Seamless Change Detection and Mosaicing for Aerial Imagery

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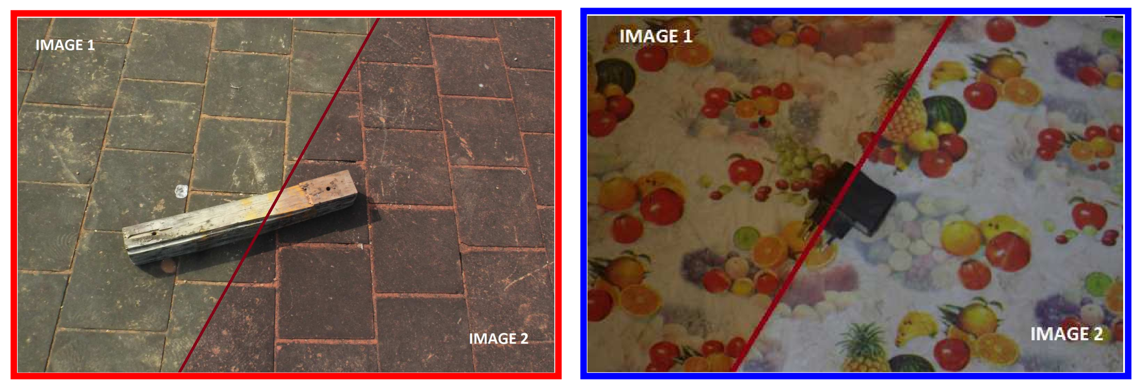
1 Introduction

- Color appearance of objects in an image depends on illumination and camera characteristics.



Different cameras   Different illumination

- Difficult to track objects, perform change detection or mosaicing in the presence of color changes.
- Necessitates the need for a domain that is invariant to changes in camera and illumination.
- *Spectral reflectance* is an intrinsic property of the scene which is independent of camera sensitivity and illumination spectrum.

2 Image Formation Model

- Intensity observed at a pixel position x is the net effect of camera sensitivity $S_c(\lambda)$, illumination spectrum $L(\lambda)$ and the scene's spectral reflectance $R(x,\lambda)$.

$$I_c(x) = \int_{\lambda \in V} R(x,\lambda)L(\lambda)S_c(\lambda)d\lambda \quad (1)$$

where $c \in \{\text{R,G,B}\}$ and V is the visible range 400-700nm.

- Discretizing eqn.(1) yields the matrix form

$$I = S \text{ . diag}(L) \text{ . } R_l \quad (2)$$

where each row of R_l is the albedo images at different wavelengths.

3 Inverse Problem and S/L/R Estimation

- Given the acquired color image and camera sensitivity, estimating surface reflectance and illumination spectrum is an ill-posed problem.
- A training based approach [Nguyen 2014] using Radial basis functions is employed to estimate reflectance from RGB image.

4 Change Detection

- Problem: Find changes between two images I^1 and I^2 taken with different cameras and different illumination settings.

$$I_c^{(2)}(x') = \begin{cases} \int R(\tau(x),\lambda)L^{(2)}(\lambda)S_c^{(2)}(\lambda)d\lambda, & \text{if } x' \not\subseteq \mathcal{C} \\ \int R_o(x',\lambda)L^{(2)}(\lambda)S_c^{(2)}(\lambda)d\lambda, & \text{if } x' \subseteq \mathcal{C} \end{cases} \quad (3)$$

where τ is geometric warping due to view-change, $\mathcal{C}$ is the set of occluding pixel positions in the image, and R_o is the spectral reflectance of the occluding object.

- Choose wavelengths corresponding to maximum of CIE standard observer function to produce a 3-dimensional image on which SIFT features are estimated.
- Align reflectance by estimating homography using RANSAC.
- Threshold the change in reflectance at each spatial location to obtain the occluded region.

