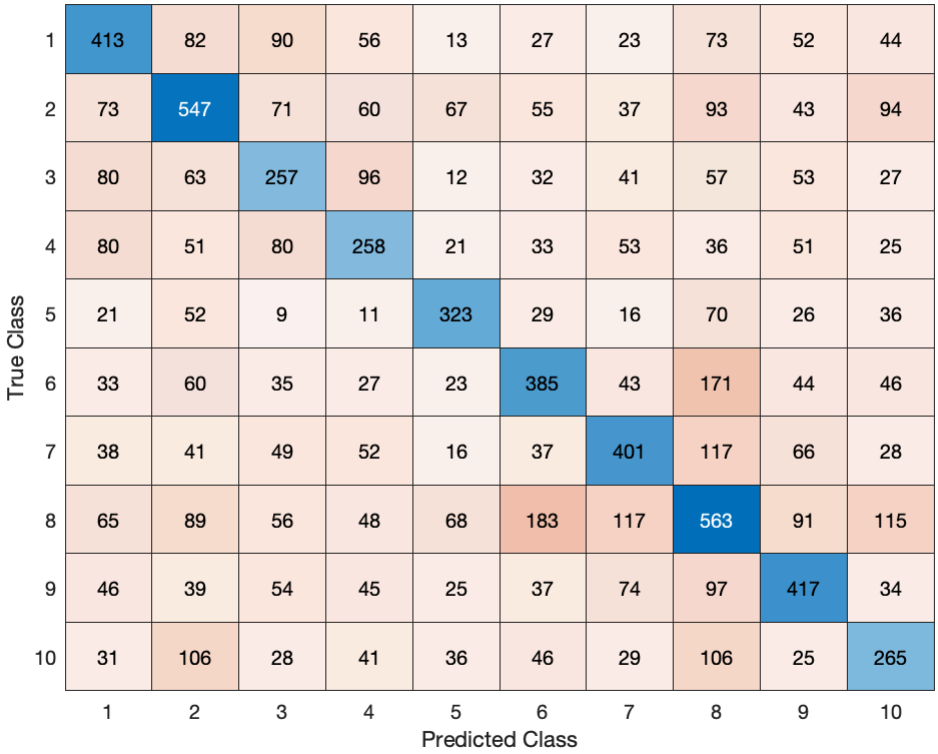
```
Accuracy for digit 0 is 0.2931
Accuracy for digit 1 is 0.35287
Accuracy for digit 2 is 0.26667
Accuracy for digit 3 is 0.25632
Accuracy for digit 4 is 0.35977
Accuracy for digit 5 is 0.41264
Accuracy for digit 6 is 0.35057
Accuracy for digit 7 is 0.4
Accuracy for digit 8 is 0.48276
Accuracy for digit 9 is 0.27701
```

```
% Plot confusion matrix
ground_truth = ones(29,300);
for i = 1 : 29
    for j = 1 : 300
        ground_truth(i,j) = str2double(files( crop_IDXs(i,j) ).name(1));
    end
end

predicted = ones(29,300);
for i = 1 : 29
    for j = 1 : 300
        predicted(i,j) = str2double(files( IDXs(i,j) ).name(1));
    end
end

C = confusionmat( reshape(ground_truth, [8700 1]), reshape(predicted, [8700 1]));

confusionchart(C)
```


True Class
Predicted Class
1 413 82 90 56 13 27 23 73 52 44
2 73 547 71 60 67 55 37 93 43 94
3 80 63 257 96 12 32 41 57 53 27
4 80 51 80 258 21 33 53 36 51 25
5 21 52 9 11 323 29 16 70 26 36
6 33 60 35 27 23 385 43 171 44 46
7 38 41 49 52 16 37 401 117 66 28
8 65 89 56 48 68 183 117 563 91 115
9 46 39 54 45 25 37 74 97 417 34
10 31 106 28 41 36 46 29 106 25 265
1 2 3 4 5 6 7 8 9 10