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```
clc;
clear all;
close all;
addpath(genpath('externalLib'));
addpath(genpath('Variables'));

%histograms
totalImages = 1000;

% Running in parallel, check if the pool of threads is already open
if matlabpool('size') == 0
    infoLocal = parcluster('local');
    maxWorkers = infoLocal.NumWorkers;
    matlabpool('open',maxWorkers);
end

bins = [256 100];% Number of bins for each problem (1 and 2)

imgHists = zeros(totalImages, bins(1)*3); % Histograms for problem 1
imgSpectralHists = zeros(totalImages, bins(2)*7*3); % Histograms for problem 2 (us

display('Reading images and computing the histograms....');
tic;
parfor_progress(totalImages);
parfor currIndx =1:totalImages
    % Read images
    fname=sprintf('corel/%i.jpg',currIndx-1);
    currImgInt = imread(fname,'jpg');

    % Reducing size of image
    currImg = double(impyramid(currImgInt,'reduce'));

    [filteredImg numFilters]= filterImages(currImg,3,1);% Filtered image for probl
    %imshow(uint8(squeeze(filteredImg(1,:,:,1))));

    imgHists(currIndx,:) = computeHist(1, currImg, 1, bins(1));
    %plot(imgHists(currIndx,:));
    imgSpectralHists(currIndx,:) = computeHist(1, filteredImg, numFilters, bins(2)
    %plot(imgSpectralHists(currIndx,:));
```

```
    parfor_progress;
end
parfor_progress(0);
toc;
```

```
Warning: Function externalLib/vlfeat/toolbox/noprefix/det.m has the same n
a MATLAB builtin. We suggest you rename the function to avoid a potential
conflict.
Warning: Function externalLib/vlfeat/toolbox/noprefix/det.m has the same n
a MATLAB builtin. We suggest you rename the function to avoid a potential
conflict.
Reading images and computing the histograms....
100%[==================================================]
Elapsed time is 26.167586 seconds.
```

Average precision and rank for Simplicity method for each class

```
simplicityPR=[  0.47477 178.3529;
                0.32446 242.0187;
                0.33027 261.6305;
                0.36296 260.7511;
                0.98117 49.3074;
                0.39964 197.1079;
                0.40218 298.6917;
                0.71858 91.5890;
                0.34188 230.2441;
                0.33971 271.2211 ];
```

Histogram distances for each method

```
for problem=1:3

    switch problem
        case 1 % Color histogram
            hists = imgHists;
            display('Calculating histogram distances');
            dists = computeHistDist(hists,totalImages);
        case 2 % Spectral histogram
            hists = imgSpectralHists;
            display('Calculating histogram distances');
            dists = computeHistDist(hists,totalImages);
        case 3 % Sift features
            dists=sift(totalImages);
    end
    [Y, ind] = sort(-dists);
```

```
    Calculating histogram distances
    100%[==================================================]

    Calculating histogram distances
```

```
    100%[==================================================]

    Elapsed time is 7.903175 seconds.
    Computing our sift score
```

Precision recall[query image, all images, PR]

```
%every image is queried against all totalImages images
tic;
display('Computing precision recall....');
precision_recall = computePrecRecall(totalImages, ind);
toc;
```

```
    Computing precision recall....
    100%[==================================================]
    Elapsed time is 1.299059 seconds.

    Computing precision recall....
    100%[==================================================]
    Elapsed time is 1.126430 seconds.

    Computing precision recall....
    100%[==================================================]
    Elapsed time is 1.425763 seconds.
```

Average precision and rank

```
display('Computing average precision and rank....');
switch problem
    case 1
        imgHistsPR=computeAvgPR(totalImages, ind, precision_recall);
    case 2
        imgSpectralHistsPR=computeAvgPR(totalImages, ind, precision_recall);
    case 3
        siftPR=computeAvgPR(totalImages, ind, precision_recall);
end
```

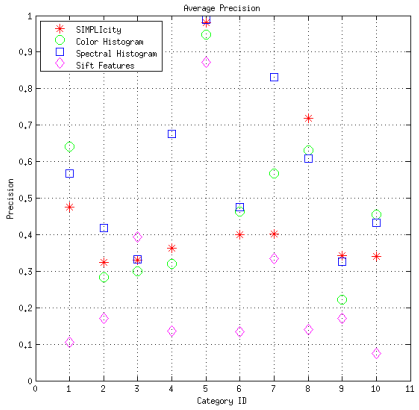
```
    Computing average precision and rank....
    100%[==================================================]

