**Università degli studi di Brescia**
**Communication Technologies and Multimedia**

# Multimedia Information Coding and Description

## Laboratory Experience No. 5

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# Contents

# Chapter 1

# Abstract

In this laboratory we simulate the predictive coding using a linear predictor. We first analyze the case of a real image predicted with optimal coefficients, obtained solving the Yule-Walker system of equations, and then with a set of suboptimal ones. In the second part we repeat the simulation with a synthetic image and finally we compare the results.

# Chapter 2

# Theory

Generally the aim of a compression method is to remove redundancy and irrelevancy present in the signal.
In the specific case the method is based on a a-priori model of the signal that permits to estimate the original signal. On the channel then we only transmit the innovations, the prediction error, that means the information that the model can't describe.

The main step of the algorithm is the estimation of the optimal coefficients, that means the one that minimize the prediction error. We assume that the signal is a realization of a wide sense stationary stochastic process, so we compute:

$$min_{a_k}\sigma_E^2 \stackrel{\mu_E=0}{=} min_{a_k}E[E^2[n]]$$

To minimize the variance we have to apply the derivative for each filter coefficient. This procedure leads to the Yule-Walker equations:

$$\underline{a} = \underline{\underline{R_u}}^{-1} \cdot \underline{\Gamma}$$

Notice that we neglect the quantization process to simplify the computation.

## 2.1 Technical details

To obtain the optimal coefficients with Matlab we use the following procedure:

- Calculate the autocorrelation of the image
- Extract needed values according to Yule - Walker equations
- Reorganize previous values in the correct order according to prediction scheme
- Compute the $\underline{\Gamma}$ vector by extracting again the values from the autocorrelation matrix according to Yule-Walker
- Obtain the $\underline{a}$ coefficients by inverting the $\underline{\underline{R_u}}$ matrix and multiplying it by $\underline{\Gamma}$

It's important to remark that we must use the statistical correlation so we need to estimate it from the deterministic one of the image. The estimation is obtained by normalizing the values of the deterministic autocorrelation with respect to the number of samples used to compute each value (in practice we compute the sample statistical autocorrelation).

# Chapter 3

# Real images

In this chapter we analyze the prediction error of a real image.
The prediction scheme is the following:

$$I(x, y) = a_{10} \cdot I(x-1, y) + a_{01} \cdot I(x, y-1) + a_{11} \cdot I(x-1, y-1) + e(x, y)$$