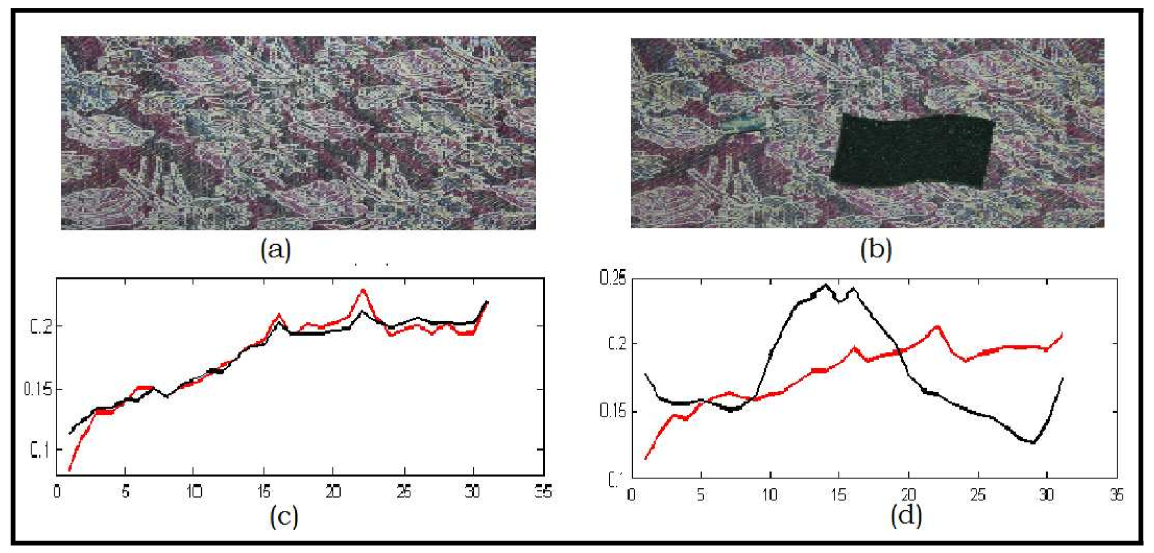
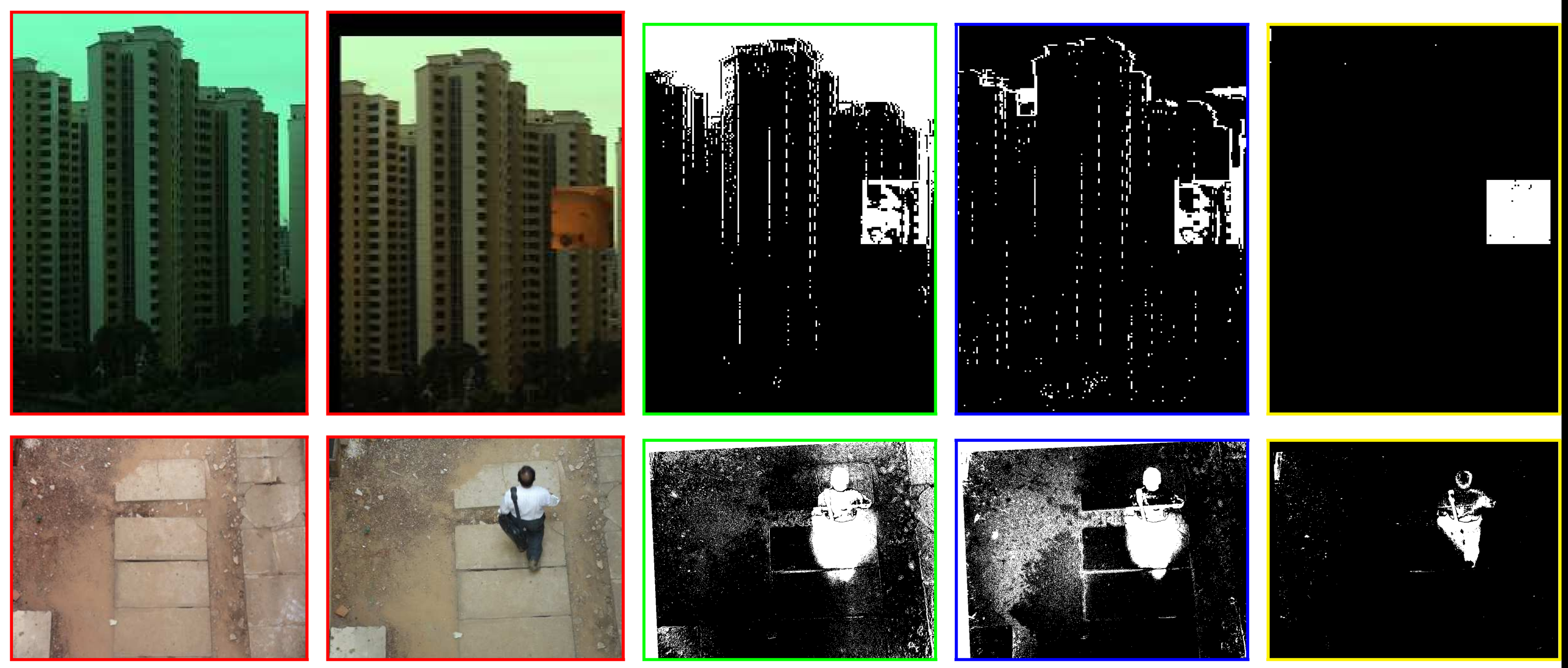


Figure 1: Variation of reflectance spectra due to occlusion.



