Problems 1 and 2.

1. Comments on type of motion and noise: The video sequences irseq1.mat and irseq3.mat exhibit a vertical movement only from bottom to top (considered as a positive shift in the $y$ direction), while in the videos irseq2.mat and irseq4.mat the movement is lateral only from right to left (considered as a negative shift in the $x$ direction). Regarding the noise, irseq1.mat and irseq2.mat are almost noiseless. On the contrary, irseq3.mat and irseq4.mat are noisy video sequences where the noise corrupting the images is a fixed pattern.

2. Correlation-based motion estimation. The results of the total shift estimation process are shown in Table 1. Cropping values of 0 and 5 pixels were employed in the computations. In Fig. 1, the estimated shift between consecutive frames, when a cropping of 5 pixels was employed, is shown for the sequences irseq1 and irseq2. It
can be commented that in absence of noise in the sequences, the estimation process is accurate. However when the fixed-pattern noise is present in the video sequences, the estimation process is strongly degraded. In general, we have to crop the edges of the images before computing the spatial correlation. Unfortunately, such an effect is not seen in the video sequences considered here. Cropping is required because camera movement introduces new information at the edges when a new image is acquired; this new information does not have any correlation with the information available at the reference frame, and it is considered as noise thereby reducing the capability of the method to estimate the motion. Hence, a fairly good motion estimation requires that, at least, one must know an upper bound on the maximum shift observed in the video sequence.

Table 1: Results of the total shift estimation using both spatial correlation and Cain’s method.

<table>
<thead>
<tr>
<th>Video</th>
<th>Correlation no cropping</th>
<th>Correlation cropping 5 pix.</th>
<th>Cain’s method no cropping</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(( \hat{\alpha}, \hat{\beta} )) Elapsed time, s</td>
<td>(( \hat{\alpha}, \hat{\beta} )) Elapsed time, s</td>
<td>(( \hat{\alpha}, \hat{\beta} )) Elapsed time, s</td>
</tr>
<tr>
<td>irseq1</td>
<td>(0,24) 27.11</td>
<td>(0,26) 23.10</td>
<td>(0,28) 0.201</td>
</tr>
<tr>
<td>irseq2</td>
<td>(-51,0) 27.08</td>
<td>(-51,0) 23.09</td>
<td>(-56,0) 0.188</td>
</tr>
<tr>
<td>irseq3</td>
<td>(0,0) 27.41</td>
<td>(0,0) 23.08</td>
<td>(0,56) 0.170</td>
</tr>
<tr>
<td>irseq4</td>
<td>(0,0) 27.07</td>
<td>(0,0) 23.08</td>
<td>(28,0) 0.191</td>
</tr>
</tbody>
</table>

3. In order to get a fast implementation of the correlation-based motion estimation algorithm, an appropriate padding and an FFT implementation should be used. Instead of providing a stabilized video, in this document we show panoramic images obtained using the estimates of the shift. See Fig. 2.

4. Cain’s algorithm for motion estimation. The results of the total shift estimation process are shown in Table 1, while the amount of shift between consecutive frames is shown in Fig. 1 for the sequences irseq1 and irseq2. First, note that the total amount of shift estimated by Cain’s algorithm is almost the same as the one computed using spatial correlation. Interestingly, the frame-by-frame estimates obtained by the methods are not the same. Note that in the case of Cain’s algorithm no cropping values are given because the cropping process is embedded in the definition of the
window functions $w_f$. In the case of sequences irseq1 and irseq2 the values of maximum shift in the $(x,y)$ directions were set to $(0,2)$ and $(3,0)$, respectively. It must be commented also that those parameters were obtained by inspection.

Problem 3.

The Matlab function shown below implements a homomorphic filter. In Fig. 3 an example of homomorphic filtering is shown. The parameters of the employed filter are: $\gamma_L = 0.25$, $\gamma_H = 2$, $c = 1$, and $D_0 = 80$. Note that the image obtained is a high-passed version of the original image. As a second example, consider the same original image and let us degrade it using an illumination pattern simulating a strong source of light concentrated in the middle of the image. The illumination pattern is defined as $i(m,n) \triangleq \alpha \exp(-0.5(m^2/D_{0,m}^2 + n^2/D_{0,y}^2))$. A homomorphic filter, with the same parameters as the one used in the previous case can be used to compensate for an illumination pattern with $\alpha = 1$ and $D_{0,x} = D_{0,y} = 150$. See Fig. 4 for the results.

function H=HomomorphicFilter(M,N,GammaL,GammaH,c,D0)

% Creates a homomorphic filter using the input parameters
% Inputs:
% -------
% M, N: Image dimensions in x and y spatial coordinates
% GammaL: Minimum value for the magnitude of the filter. It should be <1
% to attenuate low frequencies (intensity)
% GammaH: Maximum value for the magnitude of the filter. It should be >1
% to enhance high frequencies (reflection)
% c: Parameter to control the sharpness of the rise in the magnitude
% D0: Cut-off value of the frequency components to enhance/attenuate
% The function implemented is
% H=GammaL+(GammaH-GammaL)(1-exp(-c(D2/D0^2));


Figure 1: The estimates of amount of shift between consecutive frames when: (a) Correlation method; and (b) Cain’s method is employed for the noiseless video sequences.
Figure 2: Panoramic images obtained with the shift estimates: (a) irseq1.mat; and (b) irseq2.mat. Images on the left were obtained using correlation methods and images on the right were obtained using Cain’s method.
% Output:
% -------
% H: The filter
%

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
% Homomorphic filter
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
% Compute the points of the grid
m=(-M/2):(M/2-1);
M2=M/2;
n=(-N/2):(N/2-1);
N2=N/2;
% Creates the grid
[v u]=meshgrid(n,m);
% Compute D^2= u^2+v^2
D2=u.^2 + v.^2;
D02=D0.^2;
% Create the homomorphic filter (the magnitude)
H=GammaL+(GammaH-GammaL).*(1-exp(-c*D2./D02));
Figure 3: (a) An example of medical image (left) filtered using a homomorphic filter to obtain a high-passed image. (b) The magnitude of the spectrum of the original image (left), the homomorphic filter (center), and the filtered image (right).
Figure 4: A sample image (left) is corrupted by an exponential illumination pattern, with a “radius” of 150 pixels, yielding the central image. The image on the right is obtained using a homomorphic filter to compensate for the illumination pattern.