An Overview of Ghost Artifact in HDRI

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***Abstract*—**The digital cameras can contain the limited dynamic range. At the time of capturing a scene brighter area tends to be over exposed and darker area tends to be under exposed. The High Dynamic Range Image (HDRI) consists in combining multiple images of a same scene with varying exposures. The moment of object in those LDR images is a reason for ghost artifact. The particular moving object can occur more than one place in a HDRI image, this occurrence is called as a ghost artifact. The object may be required object for that image or unnecessary object. Ghost detection and Ghost removal methods are used to produce a Ghost free HDR image.

***Keywords*—**Artifact; Dynamic; Fusion; Ghost Artifact; Ghost Detection; Ghost Removal; HDRI.

***Abbreviations*—**Camera Response Function (CRF); High Dynamic Range Image (HDRI); Low Dynamic Range (LDR).

I. INTRODUCTION

THE dynamic range is the ratio between the maximum and minimum values of a physical measurement. A common technique to create HDR images is to merge multiple Low Dynamic Range (LDR) frames, each taken with a different exposure time. Many techniques are used to fusing the LDR images into a HDR image. The two main techniques used for create an HDRI: fusion in radiance domain, fusion in image domain. If the scene is not static at the time of capturing an image then the HDR image is affected by ghost artifacts [Francesco Banterle et al., 2009]. Moving an object is occurred on two situations like: Dynamic object on static background, Dynamic background with a static and dynamic object. For getting a Ghost free HDRI, the ghost in an image must be detects and removes. There are two basic methods used for removing the ghost artifacts. The first method is removing the ghost while keeping a single occurrence. The second method is removing the entire moving object while keeping the background only.

To capture for HDR, need a series of images shot using a tripod so it eliminate movement between the images. The overall camera settings should not change from one image to the next except that the exposure for each will be different. Typically the camera's Auto Bracketing feature to capture the series and it's best to limit the shooting to a scene that won't change while capturing it so don't get movement between frames. Taking multiple differentially exposed shots of a single subject is known as exposure-bracketing. The Section II denotes the multi exposure fusion of a HDR image and its fusion techniques. The Section III denotes the major concept of the survey what is Ghost artifact how it occur in an HDR image. The Section IV denotes the next step of ghost artifact that is ghost detection, how to detect the ghost in an HDR image what are all the methods used for detect the ghost. Section V denotes the ghost removal methods in HDRI. Section VI denotes the experimental result for the ghost detection and removal methods which method is best for detecting and removing the ghost in HDRI. In the final section we report the conclusion of this survey and future work about HDRI. The objective of this study is to know the details about what is an HDRI image, how it's framed, what is a ghost artifact, why it occurs, how to detect and remove those ghost artifacts.

II. MULTI EXPOSURE FUSION

Exposure is measured in lux seconds, and can be computed from Exposure Value (EV) and scene luminance in a specified region. An exposure generally refers to a single shutter cycle. A multiple exposure is the super imposition of two or more exposures to create a single image.

A multiple exposure fusion to enhance the dynamic range of an image is proposed [Takao Jinno, 2007]. Image fusion is a procedure of combining relevant information from more than one image into a single image.

Even a very small or limited movement will produce a noticeable artifact in the combined HDR image. Therefore, detecting and removing ghosting artifacts is an important issue for the HDR images of dynamic scenes.

Ghosting it occurs at the time of moving an object in an image [Abhilash Srikantha & Desire Sidibe, 2012]. When the non static different exposures and different dynamic range images combine for HDRI then it leads to Ghosting artifacts. Some global or local movements between images caused by either camera or object motions. The result of this condition may occur ghost in high dynamic range image a particular object is occur more than one time in a image [Keigo Hirakawa & Patrick J. Wolfe, 2010].