    Computing average precision and rank....
    100%[==================================================]

    Computing average precision and rank....
    100%[==================================================]
```

```
end
```

Plot average precision

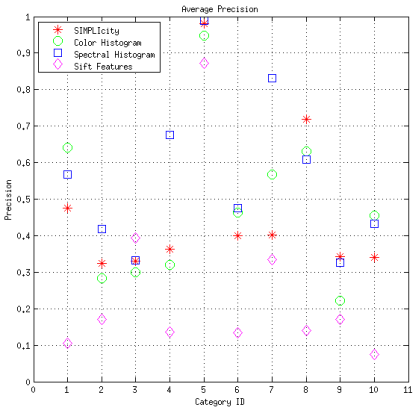
```
figure('Position',[100,100,1500,600])
```

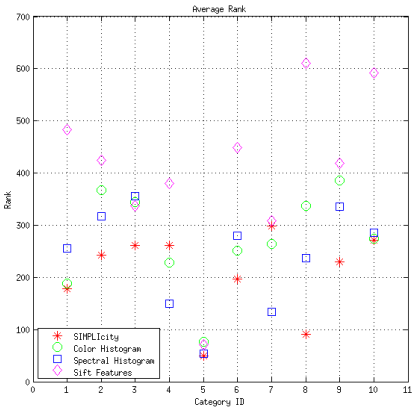
```
subplot(1,2,1);
%Simplicity results
plot(1:10,simplicityPR(:,1),'r*','MarkerSize',10);
hold on
%Our results
plot(1:10,imgHistsPR(:,1),'go','MarkerSize',10);
plot(1:10,imgSpectralHistsPR(:,1),'bs','MarkerSize',10);
plot(1:10,siftPR(:,1),'md','MarkerSize',10);
hold off
title('Average Precision')
xlabel('Category ID');
ylabel('Precision');
legend('SIMPLIcity','Color Histogram','Spectral Histogram','Sift Features');
legend('Location','northwest');
xlim([0,11]);
grid on;
```



Plot average rank

```
subplot(1,2,2);
%Simplicity results
plot(1:10,simplicityPR(:,2),'r*','MarkerSize',10);
hold on
%Our results
plot(1:10,imgHistsPR(:,2),'go','MarkerSize',10);
plot(1:10,imgSpectralHistsPR(:,2),'bs','MarkerSize',10);
plot(1:10,siftPR(:,2),'md','MarkerSize',10);
hold off
title('Average Rank','FontSize',20)
xlabel('Category ID');
ylabel('Rank');
legend('SIMPLIcity','Color Histogram','Spectral Histogram','Sift Features');
legend('Location','southwest');
xlim([0,11]);
grid on;
```





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```
function siftScore = sift(totalImages)
```

Calculate descriptors for images

```
tic;
if exist('Variables/descriptors.mat', 'file')
    load('descriptors.mat','descriptors');
else
    display('Detecting SIFT features and descriptors...');
    parfor_progress(totalImages);
    for i=1:totalImages
        [fa, descriptors{i}] = vl_sift(single(rgb2gray(uint8(squeeze(origImages(i,
        parfor_progress;
    end
    save('Variables/descriptors.mat','descriptors');
end
```

Compare descriptors to determine scores

```
if exist('Variables/scores.mat', 'file')
    load('scores.mat','score');
else
    display('Computing Scores...');
    for i=1:totalImages
        tic;
        parfor j=1:totalImages
            [matches, scores{i,j}] = vl_ubcmatch(descriptors{i}, descriptors{j});
        end
        fprintf('%d of 1000: %c',i);
        toc;
    end
    save('Variables/scores.mat','scores');
end
scores = score;
clear score;
toc;
```

Obtaining finalScore

```
% Obtaining max distance
maxDist = 0;
for i=1:totalImages
```

```
    for j=1:totalImages
        currMax = max(scores{i,j});
        if(currMax > maxDist)
            maxDist = currMax;
        end
    end
end

display('Computing our sift score');
siftScore = zeros(totalImages,totalImages);
parfor i=1:totalImages
    for j=1:totalImages
        % Utilize Cantor pairing to ensure one to one mapping for
        % number of matched descriptors with their average
        % distance(Euclidean)
        k1=round(mean(scores{i,j})/maxDist);
        k2=length(scores{i,j});
        siftScore(i,j) = (0.5*(k1+k2)*(k1+k2+1))+k2;
    end
end

end
```

