Texture analysis using the Fourier Power Spectrum

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Abstract

This paper has the purpose of documenting the third exercise given in the subject Advanced Topics on Computer Vision at UPC. The exercise given is to implement a texture analysis algorithm to find features to be used for classification. We chose to analyze two different textures, brick walls and concrete walls, using the Fourier Power spectrum as a tool. All this is implemented in MATLAB.

1. Introduction

In Computer Vision texture analysis is a complex task. Both the scale and the rotation of an object will impact its key features. However, for this exercise we choose to not tackle the problem and we assume that all the textures of the same kind are more or less oriented and scaled in the same way. Moving on, we first have a look at the dataset we are working on. Then, we have a look at the use of the fourier transform, and an explanation of the following algorithm that extracts the features that was most useful. Lastly, the results of a classification is presented.

1.1. The two types of textures

As mentioned, we will try to discriminate between two different textures: brick- and concrete walls. A sample of the dataset is given in figure 1.

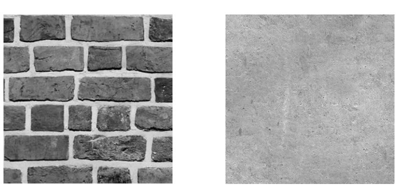

Figure 1. An example of the brick wall and concrete wall texture.

In this exercise, five pictures of bricks and four pictures of concrete walls are used later for training.

2. Fourier Power Spectrum

Assuming the reader knows the Fourier transform already, we go straight for the power spectrum. The power of the Fourier transform is defined to be

$$S = |\hat{F}(u, v)|^2 \tag{1}$$

in other words the absolute value squared of the Fourier transform of the image. The variables u and v corresponds to frequency. The power function disregards the phase information and keeps only the magnitude contribution of each frequency. This fact is used to analyze which frequencies are dominant in the image. An example power spectrum of a brick wall is seen in figure 2. We will restrict ourselves to the power spectrum throughout the whole exercise.

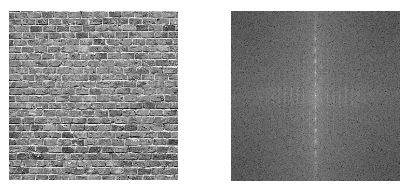

Figure 2. An example of the brick wall its power spectrum. The center of the spectrum is its origin where $u = v = 0$.

2.1. Features

The Fourier transform contains interesting information about frequencies involved in the image. A lot of thought went into which information would discriminate the different textures the most. An initial attempt of using PCA on the whole power spectrum of each image as an observation, and each pixel as its own feature was made without much success. Also an idea of doing an correlation of the mean of the power spectrum was attempted, however, even the slightest deviations in texture of the surface seemed to flatten the mean to an extent that it was unusable. The solution we landed on was to do both a radial and directional profile of the power spectrum. These are found by

$$S_r = \sum_{R=0}^{R=max} \sum_{\theta=0}^{\theta=360} |\hat{S}(R\cos(\theta), R\sin(\theta))| \tag{2}$$

$$S_d = \sum_{\theta=0}^{\theta=360} \sum_{R=0}^{R=max} |\hat{S}(R\cos(\theta), R\sin(\theta))| \tag{3}$$

An example of the profiles of a given picture is given in figure 3.

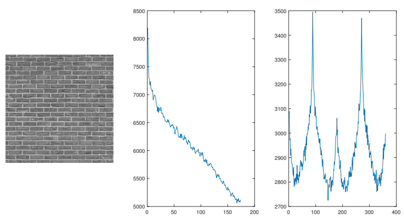

Figure 3. An example of a brick image (left) and its radial (middle) and directional (right) profiles.

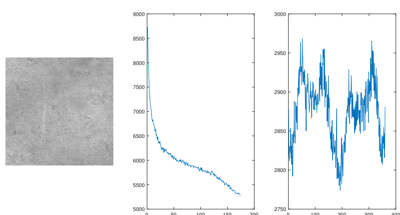

Figure 4. An example of a concrete image (left) and its radial (middle) and directional (right) profiles.

Testing for several images, we found that for the brick wall texture, the directional profile has a lot to say, and not so much the radial profile. The concrete wall has a similar radial profile, but not in the directional profile. This has to do that the spikes in the power spectrum is meaned when integrated along the circle around the origin but is amplified when integrated along the radius, as the fundamental frequency and its harmonics happen along the same direction. The directional profile is chosen to be our feature.

2.2. Remarks

Even though the directional profile seems to be a good feature for texture analysis, we encountered a case of a wall that had been a brick wall in its earlier days, but now had concrete smeared over it. In the image one could barely notice the pattern of the old brick wall, however when examining the profiles of the wall, we can see how sensitive the directional profile is to the slightest of edges. The wall and its profile is depicted in figure 5.

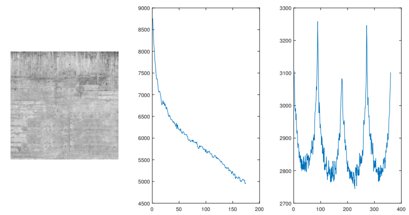

Figure 5. Anomaly in the concrete wall.

3. Classification

A binary support vector machine is used for the classification. It is trained using nine images, five of bricks and four of concrete walls. The results of the training is shown in figure 6.

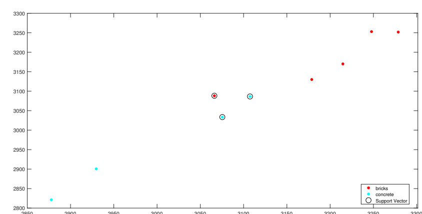

Figure 6. Post training SVM

One can see two "outliers" coming quite close to the brick texture feature as there is some concrete walls with slits.One already mentioned in figure 5. Using the SVM model to predict two brick walls and three concrete walls yields an 80 percent success rate as seen in table 1.

True Label	Predicted Label	Score
'bricks'	'bricks'	-0.77695
'bricks'	'concrete'	5.6895
'concrete'	'concrete'	2.046
'concrete'	'concrete'	1.6042
'concrete'	'concrete'	0.23491

Table 1. Predictions made by the SVM

4. Conclusion

The Fourier Spectrum is a sensitive analysis tool, prone to error under the slightest adjustments. Scale and rotation is not considered here, so further actions must be taken when generalizing its use. However, under the right circumstances, it can yield good results.