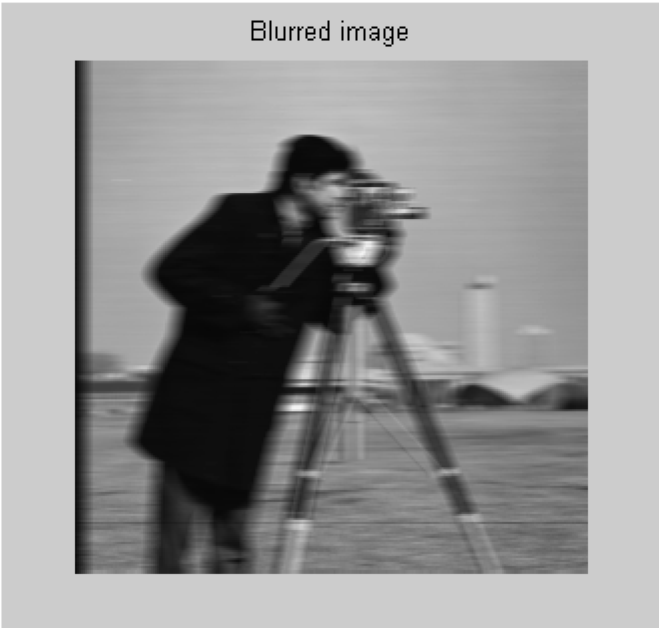
Lab 2, DIP1

The following lab will show you an example on how blur may be generated, when capturing an image using a digital camera. The Lab will provide you with a method that can be used to remove this blur. The problem may occur when the camera is moved during capture of the image.

Let's try to model the motion of the camera during capture. Below you can see an image captured as the camera is moved in a horizontal direction.



The blur is in the horizontal direction; hence the PSF (Point Spread Function) must be in the form:

$$\frac{1}{5}\begin{bmatrix} 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 1 & 1 & 1 & 1 & 1 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix} \tag{0.1}$$

Maybe more, maybe less rows (columns).

1. Try to explain the form of the PSF in (1.1) (Hint: The PSF is the image capture of a point light source). Let *M* denote the width of the PSF. Explain in word, how *M* is related to the shutter time for the camera, the speed of the movement of the camera and the distance to the object in the scene.

2. Try to measure *M* on the image above.

3. Load the image *"cameraman.tif"* into MatLab and model the blur using the MatLab function *imfilter()*. Use the PSF' in formula (1.1).

As seen in formula (0.1) only one row in the PSF is non-zero. This implies, that instead of using the function *imfilter()* on the hole image you can use the 1D filtering function *filter()* on all rows in the image. It can be done in the following way:

```
for r=1:size(I,1)
        J(r,:)=filter(h,1,I(r,:));
end;
```

4. Try using the MatLab code above to blur the image. Compare the result with the result from question 3, explain the difference.

One row in the image is filtered using the impulse response:

$$h[n] = \frac{1}{M}\begin{cases} 1 & 0 \le n \le M-1 \\ 0 & otherwise \end{cases}$$

The Z-transform of this is:

$$H(z) = \frac{1}{M} \cdot \frac{1-z^{-M}}{1-z^{-1}} \tag{0.2}$$

(can you show this?).

The invers filter must have the Z-transform:

$$H_{inv}(z) = M \cdot \frac{1-z^{-1}}{1-z^{-M}} \tag{0.3}$$

since:

$$\frac{1}{1-z^{-M}} = \sum_{k=0}^{\infty} (z^{-M})^k$$

we get:

$$\begin{aligned} H_{inv}(z) &= M \cdot 1 - z^{-1} \cdot \frac{1}{1-z^{-M}} \\ &= M \cdot \sum_{k=0}^{\infty} z^{-Mk} - z^{-Mk-1} \end{aligned} \tag{0.4}$$

Now using the inverse Z-transform we get (check this!):

$$h_{inv}[m] = M \cdot \begin{cases} 1 & M \ divides \ m \\ -1 & M \ divides \ m-1 \\ 0 & otherwise \end{cases} \tag{0.5}$$

5. Show $h * h_{inv} = \delta$ using pen and paper (or MatLab).

6. Try to recover the blurred image using h_{inv} in formula (0.5).

7. If there is more time, you may consider how the blurring in the vertical direction can be modelled and removed.