```
function [Ix, Iy, It] = ImageDerivatives(I1, I2)
%IMAGEDERIVATIVES Calculates the derivative of the given images
%   Parameters
%   ----------
%   I1 - one frame of an image
%   I2 - another frame (size identical to I1)
%   Returns
%   -------
%   Ix - the derivative of the frame on the x axis
%   Iy - the derivative of the frame on the y axis
%   It - the derivative of the frame over time

    % kernels and constants
    Ky = 0.25 * [-1, -1; 1,  1];
    Kx = -Ky';
    Kt = 0.25 * ones(2, 2);
    CONV_PARAM = 'same';
    % actual work
    Ix = conv2(I1, Kx, CONV_PARAM) ...
        + conv2(I2, Kx, CONV_PARAM);
    Iy = conv2(I1, Ky, CONV_PARAM) ...
        + conv2(I2, Ky, CONV_PARAM);
    It = conv2(I2, Kt, CONV_PARAM) ...
        - conv2(I1, Kt, CONV_PARAM);

end
```

```
function  v = LK_alg(I1, I2, lambda, mask, ...
                     v_initial, num_iterations)
%LK_ALG Runs the Lucas Kanade iterative algorithm for calc. optical flow
%   Parameters
%   ----------
%   I1 - the first frame of an image
%   I2 - the second frame of an image (same size as I1)
%   lambda - the noise variance to prior variance ratio (scalar)
%   mask - area of the image to sum upon (same size as I1)
%   v_initial - initial guess for the velocity (2d vector)
%   num_iterations - ... y'know
%   Returns
%   -------
%   v - the computed velocity (2d vector)

    At = zeros(size(I1,1), size(I1,2), 4);
    Bt = zeros(size(I1,1), size(I1,2), 2);
    v = v_initial;
    for i = 1:num_iterations
        [I2w, warpMask] = warp(I2, v);
        newMask = mask .* warpMask;
        [Ix, Iy, It] = ImageDerivatives(I1, I2w);
        Ix = Ix .* newMask;
        Iy = Iy .* newMask;
        It = It .* newMask;
        At(:, :, 1) = Ix.^2;
        At(:, :, 2) = Ix .* Iy;
        At(:, :, 3) = At(:, :, 2);
        At(:, :, 4) = Iy.^2;
        Bt(:, :, 1) = Ix .* It;
        Bt(:, :, 2) = Iy .* It;
        A = reshape(sum(sum(At, 1), 2), 2, 2) + eye(2).*lambda;
        B = -reshape(sum(sum(Bt, 1), 2), 2, 1);
        v = v + A \ B;
    end

end
```

```
function blurredI = blur_downsample(I)
%BLUR_DOWNSAMPLE Reduces image size by a factor of 2
%   Parameters
%   ----------
%   I - an image
%   Returns
%   -------
%   blurredI - a blurred and downsampled image (half the size of I)

    kernel = load('GaussKernel.mat');
    kernel = kernel.GaussKernel;
    I = conv2(I, kernel, 'same');
    blurredI = I(1:2:end, 1:2:end);

end
```

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```
function v = Full_LK(I1, I2, lambda, mask, num_iterations)
%FULL_LK The full version of the algorithm
%   for parameters reference see LK_alg.m

    % get the initial guess
    v = [0; 0];
    I1b = blur_downsample(I1);
    I2b = blur_downsample(I2);
    v = LK_alg(I1b, I2b, lambda, mask(1:2:end, 1:2:end), v, 1);
    % run the algorithm with the initial guess
    v = LK_alg(I1, I2, lambda, mask, v.*2, num_iterations);