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```
% The parameter option indicates which filters are we using.
function [filteredImg numFilters] = filterImages(images, option, totalImages)
    switch option
        case 1 %No filters (just the intensity filter)
            filteredImg = images;
            numFilters = 1;
        case 2 % Using just GaussMask
            kernelSize = 5;
            sigma = 0.7;
            filteredImg = zeros(size(images));
            numFilters = 1;
            gaussMask = oz_gaussMask(kernelSize, sigma);
            parfor_progress(length(images));
            for i=1:length(images)
                filteredImg(i,:,:,1) = conv2(squeeze(images(i,:,:,1)),gaussMask, '
                filteredImg(i,:,:,2) = conv2(squeeze(images(i,:,:,2)),gaussMask, '
                filteredImg(i,:,:,3) = conv2(squeeze(images(i,:,:,3)),gaussMask, '
                parfor_progress;
            end
            parfor_progress(0);
            % If you want to visualize any (i) of the filtered images use:
            %imshow(uint8(squeeze(filteredImg(i,:,:,3)))); % 3 is the band of the
        case 3 % Using the 4 filters from the paper
            dimsImages = size(images);
            numFilters = 7;

            if(totalImages > 1) % We have more than one image
                filteredImg = zeros(dimsImages(1)*numFilters, dimsImages(2), dimsI
            else
                filteredImg = zeros(numFilters, dimsImages(1), dimsImages(2), dims
            end

            kernelSize = 5;
            sigma = 0.7;

            theta = 0;
            gabor = gaborFilter(kernelSize, sigma, theta);

            dx = [0 -1 1]; % Range [-256 256]
            dy = [0 -1 1]'; % Range [-256 256]
            dxx = [-1 2 -1];% Range [-512 512]
            dyy = [-1 2 -1]';% Range [-512 512]
            maskLoG = maskLoGFunc(kernelSize, sigma);% Range ?
            gaussMask = oz_gaussMask(kernelSize, sigma);% Range [0 256]

            if(totalImages > 1) % We have more than one image
                parfor_progress(totalImages);
                for i=0:totalImages-1
                    % First filter is the intensity filter
                    filteredImg(i*numFilters+1,:,:,1) = images(i+1,:,:,1);
                    filteredImg(i*numFilters+1,:,:,2) = images(i+1,:,:,2);
                    filteredImg(i*numFilters+1,:,:,3) = images(i+1,:,:,3);
```