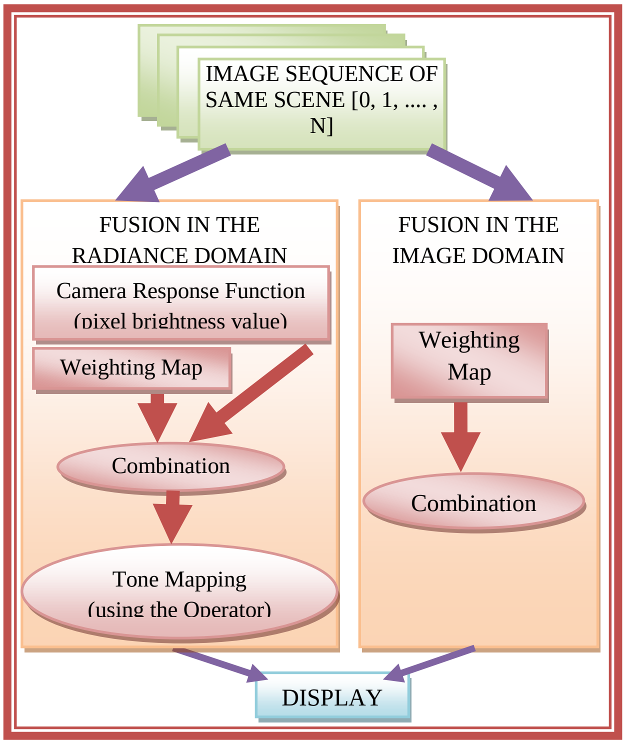


Figure 1: Fusion Methods for Creating HDRI

The two different ways to generate the HDR image is discussed in figure 1. The methods are fusion using image domain or fusion using radiance domain. The concept tone mapping is occurring in the radiance domain method. The tone mapping work is done by the operators those operators are named as tone mapping operator. The method fusion domain is done by the help of weight map calculation.

III. Ghost Artifact

Two main problems occurs in HDRI, the first one is Misalignment it occurs at the time of moving an image sensor [Sam Kavusi & Abbas El Gama, 2004], the results of misaligned images that causes the combined HDR image to look blurry. The Second one is Ghosting it occurs at the time of moving an object in an image [Abhilash Srikantha & Desire Sidibe, 2012]. When the non static different exposures and different dynamic range images combine for HDRI then it leads to Ghosting artifacts. Some global or local movements between images caused by either camera or object motions. This situation make the same object appear multiple times in the resultant HDRI.

The misalignment problem is solved by placing the camera in a static position. The Median Threshold Bitmap (MTB) is an effective one for solve these problem. The second problem is a ghosting to give the solution for this problem there are many methods and techniques are used for detect the ghost as well as remove the ghost in an image. The HDR image is created by combining more than one LDR image of a same scene. The Tone mapping is a technique used create the high dynamic range image [Vladimir Brajovic, 2004].

Sever limitation in ghosting problem is the multiple exposures technique since motion can hardly be avoided in outdoor environment. Misalignment between the different exposures and noise in the data, as well as in the estimated camera response function, can complicate the problem of detecting and correcting these artifacts. A set of manually captured LDRIs and allows the following two types of movement to take place during the LDRI capture:

3.1. *Camera Movement*

While taking LDRIs, the camera can move due to lens focusing or user movement [Jacobs et al., 2008; Abhilash Srikantha & Desire Sidibe, 2012]. The photographer move the camera lens due to cover an image. This situation occurs at the time moving object is the aim.

3.2. *Object Movement*

During the LDRI capture objects are allowed to move between different frames. The movement does not need to be of a high contrast nature. The only restriction imposed is that the moving object is reasonably small, in order not to interfere with the camera alignment, and that the area affected by the moving object is captured without saturation or under-exposure in at least one LDRI [Jacobs et al., 2008].

Figure 2: Three Level Exposures of the Same Scene

The figure 2 denotes the multi exposure LDR image with moving object. The under exposure shutter speed is 1/750s. The medium exposure shutter speed is 1/180s. The overexposure shutter speed is 1/45s. The high exposed image contains brighter details. The low exposure image contains darker details. This figure denotes the dynamic object on a static background. In this figure the boat is a dynamic object moving on a static background.

Figure 3: HDR Image

The figure 3 is a tone mapped HDRI it contains three exposures. The object is a dynamic one, it leads to ghost artifacts.

Figure 4: Ghost Artifact in HDRI

The figure 4 denotes the ghost artifact in an HDR image. The object (boat) is appears more than one place in an image. Ghosting can be tackled through motion estimation.