end
```

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Contents

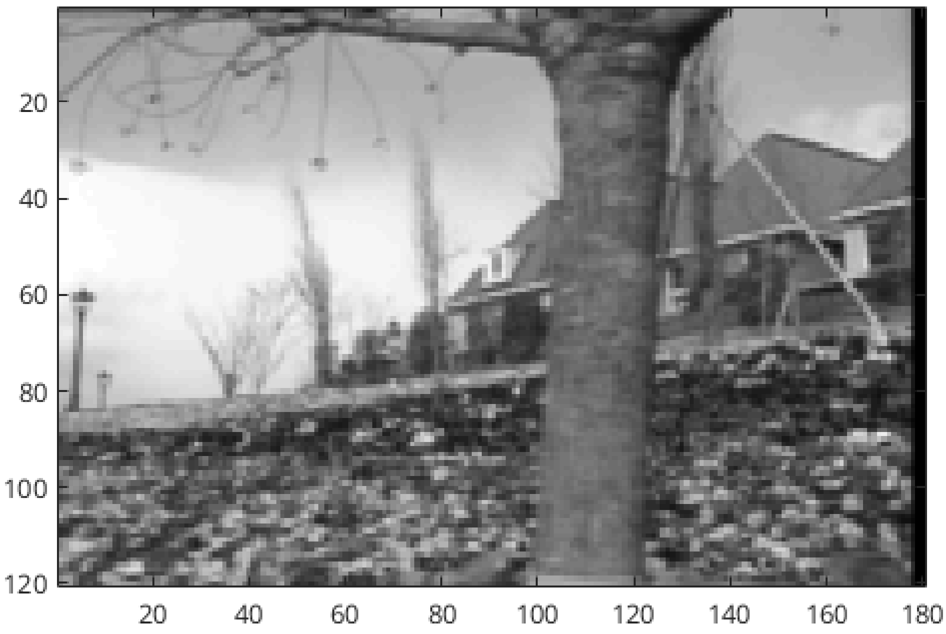
question 5

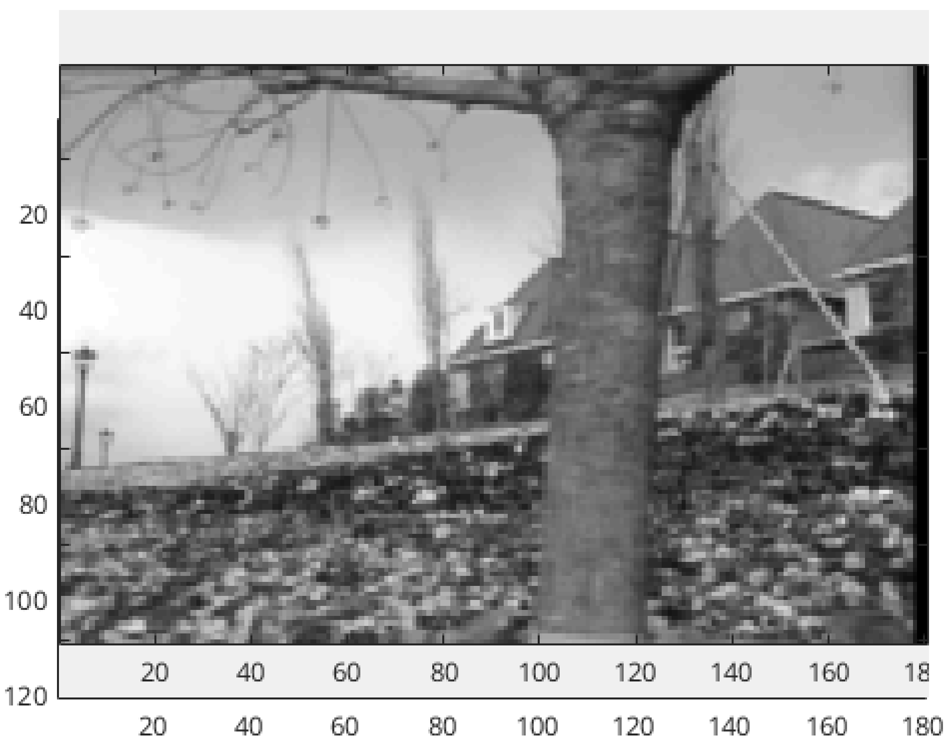
read images and view them

```
I1 = im2double(imread('flower-i1.tif'));
I2 = im2double(imread('flower-i2.tif'));
mymovie(I1, I2);

% define the algorithm's parameters
treeMasks = zeros(size(I1,1), size(I1,2), 3);
flowersMasks = zeros(size(I1,1), size(I1,2), 3);
treeMasks(1:40, 90:130, 1) = 1;
treeMasks(41:80, 90:130, 2) = 1;
treeMasks(81:end, 90:130, 3) = 1;
flowersMasks(90:end, 1:40, 1) = 1;
flowersMasks(85:end, 41:80, 2) = 1;
flowersMasks(80:end, 140:end, 3) = 1;
lambda = 0;
num_iterations = 100;

v_tree = zeros(2, 1, 3);
v_flowers = zeros(2, 1, 3);

