# A robust method for deblurring and decoding a barcode image

In collaboration with

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# Deblurring and decoding a barcode image



- The problem of deblurring and decoding a barcode image is an important application for smartphones equipped with a low quality camera.

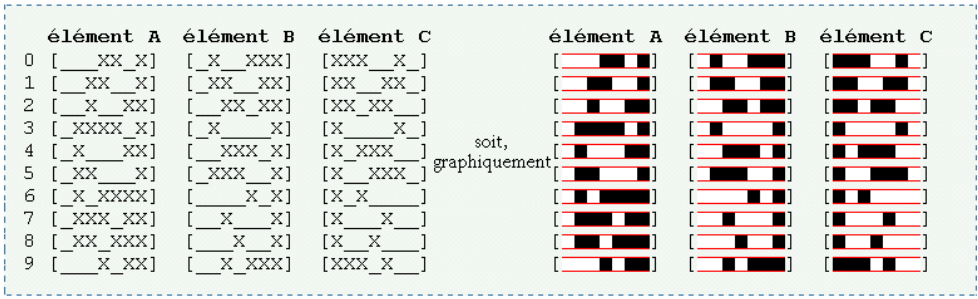

- Starting from an image as the one depicted above, the problem is to decode it, that is find the associated barcode number.
- Three factors can degrade the quality of the image and make it hardly decodable : blur due to out of focus, noise, and also variable illumination.

# How to decode a barcode



- The decoding of a barcode is based on the precise computation of the various widths of black and white lines.


- For instance, in the most popular family of barcodes called EAN13, an alphabet is used to convert the widths to a code of 13 numbers :




- A small error on the width measurement of a line can lead to a wrong decoding of the barcode.

# The model of blur and noise



- The mathematical model describing the out-of-focus blur, noise and variable illumination corresponds to the following transform of the initial signal $u \in L^2(\Omega)$ :

$$u_0(x) = I(x)(k * u)(x) + n(x)$$

- The out-of-focus blur operator takes the form of a convolution with the kernel :

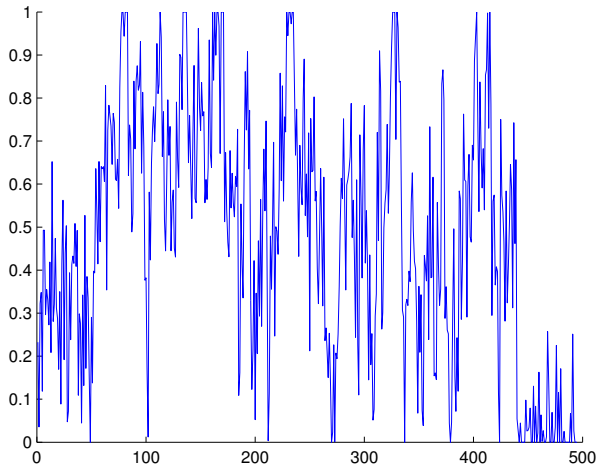
$$k(x) = \frac{1}{2r}\mathbf{1}_{|x|<r}$$

- The variable illumination consists in multiplying the blurred signal by a function $x \to I(x)$ with values in $[0, 1]$.

# The associated inverse problem



- The associated inverse problem consists thus in finding the exact barcode value starting from an observed signal $u_0 \in L^2(\Omega)$ as the one presented below :




- With the previous model, the objective is to find $(r^*, I^*, u^*)$ minimizing the cost function

$$J(r, I, u) = \int_\Omega |I(k * u) - u_0|^2 dx$$

# The associated inverse problem



- In the deterministic approach, a total variation term of the type $\int_\Omega |\nabla u(x)| dx$ is added to the cost function in order to make the problem well-posed (Esedoglu, *Inverse problems*, 2003).
- In the case of a barcode image, a penalty term taking into account the binary form of the image is also necessary.
- With this method, it is possible to restore blurred barcode images but only with a small or medium noise and without variable illumination.

# Deblurring and decoding : the algorithm

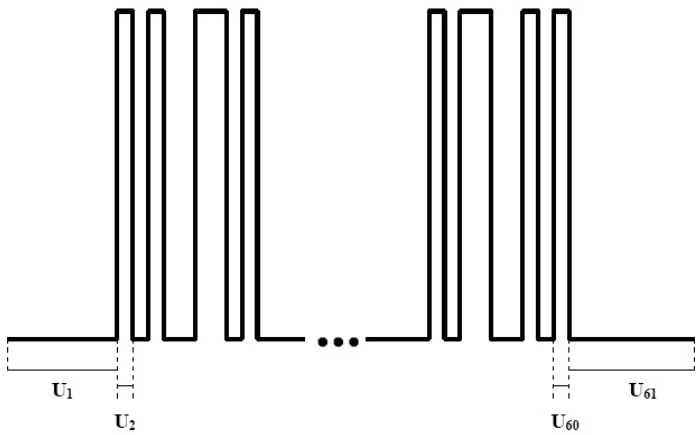


- The simultaneous deblurring and decoding of a barcode image with blur, noise and variable illumination is done here by using an evolutionary algorithm, namely a genetic algorithm.
- The cost function that has to be minimized is defined here on a mixed search space (discrete/continous).
- The robustness of evolutionary algorithms allows in particular the use of the mean square error without adding any regularization term at the cost function.

