You installed a camera in front of your house in order to monitor the speed of cars driving on the road in front of it. You assume that no more than one car is visible in each frame and no other objects are moving. In particular you want to calculate the speed of the car given three different images: bg.jpg (an image taken without any car), 1.jpg (an image of a moving car), 2.jpg (the second image of the same car taken after 2 seconds). Write a Matlab script able to perform the following steps:

a) Read the 3 input 8-bit color images (each of with the same size [N M]), convert them to double grayscale images and visualize them.
b) In order to detect the moving objects, calculate D1 and D2 defined respectively as the difference between the 1st image and the background and the 2nd image and the background.
c) In order to avoid detection errors due to the movements of small isolated objects, such as leaves, for each of the two images (D1, D2) perform the following operations:
   I. obtain a threshold t1 (or t2) equal to 1/10 of the maximum absolute values stored in D1 (or D2)
   II. calculate a binary image, B1 (or B2), associating TRUE value to moving pixels. In order to do so, set to TRUE the pixels having an absolute value greater than the threshold.
   III. define a rectangle structuring element with size equal to 0.5% of the minimum between M and N.
   IV. apply a morphological operation of your choice in order to remove isolated TRUE values from B1 (or B2) obtaining M1 (or M2)
d) Estimate the speed of the car in the following way:
   I. find the coordinates of TRUE values in M1 and M2
   II. calculate the coordinates of the central point of the car in the two images by averaging the (x,y) coordinates obtained in the previous point
   III. knowing that a displacement of 1 pixel corresponds to 0.05 meters (assume that you have calculated this value knowing the intrinsic parameters of the camera and its position in respect to the street), calculate the speed of the car in km/h (remember that the second image is taken 2 seconds after the first one).

Matlab

List of possible functions

```
figure
rgb2ind
im2double
imread
imclose
zeros
rgb2gray
imcrop
ones
imopen
imshow
find
hist
min
max
strel
imnoise
abs
round
sum
size
numel
norm
```

```
close all
clear all

%a)
I1 = imread('1.jpg');
I1 = rgb2gray(I1); I1 = im2double(I1);
I2 = imread('2.jpg');
I2 = rgb2gray(I2); I2 = im2double(I2);
bg = imread('bg_2.jpg');
bg = rgb2gray(bg); bg = im2double(bg);

%b)
D1 = I1 - bg;
D2 = I2 - bg;
```

```
%c) I. and II.
B1 = abs(D1)>0.1*max(abs(D1(:)));
B2 = abs(D2)>0.1*max(abs(D2(:)));

%c) III.
n = round( 0.005*min(size(I1)) );
SE = strel('arbitrary',ones(n));

%c) IV.
M1 = imopen(B1,SE);
M2 = imopen(B2,SE);

%d) I. and II.
[i,j] = find(M1);
p_1(2) = sum(i)/numel(i);
p_1(1) = sum(j)/numel(j);
[i,j] = find(M2);
p_2(2) = sum(i)/numel(i);
p_2(1) = sum(j)/numel(j);

%d) III.
p2m = 0.05;
t = 2;%s
v = norm(p_2-p_1)*p2m/t %m/s
v*60*60/1000
```