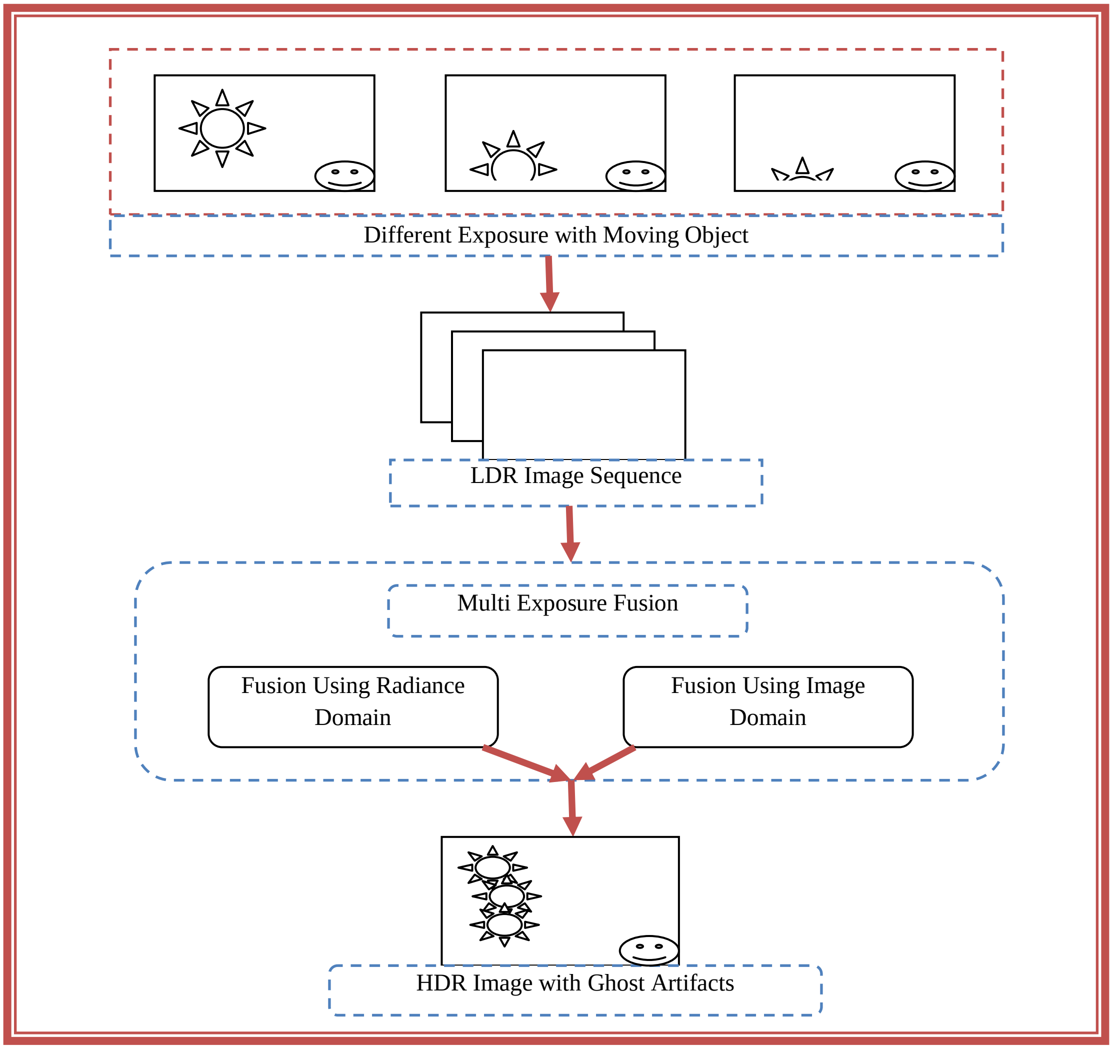


Figure 5 – Framework for HDRI with Ghost Artifact

The figure 5 denotes three level exposures of the scene with moving object. Those exposures are captured in different time, different shutter speed and low dynamic range images. The object sun is moved. In each image the sun is located in a different area. Fusion techniques are used for generate the high dynamic range image. The fusion techniques are i) fusion using image domain ii) fusion using radiance domain. The high dynamic range image in figure 5 is affected by the ghost artifacts.