# Deblurring and decoding : the search space



- The search space for $u$ is discrete and takes into account the shape of a barcode made of 30 lines of different widths.




- More precisely, $U = (U_1, ..., U_{61}) \in \mathbb{N}^{61}$ where $U_i$ is the length of the $i$th black or white line.
- $U_1$ and $U_{61}$ play a particular role because they correspond to the left, respectively right, unknown margin at each side of the barcode in the image.

# Deblurring and decoding : the search space



- Note also that the following constraint holds :

$$\sum_{i=1}^{61} U_i = M$$

  where $M$ is the width of the image.
- The search space for $r$ and $I$ is of continuous type. A spline interpolation is in particular used for describing the variable illumination.

# Deblurring and decoding : the darwinian principles

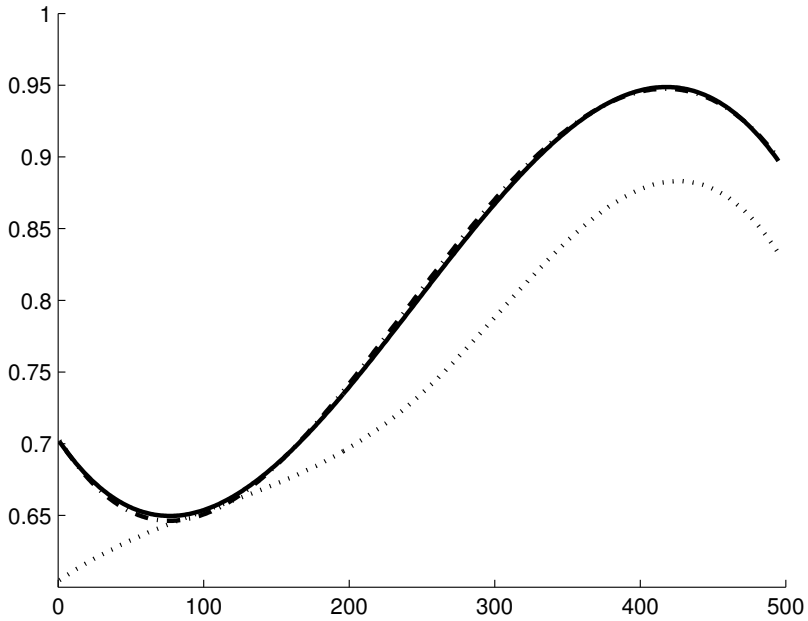


- For the discrete variable $U$, a $N$-points crossover is used. Given two parents, the offsprings are computed by exchanging $N$ successive portions between them.
- The mutation process corresponds to the resizing of the two offsprings to the original size of the image.
- For the continuous variables $r$ and $I$, a barycentric crossover and a non uniform mutation is used.

# Deblurring and decoding : obtained results



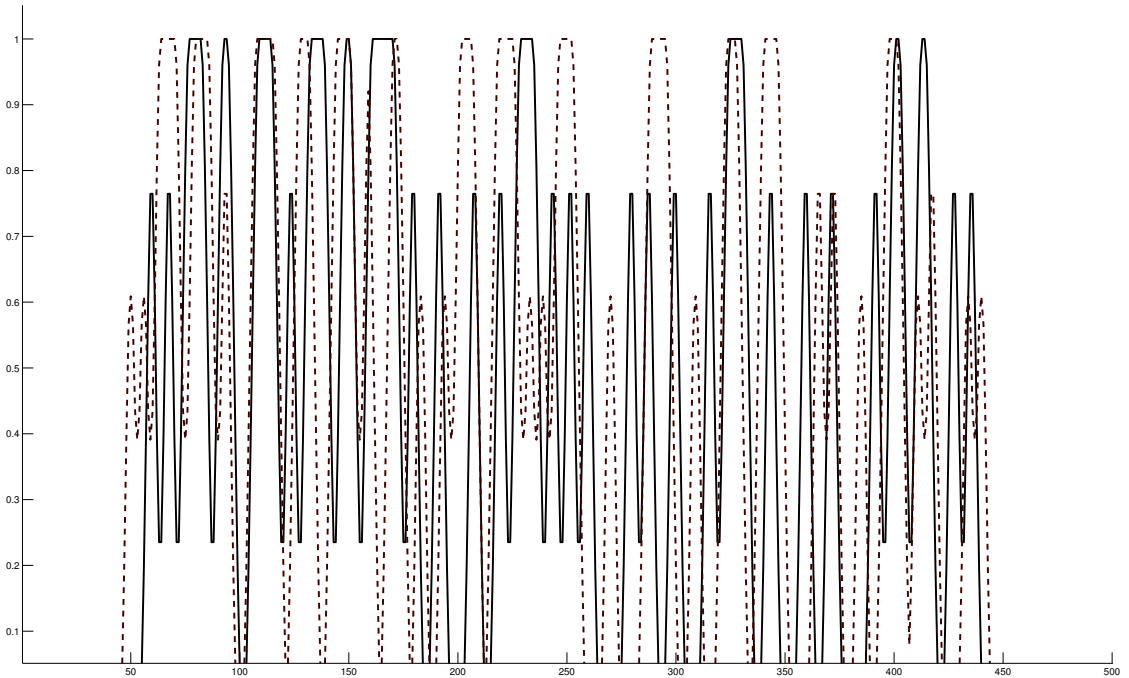
- Example 1 : determination of blur radius and variable illumination of an image with a known barcode, no noise :