% for each tree/flowers subimage, run the LK algorithm
for i = 1:3
    v_tree(:,:, i) = Full_LK(I1, I2, lambda, treeMasks(:,:,i), ...
                             num_iterations);
    v_flowers(:,:, i) = Full_LK(I1, I2, lambda, ...
                                flowersMasks(:,:,i), num_iterations);
end
v_tree
v_flowers
mean_v_tree = mean(v_tree, 3)
mean_v_flowers = mean(v_flowers, 3)
```

```
v_tree(:,:,1) =

   -2.7673
   -0.4681


v_tree(:,:,2) =

   -0.9555
   -0.1756


v_tree(:,:,3) =

   -1.8337
   -0.0013


v_flowers(:,:,1) =

   -1.1373
    0.0208
```

```
v_flowers(:,:,2) =

   -1.0938
   -0.0014


v_flowers(:,:,3) =

   -1.2313
   -0.0091


mean_v_tree =

   -1.8522
   -0.2150


mean_v_flowers =

   -1.1541
    0.0034
```

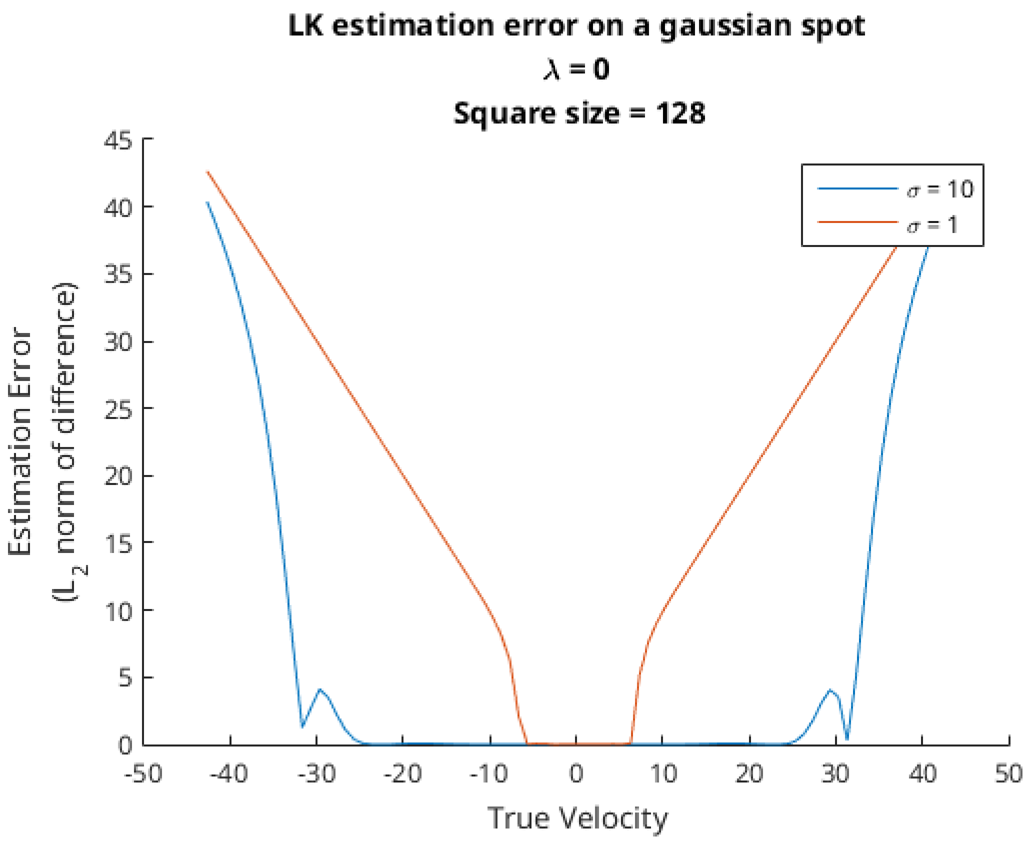




question 6

```
REALVELOCITY = 1;
L2_DIFF = 2;

squareSize = 128;
sigmas = [10, 1];
%lambda = 0.001;
lambda = 0;
mask = ones(squareSize);
num_iterations = 1;
maxVelocity = squareSize / 3;
velocities = (-maxVelocity):maxVelocity;
results = zeros(length(velocities), 2);
```

