

Efficient and Realistic High Resolution Sky Replacement

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We present a method for automatically replacing skies in landscape images [3], this implementation is available in the LandscapePro software¹. One reason that landscape photography can be challenging is because a dull sky can impair the aesthetics of a photo, and waiting for better weather might not be an option. In such cases, digitally replacing the sky can dramatically improve a photo. Our proposed pipeline involves 5 processing stages using a mixture of deep learning for large scale robustness and simple heuristics at the pixel level for speed.

Stage 1: Segmentation We use deep learning trained on a dataset of roughly 4k images to do a coarse segmentation of the scene into areas [1].

Stage 2: Detail refinement Typical deep semantic segmentation methods are not computationally tractable to work at the high resolutions expected by professional photographers, for whom accurate details are important. A naive bilinear upsampling of a low resolution segmentation map will not follow the edges of objects accurately. We need a way of respecting sharp edges that is efficient for many megapixel images. Firstly we only refine around edges between objects. Secondly, we use a bilateral filter [2] on the bilinearly upsampled mask, where the input image is used as the guiding image to improve the edges of the selection.



Figure 1: Result of segmentation refinement.

Stage 3: Tree and Sky Trees overlapping the sky are a common feature of outdoor photography, but one where semantic segmentation often fails due to the size of the features. To overcome this, instead of training on high resolution pictures with painstakingly hand segmented trees, we introduce a new coarse segmentation label called tree and sky mixture.



Figure 2: Coarse segmentation. Red:sky, Blue:tree, Green: Mix

We then separate the trees from the sky in the mixture region using a fast heuristic based method as follows. The matting equation takes a foreground colour \mathbf{F} a background colour \mathbf{B} and an alpha value α and computes a result colour \mathbf{R} , $\mathbf{R} = \alpha\mathbf{F} + (1 - \alpha)\mathbf{B}$.

Solving the matting equation (estimating α from \mathbf{R}) is underdetermined, so all matting systems must use something to regularise the solution to that equation. In our case we harness prior knowledge about the colour of trees (being generally dark brown or green) and skies (being lighter colours, generally blue, but also red and orange) to estimate the colour of the sky and tree in every pixel. We create two images of tree and sky colours by softly expanding the respective colours to nearby pixels using an adapted bilateral filter. The filter weights are based on pixel

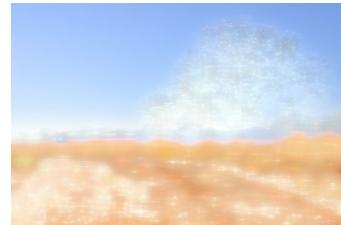


Figure 3: Sky colour map



Figure 4: Tree colour map



Figure 5: Original image and refined segmentation

distance (as with standard bilateral filtering) and closeness to the prior colour distribution (as opposed to colour difference). The result is that the relevant colours are expanded into nearby areas.

Given the estimated tree/sky colours, the matting equation becomes a simple overconstrained linear system with one unknown (alpha) and 3 constraints (R,G, and B).

Stage 4: Sky Replacement Once the sky has been segmented, it is easily replaced with a new sky using classic compositing. The bottom of the new sky is aligned with the lowest point in the sky mask, because the smallest clouds in the replacement sky should end up at the horizon.

Stage 5: Ground recolouring Because the sky is the light source for an outdoor scene, when the sky is replaced the ground should be lit according to the new sky colours. We found a simple technique works surprisingly well. We simply take the ratio between the average colours of the new and old sky and apply it to the rest of the image.



Figure 6: An example image with a replaced sky and recoloured ground.

- [1] Alexander Kirillov, Kaiming He, Ross Girshick, and Piotr Dollár. A unified architecture for instance and semantic segmentation, 2017. URL <http://presentations.cocodataset.org/COCO17-Stuff-FAIR.pdf>.
- [2] Carlo Tomasi and Roberto Manduchi. Bilateral filtering for gray and color images. In *ICCV 1998*, volume 98, page 2, 1998.
- [3] Yi-Hsuan Tsai, Xiaohui Shen, Zhe Lin, Kalyan Sunkavalli, and Ming-Hsuan Yang. Sky is not the limit: semantic-aware sky replacement. *ACM Trans. Graph.*, 35(4):149–1, 2016.

¹<http://www.landscapepro.pics>