# Deblurring and decoding : obtained results



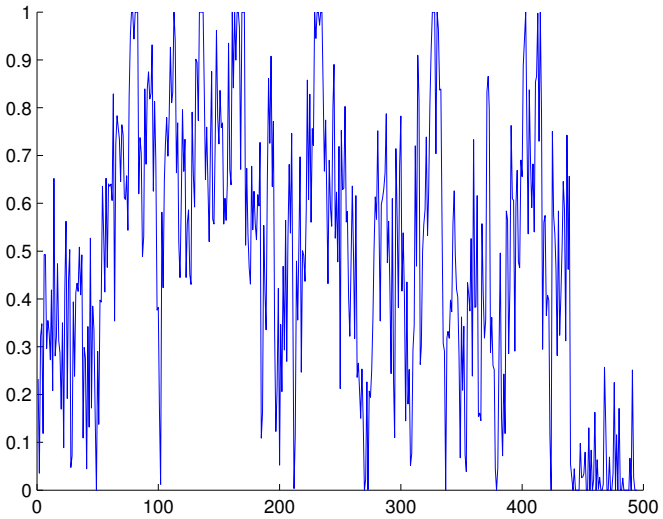
- Example 2 : determination of a barcode characteristics with a known blur, no illumination, no noise :



# Deblurring and decoding : obtained results



- Example 3 : determination of a barcode characteristics without any information on blur, illumination and noise on the image :

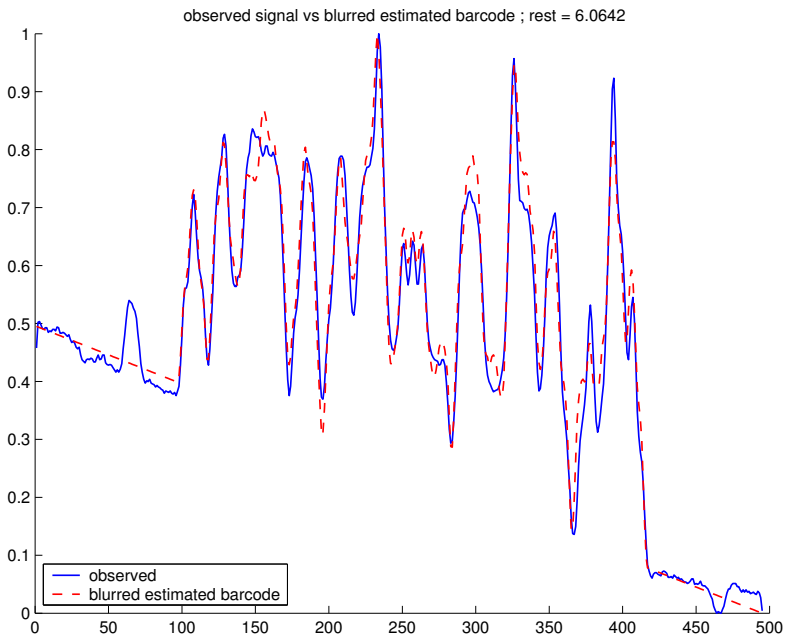


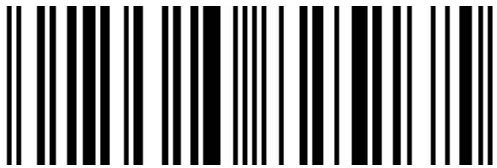

with the corresponding barcode number : **4747379384732**.

# Deblurring and decoding : obtained results



- Example 4 : decoding of a real barcode image with blur, noise and variable illumination :



with the corresponding barcode number : **4025515825135**.

# Deblurring and decoding : obtained results



- The results show a very good reproducibility of the method as well as a very strong insensitivity to the signal to noise ratio of the image.
- For real images, a correct decoding of the barcodes has been obtained independently of the camera, with a very promising success rate.
- At this stage, it is not possible to deblur and decode in real time, but the whole phase can be achieved in a few seconds by running it on a parallel server.