Algorithms seek to modify the weighted average to account for some meaningful property of the pixel, together with its exposure. Khan et al., for instance, suggest estimating the probability of a pixel belonging to a moving object; instead of employing this information to track and realign the pixels, they incorporate it in the weighting function to strongly attenuate the contribution of moving pixels. The results of this approach look very promising [Kang et al., 2003; Cecilia Aguerrebere et al., 2012]. Some properties are used to detect and remove the ghost artifacts. The properties are radiance, dynamic range, camera response function, camera curve and weighting factor.

3.3. Radiance

Radiance is a radiometric quantity that measures the light passing through or emitted from a particular point in a given direction. For a digital camera, the radiance values correspond to the physical quantity of light incident on each element of the sensor array.

3.4. Dynamic Range

Dynamic range is the ratio between the maximum and minimum measurable light intensities (white and black, respectively). Dynamic range, abbreviated DR or DNR, is the ratio between the largest and smallest possible values of a changeable quantity, such as in signals like sound and light. It is measured as a ratio, or as a base-10 (decibel) or base 2 (doublings, bits or stops) logarithmic value.

3.5. Camera Response Function

Camera Response Function is used to fuse the photograph sequence into single HDRI. The camera response function refers to how the radiance arriving on image film/CCD, after passing through the lens, is transformed to actual pixel brightness values. The camera response curve is a curve showing the relation between amount of incoming light and image pixel values of a digital camera. This curve is sometimes also called Opto-Electrical Transfer Function.

3.6. Camera Curve

The camera curve is an issue mainly in HDR generation where it is necessary to have linear (proportional to light) input data. Non-linear data (a badly estimated camera response curve) will result in banding in contrast gradients (i.e. around bright lights).

3.7. Weighting Factors

Saturation and underexposure of pixels in an LDRI can result in incorrect irradiance values after transformation to irradiance values using the camera curve. Defining the weighting factors is not straightforward and various different methods exist to define the weights.

IV. GHOST DETECTION

The first step for recovering the ghost artifact is detection. The reason for occurring ghost is moving object. It may cause in two situations:

i. Dynamic object on static background
ii. Dynamic background with a static or dynamic object.

For detect the ghost region in high dynamic range images several algorithms are used. The algorithms are:

i. Variance based ghost detection proposed by Reinhard et al.,
ii. Entropy based ghost detection proposed by Jacobs et al.,
iii. Prediction based ghost detection proposed by Grosch (2006).
iv. Pixel order relation proposed by Sidibe et al.,
v. Multi level thresholding based ghost detection proposed by Min et al.,
vi. Bitmap based ghost detection proposed by Pece et al.,
vii. RANSAC based ghost detection proposed by Fischeler et al.,
viii. Graph-Cuts based ghost detection proposed by Heo et al,
ix. Motion compensation based ghost detection proposed by Lucas et al.,

The ghost detection methods need a threshold value to classify a pixel as ghost or not. Those methods manually set parameters in their algorithms to ensure best reconstruction of HDR images [Khan et al., 2006].

V. GHOST REMOVAL

Removing ghosting artifacts in the combined HDR image is the ultimate aim of any method that addresses the ghost problem. Different methods produce different results and can be classified into two main categories.

- The first distinguish methods is remove ghosting artifacts while keeping a single occurrence of the moving object.
- The second method will completely remove the moving object in the image

5.1. Keeping a Single Occurrence of Moving Object

If the moving object is of interest for the photographer, then it is desirable to keep it at a fixed location in the final HDR image, avoiding ghosting artifact due to multiple appearances at different locations, rather than completely removing it.

Many ghost removal techniques are based on the detected ghost map and the simplest approach is to apply the standard multiple exposure fusion method in ghost-free regions while selecting a single reference exposure in ghost affected areas. This approach is based on the observation that each exposure is self-consistent [Ward, 2003; Reinhard et al., 2005].

However, using a single reference exposure introduces new artifacts in the combined HDR image. Indeed, it creates seams at ghost regions boundaries and these boundary effects have to be removed.

The final HDR image is obtained, without employing tone mapping techniques, as a weighted sum of pixel values across exposures. The weights are derived from the previously generated visibility and consistency measures.

5.2. Removing All Moving Objects

In some cases, it could be desirable to completely remove all moving objects in the final HDR image. For example, the photographer interest is static background not a moving object. In those situations removing all moving objects in the image give a best ghost free HDR image.

Moreover, these methods require a sufficiently large number of images to produce good results and can be computationally expensive since they require a certain number of iterations.