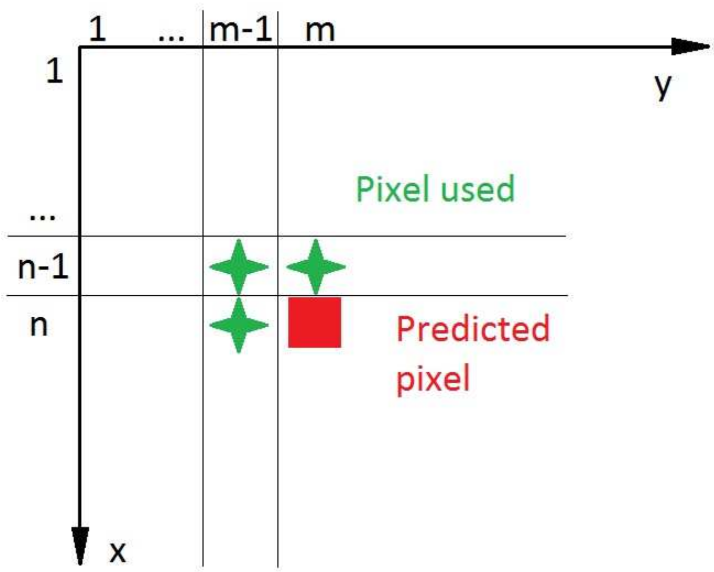


Figure 3.1: Prediction scheme

## 3.1 Optimal coefficients

The results obtained are in the Figure 3.3, Figure 3.4 and Figure 3.5

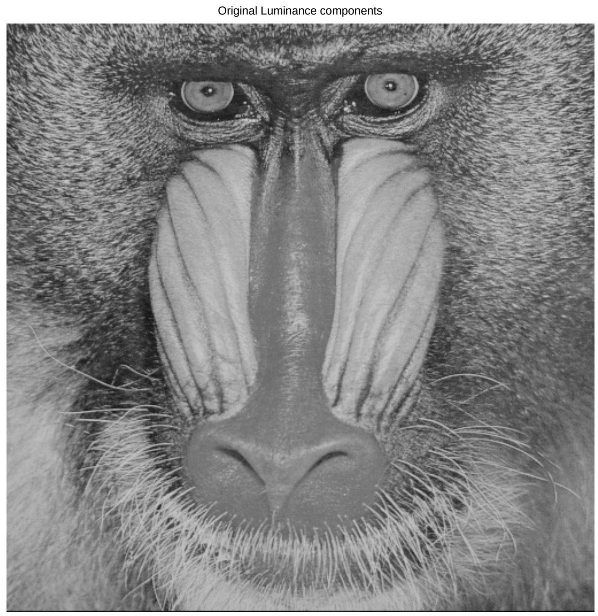


Figure 3.2: Original image (source)

Figure 3.4: Innovation (prediction error) in the optimal case

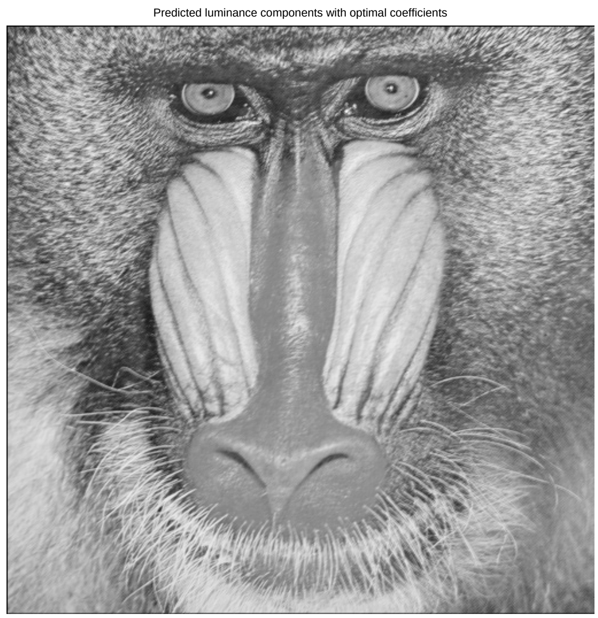


Figure 3.3: Predicted image with optimal coefficients

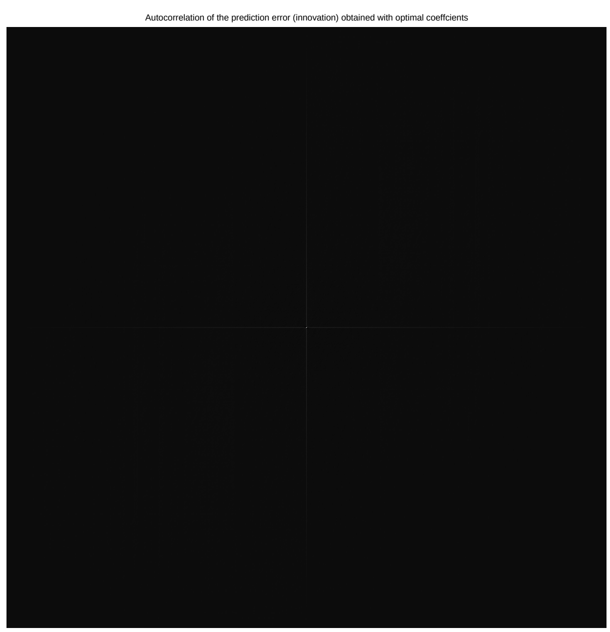


Figure 3.5: Prediction error autocorrelation

## 3.2 Suboptimal coefficients

In this section we use the following suboptimal coefficients:

$$\underline{a} = [\tfrac{1}{3}, \tfrac{1}{3}, \tfrac{1}{3}]$$

As expected the energy of the error in this case is greater than in the previous one:

- Optimal case: $W = 2.0250 \cdot 10^3$
- Suboptimal case: $W = 2.5293 \cdot 10^3$

The results of the simulation are in the Figure 3.6, Figure 3.7 and Figure 3.8

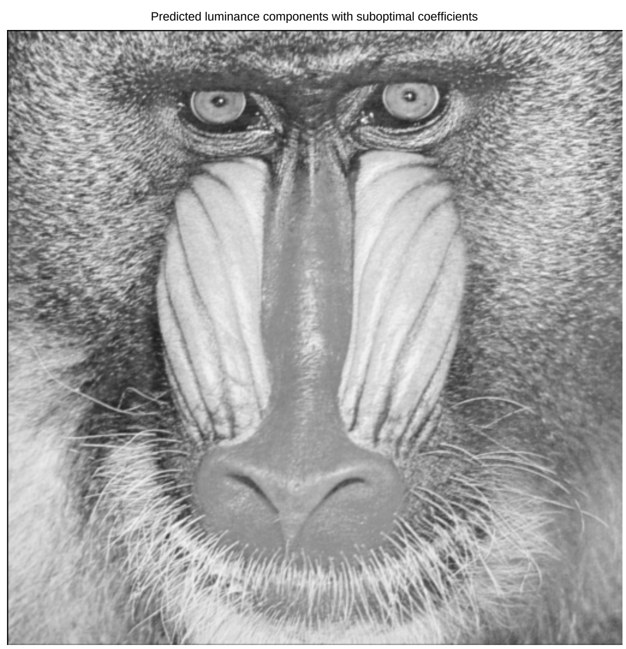


Figure 3.6: Predicted image in the suboptimal case

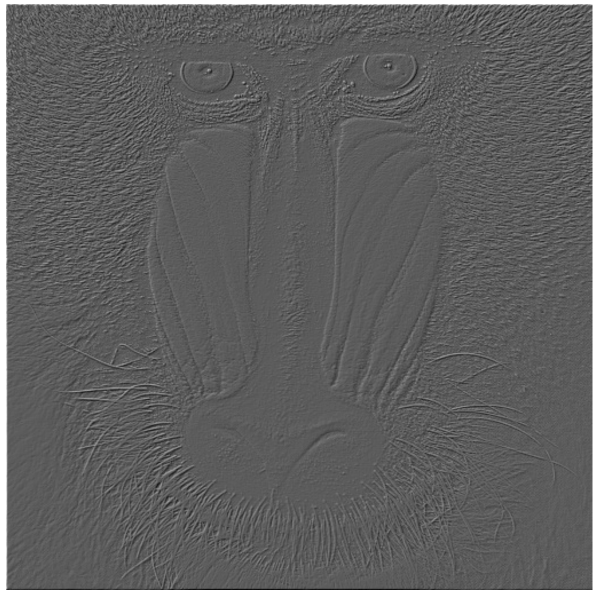

Figure 3.7: Prediction error in the suboptimal case

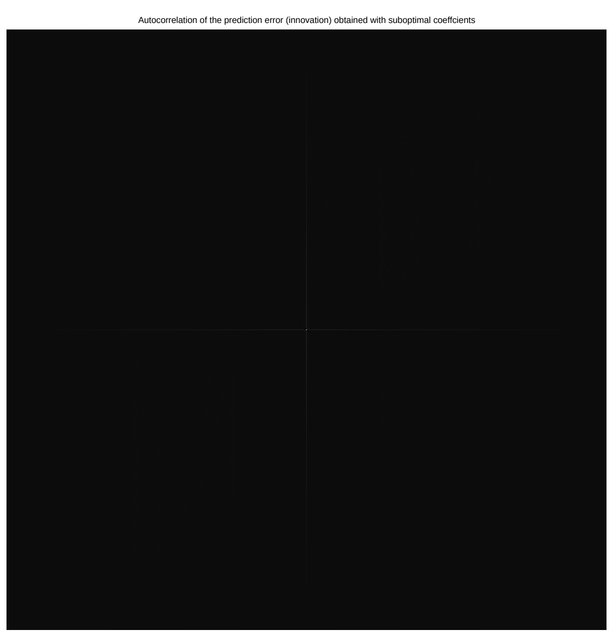


Figure 3.8: Autocorrelation of the innovation in the suboptimal case

As expected, using optimal coefficients, the energy of the prediction error is lower than the one of case with sub-optimal coefficients. The difference between the two errors is equal to $508.8$. The main differences between the two error can be seen, also visually, where there are discontinuity, for example where there are moustache of the baboon, Figure 3.9.