Input images   Change in RGB domain   Change after color transfer   Change in reflectance domain

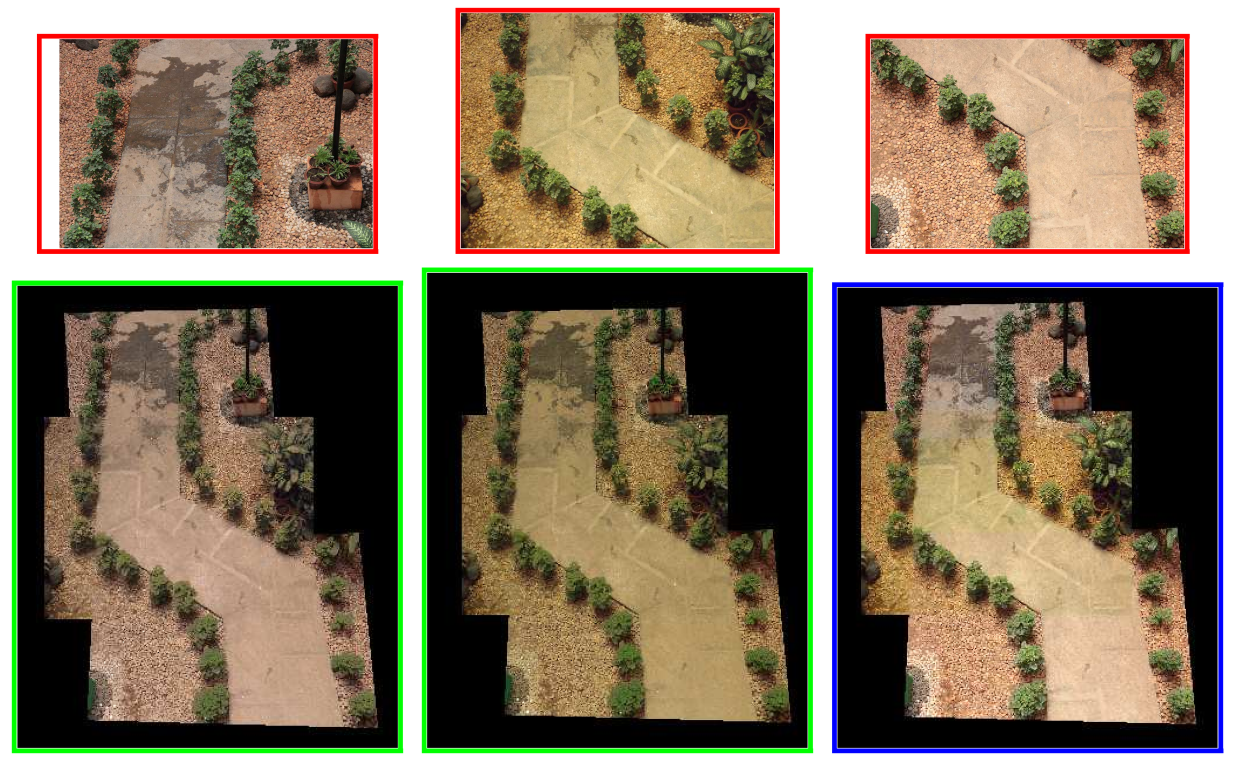
5 Mosaicing

- Problem: Given multiple images taken with different cameras and illumination conditions with overlapping regions, produce a wide panorama.

$$I_c^{(i)}(x') = \begin{cases} \int R(\tau_{ij}(x),\lambda)L^{(i)}(\lambda)S_c^{(i)}(\lambda)d\lambda, & \text{if } x' \subseteq \mathcal{M}_{ij} \\ \int R_i(x',\lambda)L^{(i)}(\lambda)S_c^{(i)}(\lambda)d\lambda, & \text{if } x' \not\subseteq \mathcal{M}_{ij}, \end{cases} \quad (4)$$

where $\mathcal{M}_{ij}$ is the set of overlapping pixel positions in $I^{(i)}$ and $I^{(j)}$ $(i \neq j)$ and R_i is the reflectance of the non-overlapping new information captured in scene $I^{(i)}$.

- Align the spectral images using SIFT features obtained in reflectance domain and stitch images corresponding to each wavelength.
- The stitched reflectance image is then re-synthesised and re-illuminated to obtain image as seen from a particular camera and for a particular illumination.



Input images   Stitched in reflectance domain   Stitched in RGB domain

6 Conclusions

- Discussed an important effort aimed at achieving inconspicuous change detection and mosaicing across different cameras and illumination variations.
- Demonstrated that undesirable color variations caused by changes in camera and illumination can be robustly handled to a good extent by working in the reflectance domain.