VI. EXPERIMENTAL RESULT

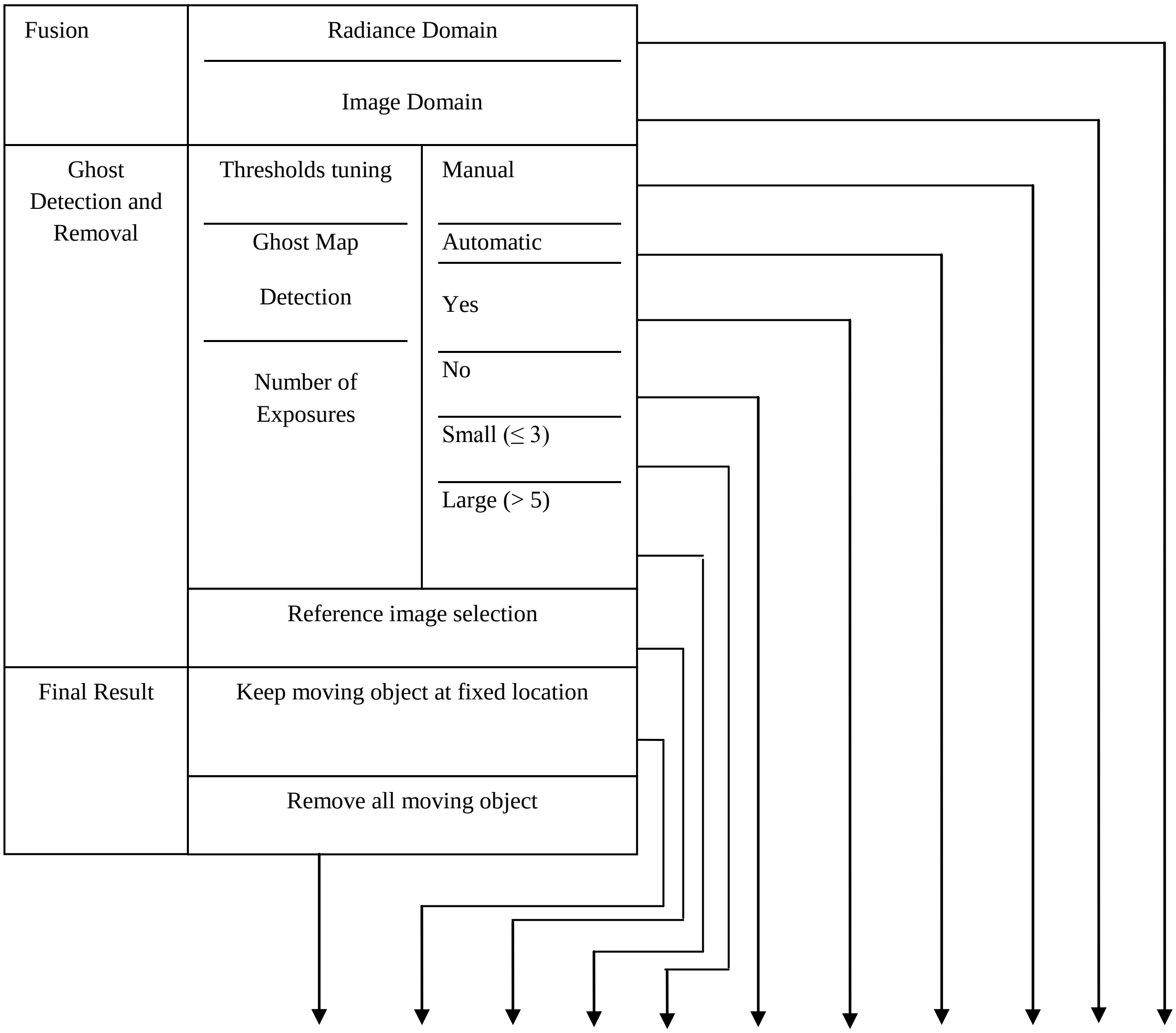
Abhilas et al, compare and classify the different ghost detection methods. The comparison is based on a quantitative evaluation of the generated ghost maps, i.e. evaluate the accuracy of the different methods in detecting moving objects in the scene.

