3D scanner colorization taking into account lighting problems (shadows, overexposures, lighting changes, and lack of light)

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3D scanner device coupled to a camera offers a good solution to obtain a digital reconstruction of an archaeological site or an object of interest in order to present it to users via different media (web presentation, virtual reality, immersive system, ...)

Visual appearance is probably one of the most critical parameters affecting an observer's perception, as well as their judgment or initial understanding of what is being presented to them. Appearance is therefore a subjective property inaccessible to direct measurement for Leloup et al. (2012). To quantify it, it is necessary to determine the physical parameters or optical properties that can be measured.

One solution is to use photographic images. In this case, the apparent texture is plated on the digital object by applying an inverse projection. The capture of the appearance for the same surface is then limited to taking a set of photographs, partially taking into account the luminous properties. In addition to geometric considerations, on-site scanning must take into account factors influencing photographs.

Factors influencing the photographic result

Influence of natural lighting

For most surveys, the measurements are spread over time, which makes it impossible to acquire all the pictures under the same conditions due to changes in natural luminosity (sun and cloud movements, variability in light intensity, …). In addition, direct sunlight is responsible for most observable critical situations (shadows, excessive illumination, reflections on surfaces that cannot be fully characterized, etc.). Ideal conditions then consist rather in a diffuse light, which conveys the color information (without taking up the information on the state of the surface) and which can be obtained with a uniform sky. However, in practice, the variations in intensity, hue, direction, ... of the light from a partially or completely diffused sky are infinite.

Influence of exposure

Defining the appropriate exposure is a fundamental problem in obtaining a photography. The correct exposure however remains a subjective opinion; it depends on the desired effect. Digital cameras have a limited dynamic range. As a result, if part of the scene has values below or beyond this range, it cannot be rendered correctly and the portion of the resulting image will be uniformly black (underexposed) or white (overexposed), without rendering details.

In most cases the user must therefore favour either shadows or highlights. An alternative solution is High Dynamic Range (HDR) photography, which involves acquiring the full dynamic range by acquiring a series of photographs with different exposures and combining them into a well-exposed image. Mertens et al. (2009) identify several methods to merge the different contributions. The HDR acquisition however is time-consuming and will not solve all the problems.

Influence of shading

Complementary to the illumination, the appearance of a site is also influenced by the shading of the objects in it.

Influence of adding lighting

In a low light environment, the difficulty is to expose the sensor sufficiently to light to collect the information from the scene. The use of artificial lighting sources makes it possible to circumvent the problem of adjusting camera parameters (exposure, aperture, ISO). On the other hand, it is often impossible to install suitable devices in a large and complex survey, without creating new obstacles and thus geometrical artifacts related to occultations.

The addition of artificial light in a scene allows for shorter exposure times, smaller apertures, and lower sensitivities, while capturing enough light to produce clear, noiseless images. The use of lighting, however, has a significant impact on the characteristics of the scene. It disproportionately brightens the objects in the scene, especially as they are close to the camera, and fades quickly.

Despite these disadvantages, flash photography remains an effective solution in low light conditions. However, only a small number of scanners can add a flash system. For a more general solution, a pre-prototype lighting has been developed; it has been designed to provide omni-directional ambient lighting, to be placed under the acquisition system so as not to appear from the acquired zone and to avoid any visible shadow in acquisitions for a given position.

Multi-view colorization

The application of all the pictures on the model by inverse projection, makes it possible to reconstruct the appearance of a model. When a digital camera is coupled with the scanner, it’s easy to obtain a colorization for each geometric survey from all the pictures taken from the same point of view. On the other hand, when acquisition conditions vary over time, mixing such coloured point clouds into one pattern usually produces an unpleasant rendering. The proposed method consists in a colorization by vertex of the depth maps taking into account all the available sources of colours. Each contribution is then weighted according to an information quality measure.

Quality of a source

A series of quality factors are defined to weight each contribution. Inspired by Callieri et al. (2008), we suggest using a geometric mean of these standardized measures to combine these scores. Thus for each image, an evaluation of the quality of each pixel is obtained from the extraction of characteristics directly related to the content of the picture considered or related to the latter by considering its environment and the derivation of these characteristics to obtain a series of quality factors.

Firstly, in the proposed process, the detection of problems related to the content of images are limited to the detections of shadows and the detections of overexposures. The need to solve these two problems is related to changes in brightness, which can induce unpleasant discontinuous stains by creating false edges. Based on this detection, quality mask can be defined.