```
            % Second filter is dx
            filteredImg(i*numFilters+2,:,:,1) = conv2(squeeze(images(i+1,:
            filteredImg(i*numFilters+2,:,:,2) = conv2(squeeze(images(i+1,:
            filteredImg(i*numFilters+2,:,:,3) = conv2(squeeze(images(i+1,:
            % Third filter is dy
            filteredImg(i*numFilters+3,:,:,1) = conv2(squeeze(images(i+1,:
            filteredImg(i*numFilters+3,:,:,2) = conv2(squeeze(images(i+1,:
            filteredImg(i*numFilters+3,:,:,3) = conv2(squeeze(images(i+1,:
            % Fordth filter is dxx
            filteredImg(i*numFilters+4,:,:,1) = conv2(squeeze(images(i+1,:
            filteredImg(i*numFilters+4,:,:,2) = conv2(squeeze(images(i+1,:
            filteredImg(i*numFilters+4,:,:,3) = conv2(squeeze(images(i+1,:
            % Fifth filter is dxx
            filteredImg(i*numFilters+5,:,:,1) = conv2(squeeze(images(i+1,:
            filteredImg(i*numFilters+5,:,:,2) = conv2(squeeze(images(i+1,:
            filteredImg(i*numFilters+5,:,:,3) = conv2(squeeze(images(i+1,:
            % Sixth filter is LoG
            filteredImg(i*numFilters+6,:,:,1) = conv2(squeeze(images(i+1,:
            filteredImg(i*numFilters+6,:,:,2) = conv2(squeeze(images(i+1,:
            filteredImg(i*numFilters+6,:,:,3) = conv2(squeeze(images(i+1,:
            % Seventh filter is Gauss
            filteredImg(i*numFilters+7,:,:,1) = conv2(squeeze(images(i+1,:
            filteredImg(i*numFilters+7,:,:,2) = conv2(squeeze(images(i+1,:
            filteredImg(i*numFilters+7,:,:,3) = conv2(squeeze(images(i+1,:
            parfor_progress;
        end
        parfor_progress(0);
    else
        % First filter is the intensity filter
        filteredImg(1,:,:,1) = images(:,:,1);
        filteredImg(1,:,:,2) = images(:,:,2);
        filteredImg(1,:,:,3) = images(:,:,3);
        % Second filter is dx
        filteredImg(2,:,:,1) = conv2(images(:,:,1),dx, 'same');
        filteredImg(2,:,:,2) = conv2(images(:,:,2),dx, 'same');
        filteredImg(2,:,:,3) = conv2(images(:,:,3),dx, 'same');
        % Third filter is dy
        filteredImg(3,:,:,1) = conv2(images(:,:,1),dy, 'same');
        filteredImg(3,:,:,2) = conv2(images(:,:,2),dy, 'same');
        filteredImg(3,:,:,3) = conv2(images(:,:,3),dy, 'same');
        % Fordth filter is dxx
        filteredImg(4,:,:,1) = conv2(images(:,:,1),dxx, 'same');
        filteredImg(4,:,:,2) = conv2(images(:,:,2),dxx, 'same');
        filteredImg(4,:,:,3) = conv2(images(:,:,3),dxx, 'same');
        %min(min(filteredImg(i*numFilters+4,:,:,3)))
        %max(max(filteredImg(i*numFilters+4,:,:,3)))
        % Fifth filter is dxx
        filteredImg(5,:,:,1) = conv2(images(:,:,1),dyy, 'same');
        filteredImg(5,:,:,2) = conv2(images(:,:,2),dyy, 'same');
        filteredImg(5,:,:,3) = conv2(images(:,:,3),dyy, 'same');
        % Sixth filter is LoG
        filteredImg(6,:,:,1) = conv2(images(:,:,1),maskLoG, 'same');
        filteredImg(6,:,:,2) = conv2(images(:,:,2),maskLoG, 'same');
        filteredImg(6,:,:,3) = conv2(images(:,:,3),maskLoG, 'same');
```

```
            % Seventh filter is Gauss
            filteredImg(7,:,:,1) = conv2(images(:,:,1),gaussMask, 'same');
            filteredImg(7,:,:,2) = conv2(images(:,:,2),gaussMask, 'same');
            filteredImg(7,:,:,3) = conv2(images(:,:,3),gaussMask, 'same');
        end

    case 4 % Intensity and Gauss
        dimsImages = size(images);
        numFilters = 2;

        filteredImg = zeros(dimsImages(1)*numFilters, dimsImages(2), dimsImage
        kernelSize = 5;
        sigma = 0.7;

        gaussMask = oz_gaussMask(kernelSize, sigma);% Range [0 256]

        % TODO missing Gabor filter
        parfor_progress(length(images));
        for i=0:length(images)-1
            % First filter is the intensity filter
            filteredImg(i*numFilters+1,:,:,1) = images(i+1,:,:,1);
            filteredImg(i*numFilters+1,:,:,2) = images(i+1,:,:,2);
            filteredImg(i*numFilters+1,:,:,3) = images(i+1,:,:,3);
            %min(min(filteredImg(i*numFilters+1,:,:,3)))
            %max(max(filteredImg(i*numFilters+1,:,:,3)))
            % Second filter is dx
            %filteredImg(i*numFilters+2,:,:,1) = images(i+1,:,:,1);
            %filteredImg(i*numFilters+2,:,:,2) = images(i+1,:,:,2);
            %filteredImg(i*numFilters+2,:,:,3) = images(i+1,:,:,3);
            % Second filter is dx
            filteredImg(i*numFilters+2,:,:,1) = conv2(squeeze(images(i+1,:,:,1
            filteredImg(i*numFilters+2,:,:,2) = conv2(squeeze(images(i+1,:,:,2
            filteredImg(i*numFilters+2,:,:,3) = conv2(squeeze(images(i+1,:,:,3
            %min(min(filteredImg(i*numFilters+4,:,:,3)))
            %max(max(filteredImg(i*numFilters+4,:,:,3)))
            parfor_progress;
        end
        parfor_progress(0);