The ghost detection methods are applied to generate ghost maps indicating the areas of the scene that are affected by ghost. It is important to mention that some methods such as the variance method [Reinhard et al., 2005], the entropy method [Jacobs et al., 2008], the bitmap method or the pixel order based method [Desire Sidibe et al., 2009], generate a single ghost map using the entire sequence of exposures. On the contrary, methods such as the multi-thresholding technique [Min et al., 2009] and the Ransac based method, generate a different ghost map for each pair of images formed by the reference exposure and another exposure. The prediction based method and the graph-cuts based approach, generate a ghost map for each pair of consecutive exposures.

Furthermore, many ghost detection methods are based of thresholding and the detection results depend on the value of the threshold. The different thresholds and have selected the values producing the best results. 0.45 is the threshold value for the variance based method, 0.45 for the entropy method and for the ransac based method, an outlier probability and a threshold value of 0.05% and 0.5, respectively [Abhilash Srikantha & Desire Sidibe, 2012].

Ghost detection can be viewed as a classification problem in which each pixel is classified as been either a ghost pixel or a nonghost pixel. Then compare the detected ghost maps with the ground truth ghost maps in terms of sensitivity and specificity. The sensitivity is the percentage of ghost pixels correctly classified as ghost and the specificity indicates the percentage of nonghost pixels correctly classified as nonghost.

Therefore, a good ghost detection method should have high sensitivity, i.e. correctly detect all ghost pixels and high specificity, i.e. not misclassify nonghost pixels as ghost.



Variance		*	*		*		*		*		*
Entropy		*	*		*		*		*		*
Prediction		*	*		*		*		*		*
Pixel – order	*			*			*	*			*
Multi thresholding		*	*		*		*	*			*
Bit Map		*			*		*		*	*	
Ransac	*	*	*		*		*		*		*
Graph-cuts		*	*		*		*		*		*

Figure 6: Results of Ghost Detection Algorithms

The detection results for different ghost detection algorithms are summarized in Figure 6. In the cases where a particular method generates multiple ghost maps, the presented sensitivity and specificity values are the average of the individual values for each ghost map. As can be seen, most of the detection methods show a high specificity value, more than 80%, meaning that they do not misclassify many nonghost pixels as ghost. However, the multi-thresholding method [Min et al., 2009] shows a specificity of only 54%, which means that most pixels of the scene are incorrectly detected as, ghost pixels [Abhilash Srikantha & Desire Sidibe, 2012].

VII. Conclusion

The generation of HDR image is done by the fusion techniques. The contrast movement of an object in LDR sequence is the reason for Ghost artifact. The contrast movement in an image may small or large. The similarity in colours between the object and the background, are more difficult to detect. The perfect alignment of LDR sequence also reduces the Ghost artifact. Several methods are proposed by different authors for detect and remove the ghost. For keeping the moving object at a fixed location in the combined HDR image, a good ghost map is required at the ghost detection stage. In addition, it is better to use a weight adaptation approach rather than a single exposure to avoid boundary effects in the combined image.

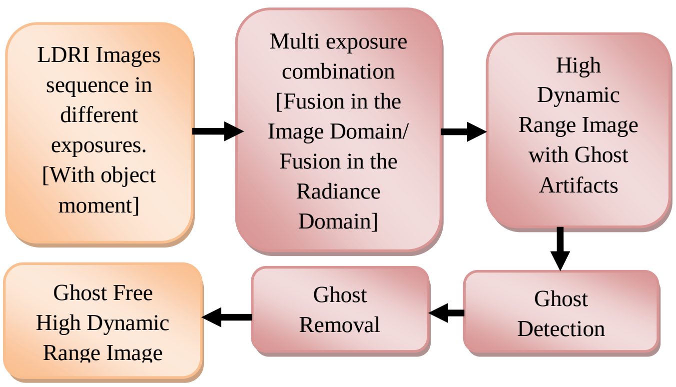


Figure 6: The Overall Process of HDRI

The Figure 6 denotes the overall process of an HDRI. The fusion methods image and radiance domain are used to create an HDRI. Compare to radiance domain, image domain take less time to create an HDRI. Because, in image domain method no need to calculate the tone mapping operation. In future we plan to make an analysis and experiment about the method used for ghost detection and removal. As well as we have a plan to frame a new tone mapping operator for create an HDRI image with high and best dynamic range.

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