Figure 3.9: Absolute difference between the optimal and suboptimal case

# Chapter 4

# Synthetic images

In this chapter we repeat the same steps made in the previous one using a synthetic image generated with the following analytical expression:

$$s(x,y) = 128 + 127 \cdot sin(2\pi \frac{1}{60} x) \cdot cos(2\pi \frac{1}{60} y)$$

Notice that in the next image we rescale the dynamic of the error in order to show better the difference between the two cases.

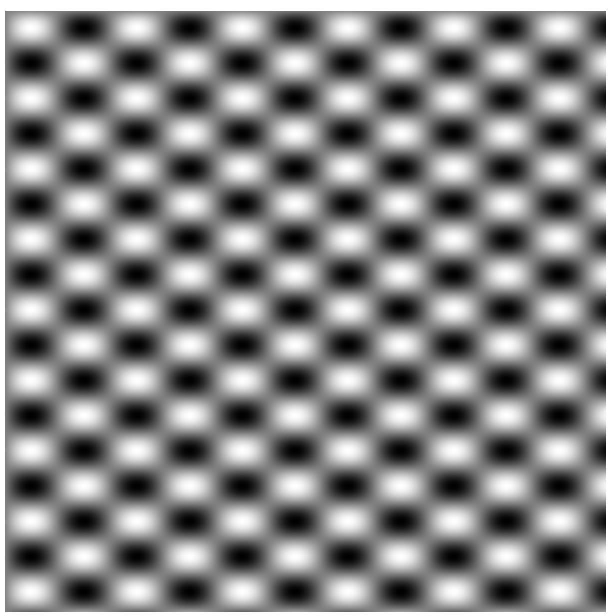

Figure 4.1: Synthetic image used for the simulation

## 4.1 Optimal coefficients

We plot the same quantities of the real images, Figure 4.2, Figure 4.3 and Figure 4.4. As a result we obtain these coefficients:

$$[a_{10}, a_{01}, a_{11}] = [0.9841, 0.9893, -0.9735]$$

And the following energy of the error:

$$W_E = 301.6$$

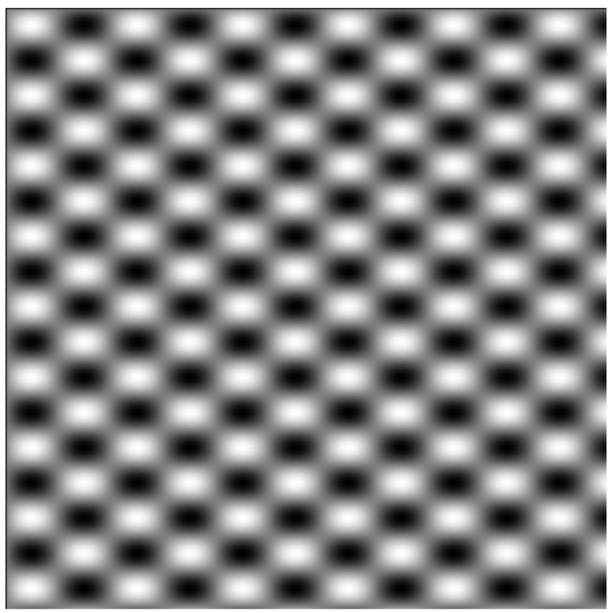

Figure 4.2: Predicted image with optimal coefficients

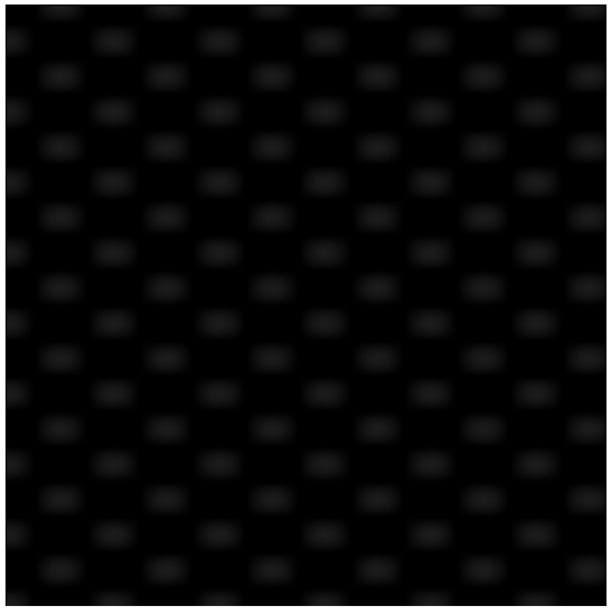

Figure 4.3: Prediction error in the optimal case

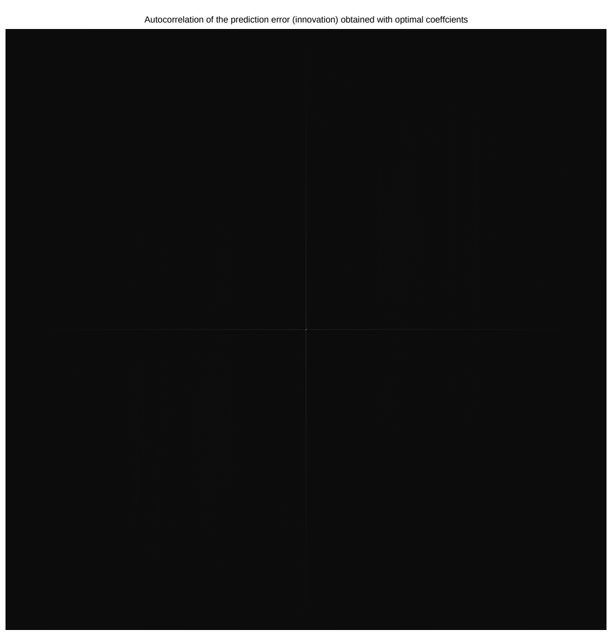


Figure 4.4: Error autocorrelation in the optimal case

## 4.2 Suboptimal Coefficients

As expected the energy of the prediction error in the suboptimal case is greater than the optimal one:

$$W_E = 615.6$$

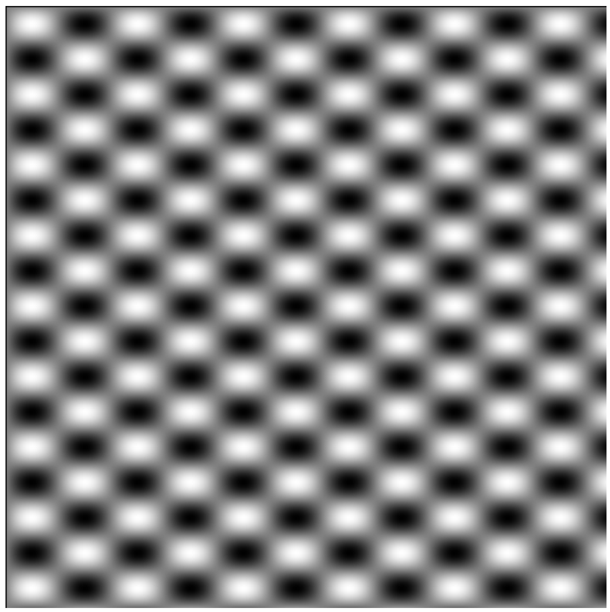

Figure 4.5: Predicted image with suboptimal coefficients

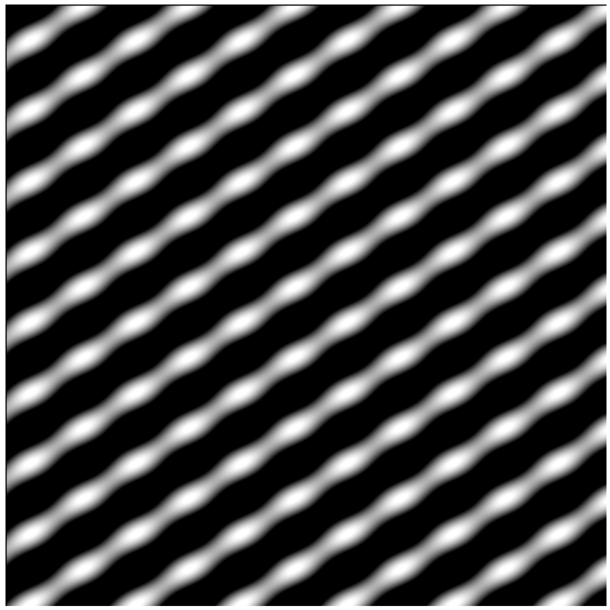

Figure 4.6: Prediction error in the suboptimal case

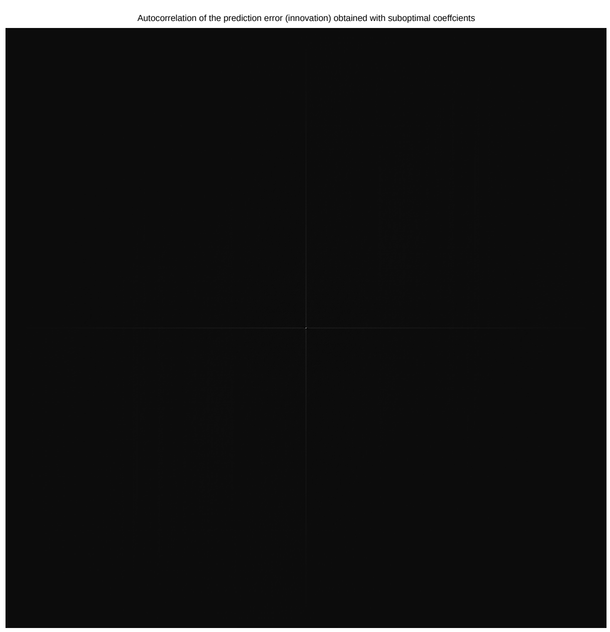


Figure 4.7: Error autocorrelation in the suboptimal case

Similarly to what happens in the case of a natural image, also with a synthetic one the energy of the error obtained with optimal coefficients is lower than the one obtained with sub-optimal coefficients. Now the difference between the two errors is equal to $314$.

Comparing the results obtained with a natural image to the ones obtained with a synthetic image we can notice that, in the first case, the errors obtained are higher. Instead, the difference between the error obtained using sub-optimal coefficients and the one obtained with optimal coefficients is higher for the synthetic image.