Illumination Compositing for Dark Scenes (sap_0078)

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1 Introduction

Compositing the frames of a video into a single image can be quite useful in many applications like surveillance and special effects. We propose a novel, and interactive if desired, technique for compositing a video of a scene illuminated part by part by a moving light source into a single image. The automatically composited image provides well illuminated details of the objects in the scene which are in the path of the moving light. The proposed method also recovers the light path along with the illuminant direction and, through the user interaction, allows the user to select any specific sub-path and perform compositing on the corresponding video frames. This approach could prove to be an interesting idea since there is no requirement of camera calibration, modeling of the scene reflectance and light source estimation.

2 Proposed Method

We use a flash light with a parabolic reflector and with minimal focusing artifacts in the light beam as our moving light source. Having acquired the video for a duration of a few seconds, we are left with a large number of frames to be composited to obtain the maximally illuminated scene. While selecting the frames to be composited, we stressed on minimising the number of frames in such a manner that the details of the entire scene are available.

Figure:1 A composited scene along with the light path

We perform a morphological closing operation on the binarized image with a disc shaped structuring element to fill out any holes. The centroid of a beam pattern is then obtained from the bounding edges of the light pattern. We calculate the centroid $(\overline{x}, \overline{y})$ of the resulting binary image and the average spread of the light pattern. Video frames are selected using a greedy scheme so that the overlap of the illumination pattern is approximately half of each light beam pattern. In other words, the distance between the centroids for consecutively selected video frames should be approximately half of the sum of spreads. This way, we will be able to select a set of frames from the video in such a way that the illumination pattern covers the entire scene.

With the selected video frames at hand our main task is to composite them onto a single image that will comprise of all the details of the scene. We found that the methods which composite scene using multi-exposure images are quite suitable for this application. Properly exposed regions of the scene will have high contrast, well-exposedness and no saturation. These properties are quite similar to those of the regions which are illuminated by the flash light in our application. We decide to employ an existing multi-exposure compositing approach called exposure fusion [Mertens et al. 2009] to composite the video frames as follows.

The unnormalized matte function for the mth frame is given by $\alpha_m(x,y) = C_m(x,y) \times S_m(x,y) \times E_m(x,y)$ where $C_m(x,y) = |\nabla^2(G_m^{gray}(x,y))|$ is the absolute value of Laplacian on the grayscale version of the mth image and provides a measure of local contrast, $S_m(x,y) = stddev(G_m^R(x,y), G_m^G(x,y), G_m^B(x,y))$ is the standard deviation within the R, G, B channels of the mth image measuring the saturation level, and
$E_m(x,y) = \prod_{Q \in \{R,G,B\}} \exp\left(-\frac{\left(G_m^Q(x,y) - \beta\right)}{2\sigma^2}\right)$ is the measure of well-exposedness. We select $\beta = 128$ and $\sigma = 3.2$ as suggested in [Mertens et al. 2009]. We composite all the selected frames to get a completely illuminated image of the scene which is used as a reference image while showing the light path as specified by the line connecting the centroids of the illumination zone (Figure 1). If the user wants to select a sub-path along the light path, clicks can be made near any subset of points. The program automatically calculates the composite image using relevant frames of the video.

To determine the illuminant direction we have assumed that the incident light has originated from a circular aperture and the light when incident normally on a flat surface forms a circular region of illumination. Thus when this light is incident on a scene at an angle the circular region can be approximated to an ellipse. To determine the major and minor axes of the ellipse, we need to find out the eigenvectors and eigenvalues of the following matrix.
$\begin{pmatrix} \sum_{i=1}^{n}(x_i-\overline{x})^2 & \sum_{i=1}^{n}(x_i-\overline{x})(y_i-\overline{y}) \\ \sum_{i=1}^{n}(x_i-\overline{x})(y_i-\overline{y}) & \sum_{i=1}^{n}(y_i-\overline{y})^2 \end{pmatrix}$ where $(\overline{x}, \overline{y})$ is the centroid and (x_i, y_i) are the locations of edges. The eigenvectors of the matrix determine the angles at which the axes are inclined whereas the eigenvalues determine the relative magnitude of the axes.

3 Conclusion

The proposed technique is a very effective tool that can composite a video of a dark scene illuminated part by part by a moving light source. In future, we would like to extend the capability of the tool to determine the direction of incidence of the light beam to the scenes which have high depth variations. The knowledge about the direction of the incident light, image plane and scene modeling would help us to remove glares and multiple shadows.

References

MERTENS, T., KAUTZ, J., AND REETH, F. V. 2009. Exposure fusion: A simple and practical alternative to high dynamic range photography. *Computer Graphics Forum 28*, 1, 161–171.