ABSTRACT
This paper examines the problem of white-balance correction when a scene contains two illuminations. This is a two step process: 1) estimate the two illuminants; and 2) correct the image. Existing methods attempt to estimate a spatially varying illumination map, however, results are error prone and the resulting illumination maps are too low-resolution to be used for proper spatially varying white-balance correction. We show that this problem can be effectively addressed by not attempting to obtain a spatially varying illumination map, but instead by performing illumination estimation on large sub-regions of the image. Our approach (published in [1]) is able to detect when distinct illuminations are present in the image and accurately measure these illuminants. Since our proposed strategy is not suitable for spatially varying image correction, a user study is performed to see if there is a preference for how the image should be corrected when two illuminants are present, but only a global correction can be applied. The user study shows that when the illuminations are distinct, there is a preference for the outdoor illumination to be corrected resulting in warmer final result. We use these collective findings to demonstrate an effective two illuminant estimation scheme that produces corrected images that users prefer.

1 INTRODUCTION
Scene illumination affects the overall color of a captured image. Estimating the illumination and subsequent correction, i.e. white-balance, to remove the color cast caused by the illumination is a fundamental processing step applied to virtually all images. Most white-balance methods assume the imaged scene is uniformly illuminated with a single light source, however, it is not uncommon for a scene to be illuminated by more than one light as shown in Figure 1a. Most existing approaches that attempt to estimate multiple illuminations use a sliding window strategy or image segmentation to perform local illumination estimation. This results in a spatially varying illumination map over the image. Such illumination maps are typically low-resolution (e.g. 15 × 20) and their effectiveness in subsequent white-balance correction is often not demonstrated. Moreover, these methods tend to be slow and require prior knowledge that the imaged scene contains two illuminations.

In this paper, we advocate a different strategy for addressing the two illuminant estimation problem. Specifically, we find it more effective not to attempt to estimate a spatially varying illumination map. Instead, we show that applying a single-illuminant estimation method on a relatively small number of large sub-images in the input image can not only detect if two distinct illuminants are present, but provide accurate estimations for these illuminations. To this end, we perform a user study to determine if users have a preference for which illumination they would prefer to be corrected (see Figure 1). Our study found that users have a clear preference for a result that is a mixture of the two illuminations, with more weight on the outdoor illumination.

2 TWO ILLUMINANT ESTIMATION
The overall framework of our method is illustrated in Figure 2b. The image is divided into 4 × 8 sub-images. For each sub-image, the multiple regression tree [2] method is applied. Cross-feature consensus is examined on these initial candidates and only candidates in agreement are kept. If the regression tree approach does not obtain a consensus or the collective candidates from the trees have too high variance (set to 0.0001 in chromaticity space in our approach), the results for this sub-image are ignored, otherwise the median of the results is kept as the estimate for that sub-image. Figure 2b shows an example, where rejected sub-images are marked with an × and those that have passed are marked with a ✓. After the sub-images have been processed, we are left with a set of 2D illumination estimates in the r-g chromaticity space of the input image. We then compute the pair-wise distance of all candidates. If the average pair-wise distance is less than 0.025, it is assumed there is only a single illumination in the scene and the median of all the candidates is reported as the illumination estimation. Otherwise, the image is classified as having two illuminations, and k-means (k = 2) clustering is applied and the centroids of the two clusters are taken as the estimates of the two illuminations.

3 USER-PREFERRED IMAGE CORRECTION
We conducted a user study to see if the users would prefer some mixture of the two illuminants to correct the images. The average user choices of each of the 5 illuminant corrections for each category of images are shown in Figure 4b along with their 95% confidence intervals represented by error bars. From this result, we see that Cat. I (two distinct illuminations) have a clear preference leaning towards the outdoor illuminant (i.e. the L4 = 0.25L1 + 0.75L2 illuminant). For Cat. II (two similar illuminations) the preference is less pronounced and slightly favors the indoor illuminant. This is consistent with the finding in [4] that visual difference illuminant corrections within 3° is not noticeable.

4 RESULTS
Figure 3 shows some examples for two-illumination images. To have a comparison, the Corrected Moments [3] method was used
to represent single illuminant estimation methods. We can see that for these images, the Corrected Moments method tends to give the indoor illuminant estimation or the mixture of indoor/outdoor. These illuminant estimates make the corrected images bluish in nature. In contrast, our results are closer to the user preferred correction.

REFERENCES

Figure 2: (a) This image provides an illustration of the regression trees method proposed by Cheng et al. [2]. This method produces a set of candidate estimates in the 2D rg-chromaticity space. The median of the candidates is used as the final estimate. (b) This image is an overview of our two-illumination method. The image is divided into sub-images. The method in (a) is applied on each sub-image. If the illumination estimate candidates obtained by (a) per sub-image are similar, the estimate result is kept (denoted with a ✔), otherwise they are rejected denoted with an ✗. The final set of reliable estimations (i.e. those kept) are examined to see if they form one or two clusters, which are used as the illuminant estimates.

Figure 3: Visual comparison of image global correction. The three images are from the Gehler-Shi data set [5, 6]. The Corrected moment [3] result is compared.

Figure 4: (a) User preferences for the indoor (L₁) and outdoor illuminant (L₅) corrections. (b) User preferences for each of the 5 illuminants, over the two categories (distinct and similar illuminants). Error bars represent the 95% confidence intervals.