        % If you want to visualize any (i) of the filtered images use:
        %imshow(uint8(squeeze(filteredImg(i,:,:,3)))); % 3 is the band of the
    end
```

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```
function hists = computeHist(totalImages, images, numFilters,bins)

    hists=zeros([totalImages,bins*3*numFilters]);%One filter for each band

    if(totalImages>1 || numFilters>1) % We have more than one image
        totRows = size(images(1,:,:,:),2);
        totCols = size(images(1,:,:,:),3);
    else
        totRows = size(images,1);
        totCols = size(images,2);
    end

    minRange = 0;
    maxRange = 256;
    histRange = [minRange:(maxRange-minRange)/(bins-1):maxRange];
    tempSpectralHist = zeros(3*bins*numFilters,1);
    for i=0:totalImages-1
        for j=0:numFilters-1
            % Modifying the range depending on the filter used (it didn't help)
            switch j
                case 0
                    minRange = 0;
                    maxRange = 256;
                case 1
                    minRange = -256;
                    maxRange = 256;
                case 2
                    minRange = -256;
                    maxRange = 256;
                case 3
                    minRange = -512;
                    maxRange = 512;
                case 4
                    minRange = -512;
                    maxRange = 512;
                case 5
                    minRange = 0;
                    maxRange = 256;
                case 6
                    minRange = 0;
                    maxRange = 256;
                case 1
            end

            histRange = [minRange:(maxRange-minRange)/(bins-1):maxRange];

            if(totalImages>1 || numFilters>1) % We have more than one image
                im = images(i*numFilters+1+j,:,:,:);
                im = squeeze(im);%Remove the first 'simgle' dimension
            else
                im = images;
            end
```

```
            % ---- Using bins ---------
            %tempSpectralHist(j*bins*3+1:j*bins*3+bins) = hist(reshape(im(:,:,1),[
            %tempSpectralHist(j*bins*3+bins+1:j*bins*3+2*bins) = hist(reshape(im(:
            %tempSpectralHist(j*bins*3+2*bins+1:j*bins*3+3*bins) = hist(reshape(im

            % ---- Using ranges ---------
            tempSpectralHist(j*bins*3+1:j*bins*3+bins) = hist(reshape(im(:,:,1),[1
            tempSpectralHist(j*bins*3+bins+1:j*bins*3+2*bins) = hist(reshape(im(:,
            tempSpectralHist(j*bins*3+2*bins+1:j*bins*3+3*bins) = hist(reshape(im(
        end

        if(totalImages>1) % We have more than one image
            hists(i+1,:)= tempSpectralHist;
        else
            hists= tempSpectralHist;
        end
    end
```

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```
function dists = computeHistDist(hists,totalImages)

    parfor_progress(totalImages);% External library Copyright (c) 2011, Jeremy Sch
    dists=zeros([totalImages,totalImages]);
    parfor i=1:totalImages
        parfor_progress;
        for j=1:totalImages
            dists(i,j)=sum(min(hists(i,:),hists(j,:)));
        end
    end
    parfor_progress(0);
```

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This function creates a Gaussian mask of nxn

```
function gauss2d = maskLoGFunc(n,sigma)

T = sqrt(2)*sigma;
f = @(x,y,sigma) ( x.^2 + y.^2 - T.^2 ) .* exp( -(x.^2+y.^2)/T^2 );

width = 5;
height = 5;
x = [-width/2:width/n:width/2];
y = [-height/2:height/n:height/2];

[X,Y] = meshgrid(x,y);

gauss2d= f(X,Y,sigma);

%Normalization of the gauss function
total = sum(sum(gauss2d));
gauss2d = gauss2d./total;%It doens't validate that the minimum can be 0

%surf(gauss2d);
```

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```
function images = readImages(totalImages, imgPath)

    % Read one image and obtain the dimensions
    fname=sprintf('%s/%i.jpg',imgPath,0);
    tempImg = double(imread(fname,'jpg'));
    dim = size(tempImg);
    images = zeros(totalImages, dim(1), dim(2), dim(3));
    parfor_progress(totalImages);
    for i=1:totalImages
        fname=sprintf('%s/%i.jpg',imgPath,i-1);
        clear tempImg;
        tempImg = imread(fname,'jpg');
        if( size(tempImg,1) ~= dim(1) ) %The image is rotated
            images(i,:,:,1)= tempImg(:,:,1)';
            images(i,:,:,2)= tempImg(:,:,2)';
            images(i,:,:,3)= tempImg(:,:,3)';
        else
            images(i,:,:,:)= tempImg;
        end
        parfor_progress;
    end
    parfor_progress(0);
```

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