HDR Imaging Using Augmented Lagrange Multipliers (ALM)

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Summary

- We consider the High Dynamic Range (HDR) imaging problem for real world scenes. We can change either the exposure time or the aperture while capturing multiple images of the scene to generate an HDR image.
- This poster addresses the HDR imaging problem for static and dynamic scenes when we do not have any knowledge of the camera settings.
- We have proposed a novel threshold for Augmented Lagrange Multipliers (ALM) framework for solving robust PCA (RPCA) which enables us to process the images getting rid of artifacts due to moving objects and defocus blur.

Augmented Lagrange Multipliers (ALM)

RPCA problem [WGR*09] is to recover a low rank matrix $\boldsymbol{A}$ from observation matrix $\boldsymbol{D}$.

$$\boldsymbol{D} = \boldsymbol{A} + \boldsymbol{E},\ \boldsymbol{D} \in \Re^{m \times n} \tag{1}$$

where $\boldsymbol{E}$ is the sparse error matrix. The Lagrangian function [LCM10] to be minimized is given by equation 2.

$$L(\boldsymbol{A}, \boldsymbol{E}, \boldsymbol{Y}, \mu) \doteq \|\boldsymbol{A}\|_* + \lambda \|\boldsymbol{E}\|_1 + \langle \boldsymbol{Y}, \boldsymbol{D} - \boldsymbol{A} - \boldsymbol{E} \rangle + \frac{\mu}{2} \|\boldsymbol{D} - \boldsymbol{A} - \boldsymbol{E}\|_F^2 \tag{2}$$

where $\boldsymbol{Y}$ is the Lagrange multiplier and μ is the penalty parameter.

Proposed Approach

We consider images with different exposure and aperture settings and try to recover the underlying matrix $\boldsymbol{A}$ and accounting for the dynamic objects and defocus blur in the error matrix $\boldsymbol{E}$. Without assuming the knowledge of CRF and exposure settings we recover the matrix $\boldsymbol{A}$ using the inexact ALM method [LCM10] with few modifications and improvements to the original iterative algorithm.

- **Linearisation of intensity values**
  The multiple images are dependent but because of CRF suffers from non-linearity leading to poor performance of the RPCA algorithm. To perform linearisation, we model CRF as a gamma $(0 < \gamma < 1)$ correction function as shown in equation 3.

$$I_i' = I_i^{\gamma} \tag{3}$$

We implement the algorithm on this processed observation matrix $(\gamma = 0.33)$ to recover the underlying low rank matrix $\boldsymbol{A}$.

- **Inexact ALM and Fusion**
  We define a new soft thresholding operator $S_\epsilon[x_i]$ for attenuating the singular values x_i during each iteration as shown in equation 4.

$$S_\epsilon[x_i] = \left\{ \begin{array}{lr} x_i - \epsilon, & x_i > \epsilon \\ x_i, & x_i = \max(x_1, x_2, \ldots x_n) \\ x_i + \epsilon, & x_i < -\epsilon \\ 0, & \textit{otherwise} \end{array} \right\}. \tag{4}$$

Choosing $S_\epsilon[x_i]$ as in the above equation preserves the largest singular value and penalises the smaller singular values increasingly larger during each iteration. This doesn't affect image details and rejects only the sparse error. We apply the inverse of the gamma correction $(= 3)$ to the columns of $\boldsymbol{A}$ to obtain the LDR images and fuse them into a high quality LDR image, using exposure fusion [MKVR07].

Results

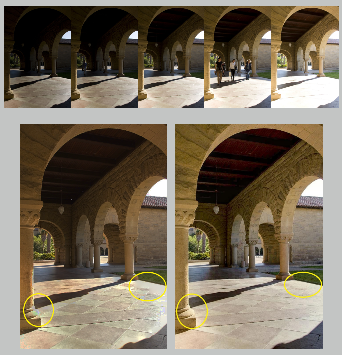
(a) (b)

Figure 1: Top Row: Multi-exposure images of a dynamic scene. (a) Tone mapped result of [GGC*09], and (b) LDR image obtained using our approach.


(a) (b)

Figure 2: Top Row: Multi-aperture images of a static scene, (a) Tone mapped result using [HK07], (b) LDR image obtained using the proposed approach.

Conclusion

- We introduce an approach to remove the dynamic objects from the LDR images of a dynamic scene captured with different exposure times.
- We extend the approach to process images of a static scene captured with different aperture settings to obtain a single image free from defocus blur.
- Varying aperture setting is a good alternative to capture the high dynamic range of a scene and proposed framework produces satisfactory results for this approach.
- The proposed approach might need registration for processing multi-exposure or multi-aperture images captured using a hand-held camera.

References

[GGC*09] Gallo O., Gelfand N., Chen W.-C., Tico M., Pulli K.:
Artifact-free high dynamic range imaging.
In *IEEE ICCP* (2009).

[HK07] Hasinoff S. W., Kutulakos K. N.:
A layer-based restoration framework for variable-aperture photography.
In *IEEE ICCV* (2007).

[LCM10] Lin Z., Chen M., Ma Y.:
The augmented lagrange multiplier method for exact recovery of corrupted low-rank matrices.
arXiv preprint arXiv:1009.5055 (2010).

[MKVR07] Mertens T., Kautz J., Van Reeth F.:
Exposure fusion.
In *Pacific Graphics* (2007).

[WGR*09] Wright J., Ganesh A., Rao S., Peng Y., Ma Y.:
Robust principal component analysis: Exact recovery of corrupted low-rank matrices via convex optimization.
In *NIPS* (2009).

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