In addition to shadows, the elaborated method also tends to detect clean shadows or dimly lit areas that cannot be unilaterally categorize as shadows. It gives good results (according to a visual evaluation) automatically for fixed parameters. About the overexposures, this method combines the detection of shadows on a negative image and an adaptation of the thresholding proposed by Yoon et al. (2014) and based on human perception. Figure 1 gives the results of these detections for an image.

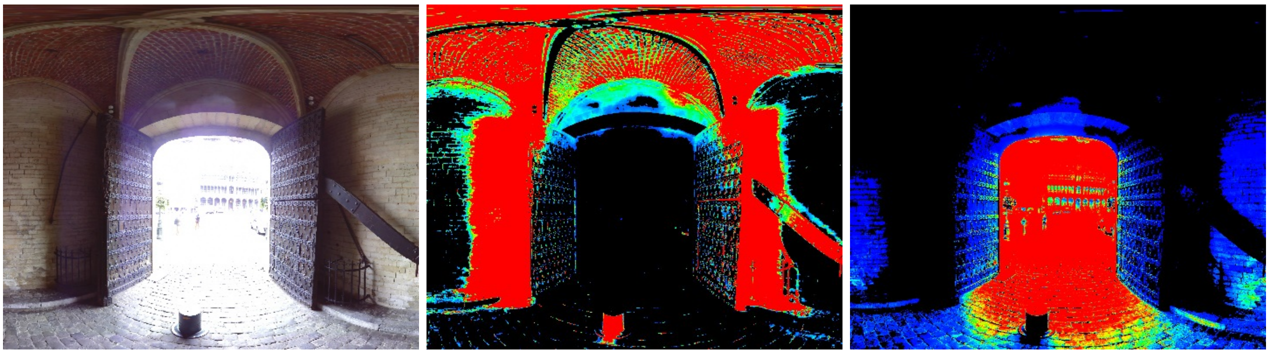

Fig. 1. Proposed shadow and overexposure detections (left to right): initial image, shadow detection discrimination map, overexposures discrimination map (© Arnaud Schenkel).

The second step of the proposed approach consists in extracting elements of the acquired geometry relative to the image considered. Two data are essential in this specific colorization process: the depth map and the normal map. These two sets of data are firstly necessary to determine if any one of the set of digitized data is visible from the camera, and secondly derived to extract different masks of quality. A weighting of the quality considering the distance reflects in particular the effect of the additional lighting (decreasing according to the distance).

The figure 2 gives an illustration of the considered quality masks.

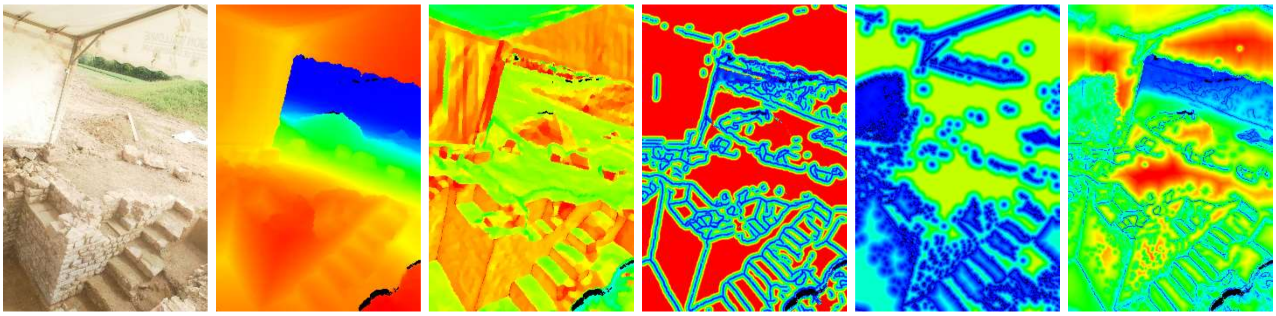

Fig. 2. Quality masks, calculated for an image (left to rigth): image considered, distance, orientation, silhouette, shadows and over-exposures, combination of the quality factors (© Arnaud Schenkel).

Results

The proposed method was evaluated on acquisitions made using two scanners a Riegl LMS-Z360i coupled to a camera equipped with a flash and a scanner FARO 3D S350 with an integrated camera.

The method allowed to obtain quality colorizations for all the acquisitions, as well for small surveys (e.g. Merbes-le-Chateau, including 4 scans and 32 photos) as complex surveys (e.g. City Hall of Brussels, including 97 scans and 5841 photos). The figure 3 gives a comparison of the results obtained for the acquisition of the El Castillo Cave (Spain), comprising 177 scans and 1770 photographs using a flash.

Fig. 3. Results on El Castillo Cave dataset: scanner software colorization and our proposition.(© Arnaud Schenkel).

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