Patching of Moving Objects for Ghosting-free HDR Synthesis

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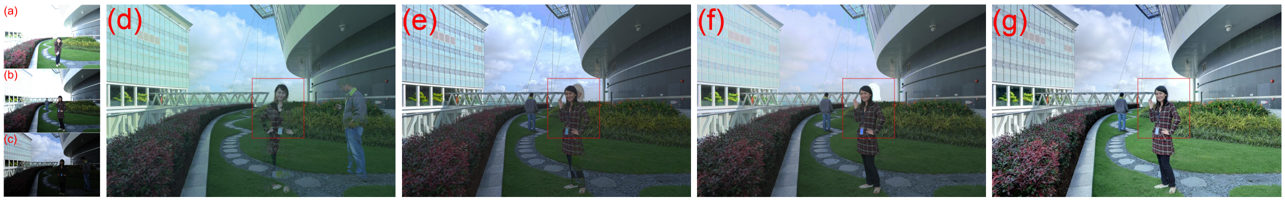

Figure 1: (a)-(c) A set of differently exposed images with moving objects. The images produced by anti-ghosting schemes of (d) [Jacobs et al. 2005]; (e) Photoshop CS5; (f) [Li et al. 2010]; (g) our hybrid patching scheme. Part of patched areas is highlighted by red box.

1 Introduction

It is very challenging to synthesize a ghosting-free high dynamic range (HDR) image using differently exposed low dynamic range (LDR) images with moving objects. To achieve this, an anti-ghosting scheme is required to detect and patch occluded motion regions. In this poster, a new optimization problem is formulated on patching motion regions along a differently exposed image sequence, which optimizes consistencies in both spatial and temporal domain. To solve this optimization problem, a hybrid patching scheme including pixel-level intensity mapping function and block-based template matching is proposed .

2 Approach

To compose a complete anti-ghosting scheme, the proposed patching scheme is integrated with a detection module presented in [Li et al. 2010]. Suppose an image to be corrected is Z_{k_0+1} and its reference image is Z_{k_0}. The non-consistent pixels are detected by [Li et al. 2010] and labelled in a binary map. The goal of patching is to reconstruct new pixels $\hat{Z}_{k_0+1}(p)$ for all non-consistent pixels in a set $\bar{C}_{k_0+1}$ by solving the following optimization problem:

$$\arg\min_{\hat{Z}_{k_0+1}(p)} \sum_{p\in\bar{C}_{k_0+1}} \|\nabla\Lambda_{k_0+1,k_0}(\hat{Z}_{k_0+1}(p)) - \nabla Z_{k_0}(p)\|_2, \quad (1)$$

subject to

$$\hat{Z}_{k_0+1}(p)|_{\partial\bar{C}_{k_0+1}} = Z_{k_0+1}(p)|_{\partial\bar{C}_{k_0+1}}, \quad (2)$$

where $\nabla. = [\frac{\partial.}{\partial x}, \frac{\partial.}{\partial y}]$ is the gradient operator, and Λ_{k_0+1,k_0} is an intensity mapping function (IMF) from Z_{k_0+1} to Z_{k_0} [Li et al. 2010]. $\partial\bar{C}_{k_0+1}$ is the boundary of $\bar{C}_{k_0+1}$.

Solution of the new problem (1) is very challenging, as it includes a non-linear function Λ_{k_0+1,k_0}. Instead of directly solving the new problem (1), it is converted into an optimization problem that was defined in [Perez et al. 2003] as

$$\arg\min_{\hat{Z}_{k_0+1}(p)} \sum_{p\in\bar{C}_{k_0+1}} \|\nabla\hat{Z}_{k_0+1}(p) - V(p)\|_2, \text{ subject to (2)}, \quad (3)$$

where V is a guidance field on detail information of reconstructed motion regions. Then a vector field V and initial value $\hat{Z}^0_{k_0+1}$ is built up for all $p \in \bar{C}_{k_0+1}$ by using a hybrid patching scheme, which exploits the spatial redundancy of Z_{k_0+1} and the temporal correlation between Z_{k_0+1} and Z_{k_0}.

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The hybrid patching scheme includes two correction methods based on pixel-level IMF and block-level template matching respectively. For the motion regions where collocated areas in Z_{k_0} are well exposed, IMF based correction scheme is applied. An auxiliary pixel $\hat{Z}^0_{k_0+1}(p)$ is computed as $\Lambda_{k_0,k_0+1}(Z_{k_0}(p))$ which will be used to compute vector filed V. For the remaining parts of motion regions that IMF based correction is not applicable, block-level template matching based correction scheme is applied to compute vector field V and initial value $\hat{Z}^0_{k_0+1}$. Let $B_{k_0+1,i}$ denote a block at position *i* in Z_{k_0+1}, containing non-consistent pixels. A matching search, spanning a searching window, is conducted to find a best-match block. Then the pixels of best-match block are used to replace the non-consistent pixels in $B_{k_0+1,i}$. A new matching criterion is proposed for searching best-match block, which includes two parts: one measures the spatial similarity of consistent pixels in $B_{k_0+1,i}$ and their counterparts of candidate block in Z_{k_0+1}; and the other measures the similarity of collocated blocks in Z_{k_0}. After template matching correction, auxiliary pixels can be obtained as $\hat{Z}^0_{k_0+1}(p)$'s, which are critical for convergence speed. The vector field V can then be computed. To include all available information, the gradients from both Z_{k_0} and Z_{k_0+1} are adopted to compose V. For a pixel $Z_{k_0+1}(p)(p \in \bar{C}_{k_0+1})$, if its collocated surrounding pixels in Z_{k_0} are well exposed, then the gradients $\nabla Z_{k_0}(p)$ is considered as reliable, and $V(p)$ is computed as $\nabla\Lambda_{k_0,k_0+1}(Z_{k_0}(p))$. Otherwise, the gradient $\nabla\hat{Z}^0_{k_0+1}(p)$ is adopted. It is worth noting that $\hat{Z}^0_{k_0+1}$ and V are selected such that the problem (3) is equivalent to the problem (1). With $\hat{Z}^0_{k_0+1}$ and V, the motion regions can be reconstructed by solving problem (3).

We compare the proposed scheme with anti-ghosting approaches of [Jacobs et al. 2005], [Li et al. 2010] and Photoshop CS5. In [Jacobs et al. 2005], each motion region is presented by one image containing the least saturation in that particular area. Phothshop CS5, [Li et al. 2010] and proposed scheme synchronize motion regions according to a pre-selected input image. The ghosting effects have been significantly alleviated by proposed scheme.

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