Improvement of Automatic Spatial Objects Recognition Using Spectral Reflectance

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Abstract

In this paper we investigate the problem of automatic detection of specific spatial objects using colorimetric attributes. We present a new solution based on the use of a multispectral camera instead of an RGB classical one. Using such a multispectral camera combined with a flexible protocol of calibration and a supervised algorithm of spectral reflectance reconstruction avoids metamerism encountered with the classical RGB camera.

In each pixel of an imaged scene, we reconstruct a spectral reflectance. Afterwards this spectral reflectance is projected on color space using a standard illuminant. Doing this, the algorithm of color attribute detection works better since we retrieve the colors for which such algorithm was designed. The results are satisfying and demonstrate the reliability of such a solution.

Introduction

Within photogrammetric applications several images are necessary for the determination of spatial objects. The images have to be tied together by a varying number of identical object points measured in the image space see Figure 1. This measurement should be performed automatically. Algorithms actually available work properly if only two images have to be tied together or if the object has been prepared with artificial signals. The planar shape of the signals and the projective geometry of images result in more or less strong deformations. A practical solution consists in the use of spatial tie objects: cubes for example [1]. The cubes have the advantage to be visible from any viewing direction and allow a sure identification. For their identification an localisation an algorithm has been developed. This algorithm uses shape and color as coding information. Unfortunately, a color value registered within an image may considerably vary compared to the value directly measured at the face itself due to changes in viewing direction and in intensity or spectral power density (SPD) of the illuminant. This color deviation affects the robustness of the cube detection algorithm. Since color information as captured by a classical camera is not reliable, we use a multispectral system. This offers the advantage to reconstruct a spectral reflectance value for each pixel of the scene. Thus, we avoid color deviations from which the algorithm originally suffers. We present the experimental set up, the acquisition protocol using a multispectral camera and a robust method to reconstruct spectral reflectance based upon neural networks. Then, we briefly describe the algorithm used for automatic cubes detection using the spectral information. Finally some of the results are given and discussed.

Figure 1. A 3D-object to be surveyed

Experimental Setup

We use spatial cubes as tie objects. However, the use of cubic tie objects needs to take some additional aspects into account, because of their higher complexity compared to planar targets. Multiple surfaces have to be detected, and each surface has to be uniquely identified. To do this, we chose color as coding information. A cube with its six sides gives a good separation using the principal and the complementary colors (R,G,B,C,M,Y). In this way, the required uniqueness and amount of difference can be assured (see Figure 2).

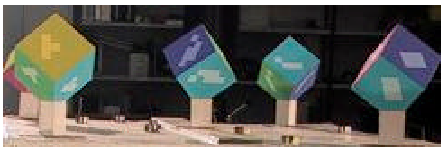

Figure 2. Sample cubes

Conventional color imaging presents a major limitation: during image acquisition, the scene is captured using a given but unknown illuminant. The same scene may appear completely different, if the illumination is changed, what might be the case within a couple of minutes. From the changes in the illumination a color deviation is introduced causing a failure in cube detection. By increasing the number of acquisition channels, which furthermore have a better spectral separation multispectral imaging systems may avoid this problem. Indeed, such systems have the potential to recoverthe spectral reflectance of the scene, simply using the camera output. In fact, spectral reflectance is valuable because it represents a physical property, depending neither on the acquisition conditions nor on the sensor used for the acquisition. Furthermore, a multispectral camera has as major advantage that it can be recalibrated

$$d_k = \mathbf{r}(l)\mathbf{S}_k(l) \qquad (1)$$

according to the changes of the acquisition conditions (outdoors, indoors…). Calibrating a multispectral camera is the same step as characterizing its spectral response including an illuminant. It follows the Equation 1

Where d_k is the signal observed from the camera output, relative to channel *k*, **r***(?)* is the vector representing the spectral reflectance, and $\mathbf{S}_k$*(?)* is a vector containing the spectral sensitivity of the acquisition system relating to the channel *k*.

The aim of calibration is to calculate the matrix **S***(?)* from Equation 1. To do this, we use the Macbeth Color Checker patches for which reflectances are perfectly known as object to be imaged. By observing the camera output responses, we estimate the system response in relation to the known theoretical reflectances in the input. So, under an ambient illuminant and before any acquisition, we simply need to acquire an image of the Macbeth chart (see Figure 3). This image allows us to calculate the system response for the actual illuminant.

Figure 3. Calibration with Macbeth color checker

Spectral Reflectance Reconstruction

Assuming stable conditions for the illumination we know the spectral response of the multispectral system for images taken during that period. Then an estimate of the reflectance spectrum in each pixel of an acquired scene is now possible. From Equation 1 we seek to estimate **r***(?)*. Several methods exist to solve this estimate. We use an algorithm based upon neural networks [2] to invert Equation 1.. In this method, we take advantage of the fact, that neural networks are generally robust to noise. In addition we generated the spectral reflectance of the cubes by scanning of each side using a spectrophotometer. In this way we have an *a priori* information about the reflectance to be reconstructed, since all channel responses are gathered in a the matrix **S**. The reconstruction is fast and easy: the estimated spectral reflectance **r**(λ) in each pixel of a scene is equal to the product between this matrix and the camera response.

Cube Detection Algorithm

First, the algorithm starts with the detection of color edges, then it checkes the color values of the faces, followed by first assumptions about target candidates and will finish by final tests onto the exact shape. Figure 4 summarizes this algorithm.

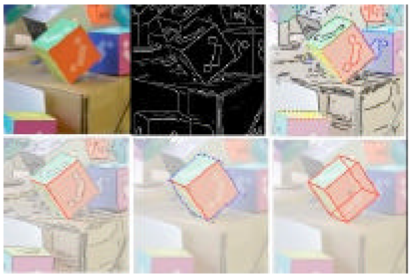

Figure 4. Algorithm of cube detection

Results and Discussion

In order to test this method, we used the multispectral camera and a professional Fuji Finepix S2 Pro. camera to acquire the same scene under different conditions. Then we applied the algorithm for the cube detection. Using the multispectral camera as reference, the cube detection could be improved for about 20% in average. So we can notice, that the additional use of a multispectral camera gives best results when different illumination sources are used. Figure 5 illustrates a successful case in which we detect all cubes in a color image reconstructed from a multispectral image.

In conclusion, the use of the spectral reflectance reduces the impact of unknown light conditions and allows to improve the detection of color objects. The next stage is to combine reflectance with an appropriate color transformation to enhance cube detection

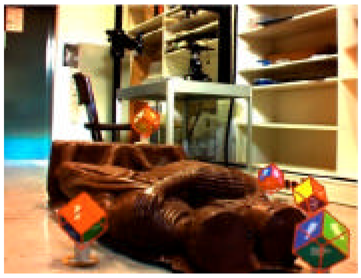

Figure 5. Cube detection within a reconstructed image

References

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