Bibliography

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1 Introduction to Photometric Stereo

1.1 Problematic

Photometric stereo is a 3D reconstruction technique introduced by Woodham [1] in the 80's. The principle of this method is to take successive images from a constant point of view, while varying the direction of incident light, in order to determine surface orientation at each image point. This technique is based on the idea that the amount of light reflected by a surface depends on the orientation of the surface in relation to the light source and the observer [2]. Woodham's method was based on a couple of assumptions: Lambertian reflectance, uniform albedo, and known point-like distant light sources.

However, these assumptions are not applicable to real-world scenarios, as the bidirectional reflectance distribution function (BRDF) is a complex aspect of photometric stereo that can vary depending on the surface properties, which makes it difficult to analyse using traditional methods. More recent methods are using machine learning techniques, such as neural networks [3], to handle the BRDF implicitly.

1.2 The Photometric Stereo Microscope

The goal of this research isn't solving photometric stereo, instead, we're aiming to create a photometric stereo microscope using low-cost components, and a low number of light sources, in order to make it more affordable, more compact, and yet still competitive with existing, expensive models. Usually we find two different type sof acquisition systems:

Multiple views with multiple lights: These systems attempt to capture all combinaisons of the view and light directions, and it requires a complex hardware design and a long acquisition time(e.g. [4]). Moreover, in order to acquire accurate images, we need to avoid any vibration that would generate noise in our capture, which can be very challenging with this type of systems as they are usually using mechanical components. These systems can only be used in labs due to their size.

Fixed view with multiple lights: These systems on the other hand are fixing the viewpoint and capture shading under multiple light directions(e.g. [5], [6]), this offers the possibility of electrically controlling the light sources, which reduces the noise generated by mechanical components. But, due to the high number of led's used by these methods of measure, the acquisition time is still high.

Our approach: We are aiming to employ IoT techniques to conceive this microscope: By using a Raspberry Pi, all of the computation can be done on the microcontroller level instead of the user's computer, also the use of a Raspberry HQ camera and a limited number of leds would make the system easier to calibrate, and more compact. It is also worth nothing that our main focus during this work is making the usability of the system as friendly, and intuitive as possible for the normal user.

2 Key Steps in the Photometric Stereo Acquisition Process

Basically, the problem of photometric stereo is recovering precisely the 3d shape of a scene, given a set of images of the same scene under different but known lights. In order to achive that, it is mandatory for us to keep the captured data as close as possible to the real physical data, which imposes applying the following pipeline:

capturing RAW data images → demosaicing → white balancing the images → recovering HDR images

RAW images capture: RAW images contain all of the data captured by the camera's sensor, and when this data is processed into a JPEG or another compression format, some of this information is lost, which is why it is crucial for us to work with RAW images in photometric stereo, because it gives us greater control during the reconstruction process.

Demosaicing: Demosaicing is the process of converting a RAW image, which is captured using a Bayer filter, into a full-color image. A Bayer filter is a mosaic color filter array that is placed over the sensor of a digital camera. The filter is made up of tiny squares of red, green, and blue filters, which are arranged in a specific pattern. When an image is captured, each pixel on the sensor only records the intensity of one color, either red, green, or blue. Multiple demosaicing approaches can be found and applied[7], some uses complex algorithms to interpolate the missing color information for each pixel by using the color information of the surrounding pixels, which allows us to recreate an image with the original resolution, but the downsize will be the loss of real physical data. Our goal is to accurately measure the intensity of light at each pixel, rather than creating a high-resolution image, so, we will be demosaicing without interpolation, by relying on the knowledge of the CFA pattern used in the sensor. This method is called color filter array (CFA) pattern, and it uses the color information of one color channel per pixel, without the need for interpolation.

White balance: White balancing is an important aspect of image processing, the idea is to take an image of a white reference first, using the same capture parameters (exposure time and source of light), and since we know that each pixel of this image should be white, then we know what the real values of each pixel should be. This allows us to build a matrix of coefficients, that will allow us to calibrate the object image.

HDR images: HDR (High Dynamic Range) images are created by combining multiple images of different exposures to produce a final image with a greater dynamic range of colors and brightness levels[8]. This is important in photometric stereo as it allows us to handle scenes with a wide range of illumination conditions, which would otherwise cause under- or over-exposure in standard images. By recovering HDR images, we can ensure that the final image will have a more natural and realistic appearance and that the surface normals can be accurately estimated. These steps are important because they ensure that the data is of high quality and that it can be effectively used in the photometric stereo reconstruction process.

3 Conclusion

In conclusion, photometric stereo is a powerful technique for 3D reconstruction with many real-world applications, however, traditional methods have limitations and recent methods are currently in development to overcome these challenges. This Project will make a low cost, more accessible acquisition system, that can be used to bring new ideas and innovations to the field of photomoetric stereo.

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