```
figure;
hold on;
for sigma = sigmas
    firstFrame = GausSpot(squareSize, sigma, [0, 0]);
    for i = 1:numel(velocities)
        real_v = velocities(i);
        secondFrame = GausSpot(squareSize, sigma, [real_v, 0]);
        estimated_v = Full_LK(firstFrame, secondFrame, lambda, ...
                              mask, num_iterations);
        results(i, REAL_VELOCITY) = real_v;
        % the L2 norm of a scalar is the abs value
        results(i, L2_DIFF) = abs(estimated_v(1) - real_v);
    end
    plot(results(:, REAL_VELOCITY), results(:, L2_DIFF));
end
hold off;
title({'LK estimation error on a gaussian spot', ...
       ['\lambda = ', num2str(lambda)], ...
       [' Square size = ', num2str(squareSize)]});
xlabel('True Velocity');
ylabel({'Estimation Error', '(L_2 norm of difference)'});
legend(['\sigma = ', num2str(sigmas(1))], ...
       ['\sigma = ', num2str(sigmas(2))]);
```

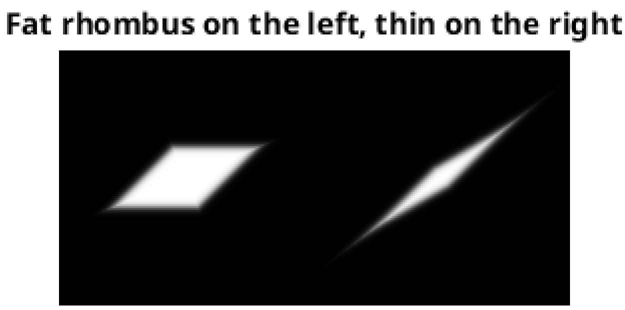


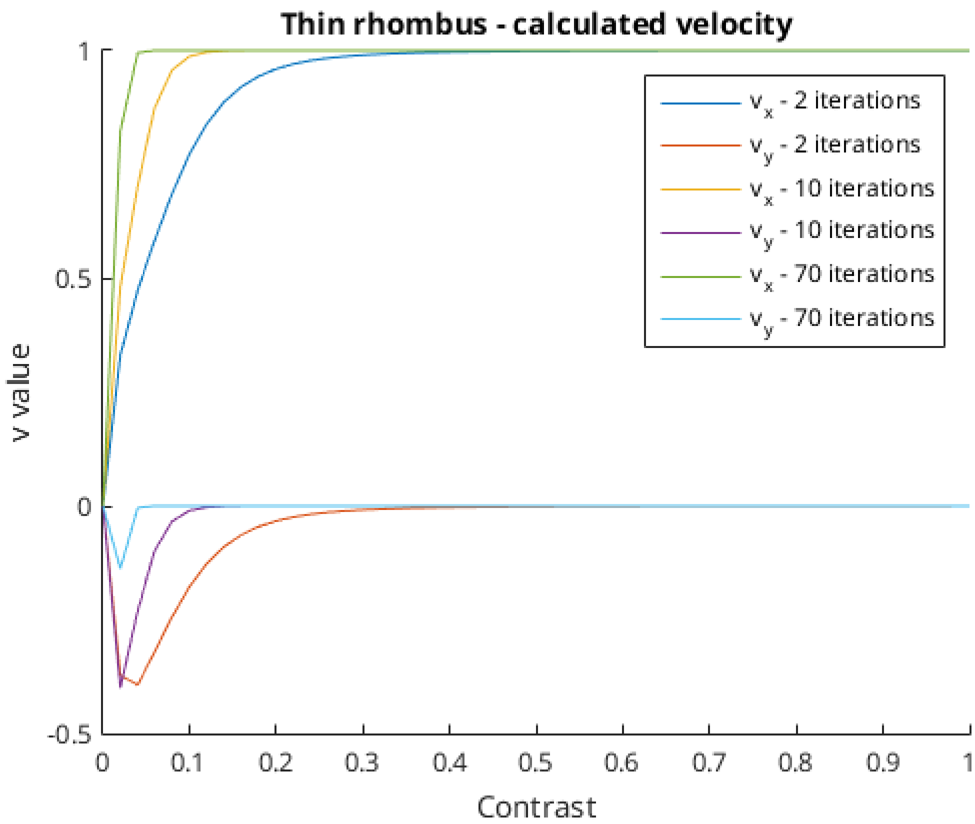
question 7

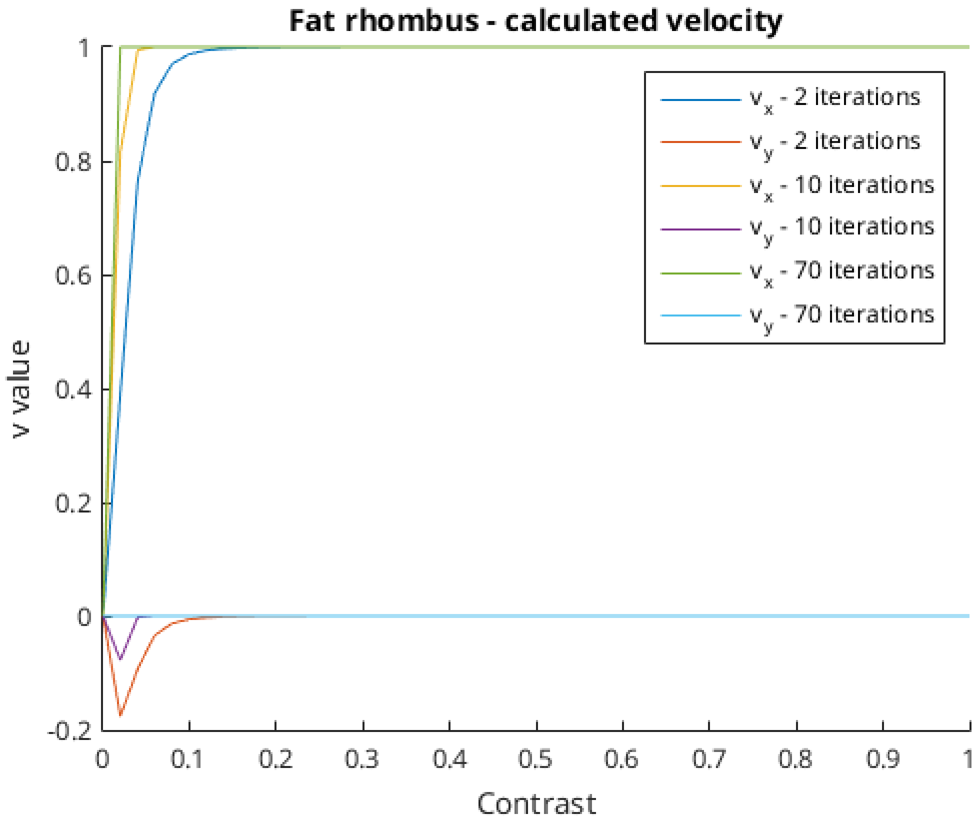
constants

```
fatStr = {'Thin', 'Fat'};
THIN = 0;
FAT = 1;
lambda = 0.01;
contrasts = 1:-0.01:0;
iters = [2, 10, 70];
legends = cell(2, numel(iters));

% plotting
fatRhom = rhombusMovie(1, 1);
thinRhom = rhombusMovie(0, 1);
figure; imshow([fatRhom, thinRhom]);
```

```
title('Fat rhombus on the left, thin on the right');

for fatFlag = [THIN, FAT]
    figure;
    for i = 1:numel(iters)
        iter = iters(i);
        hold all;
        plotRhombus(fatFlag, lambda, iter);
        legends{1, i} = sprintf('v_x - %d iterations', iter);
        legends{2, i} = sprintf('v_y - %d iterations', iter);
    end
    legend(legends{:})
    title([fatStr{fatFlag+1}, ' rhombus - calculated velocity']);
    hold off;
end
```







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