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Luminance-chrominance-gradient high dynamic range imaging with improved bitonic filter tone mapping technique

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ABSTRACT

In this paper, we will discuss a new process for High-Dynamic-Range Imaging. In contrast to the traditional method, we are processing the High-Dynamic-Range imaging process in luminance-chrominance-gradient space rather than RGB space. The main motive is to get the more efficient technique and also to avoid color-distortion generating from three different color channels. We introduced a camera responsive function for luminance channel so that we can find out the HDR luminance. On the other hand, for chrominance channels, we introduced weighting in relation to the saturation level. Our technique produces more natural tone-mapped images with more information. Once the luminance, chrominance, and gradient values are extracted from the image, based on logarithmic of the luminance value, the tone mapping technique approximates the appearance of the HDR image. In local tone mapping, there is a detail loss, artifact and higher computation time because of the tone mapping technique. To increase the image quality and to increase the performance of tone mapping is the main idea of the research. Improved Bitonic Tone Mapping (IBTM) is a new technique proposed for efficient tone mapping. In this method, edges have high weights than flat surfaces and a weight factor is added to the bitonic filter. When compared to different tones mapping algorithms like Reinhard, Drago, Exposure, and Gamma, Local adoption etc. shows that from the proposed technique we can achieve higher performance.

Keywords— *Improved bitonic filter, Luminance, Chrominance, Gradient, Tone mapping, High-Dynamic-Range*

1. INTRODUCTION

Spatial resolution is not at all an issue any more in natural scenes. Realistic images are obtained either by adding the third dimension or by using more and more gamut of light or colour. The problem with using lighter and colour is addressed by HDR imaging. It addresses the problem by capturing different images of the same scene with different exposures and then composing all of them to get a single image. This image composition technique requires a primary calculation of camera response function, then it should be adequately tone mapped hdr image back to low dynamic range display. Traditional techniques for HDR imaging are developed by from RGB colour space, where the luminance, chrominance colour space is neglected. We consider luminance-chrominance colour space is related to RGB space linearly. It is composed of one luminance component and two chrominance components. Some examples are YUV and opponent colour spaces. We denote one luminance and two chrominance components as Y, U, and V respectively. An image in RGB space is denoted by $z = [z_R, z_G, z_B]$ and luminance-chrominance space of the same image is denoted by $\zeta = [\zeta_Y, \zeta_U, \zeta_V]$. $\zeta = zA$ it defines the transformation of luminance-chrominance space from RGB in matrix form.

They are many reasons for choosing HDR imaging working in luminance-chrominance space. Firstly, better compressibility is offered by decorrelated colour space. The images are stored in luminance-chrominance space in image compression techniques. So, it is more efficient to compose the HDR image directly in the same colour space. Then the resultant HDR image is better suited for compression and can be mapped with RGB during the tone mapping stage to display. If an image is compressed using the HDR technique operating in RGB space requires post composition white balancing because the colour channels go through a parallel transformation. While white balancing yields the most beautiful and pleasant colour for the naked eye, they might not be the true colours. For better compression, it is best to go for a luminance-chrominance colour space. From the above points, we address the HDR imaging in luminance-chrominance space.

Whenever we click the image of natural scenes it always contains High Dynamic Range areas when it is compared to limited dynamic range capabilities of cameras or display. The ratio between maximum and minimum light intensities of the image is called the dynamic range. So in many multimedia applications, HDR imaging/video has received significant attention. Such as digital photography, ultra HD movies and video games and so on. HDR images are generally different from low dynamic range images which use 24-bit pixel data format. Can adopt additional data bit to represent real-world images. One key limitation of conventional 8-bit image representations is that the range of luminance available in the physical world substantially exceeds the dynamic range handled by traditional imaging pipelines, resulting in a loss of visual information in over/under-exposed image regions. When it comes to global tone mapping it applies single tone mapping to all the pixels in the image. Therefore, one input pixel value will result in a particular output value irrespective of its spatial location.

When it comes to local tone-mapping technique uses symmetrical analysis filter bank applies local gain bank to control. When we consider consumer products the number of LDR images are very low in HDR imaging due to processing time. When it comes to these methods, they usually consider that all pixels of different LDR images are aligned. Local contrast and details are enhanced when we use small scale Gaussian filter though Arti-crafts are increased. Many researchers are made by using global and local tone mapping because HDR cameras are high cost. Quality of LDR images is also affected by the tone mapping technique. In this paper, a new tone mapping technique is proposed based on the improved bitonic filter to achieve the best image quality. It does not contain data level sensitivity parameters and can adjust to noise and pixel levels of the image which decreases the noise level. The weight factor is introduced in bitonic filters and high weights are assigned to edges. The edge loss had been prevented and smoothness is maintained in this technique.

2. LITERATURE REVIEW

The visual details of the image have been lost in the ordinary display due to the bright and dark area of the image. Tone mapping technique has been used to minimize the dynamic range of the image. Several techniques have been proposed to improve the image quality in the tone mapping technique. The recent technique used in tone mapping has been surveyed in this section to analysis the robustness.

David Gommelet, et al. [1] analyzed the problem of tone mapping operator for rate-distortion optimized backwards compatible compression of HDR images. The distortion and rate are expressed as a function of the gradient in the HDR image. The proposed rate and distortion model are based on the function of the gradient in the HDR image. The experimental result shows that the proposed operator achieves optimal value for rate-distortion performance in global tone mapping. The second tone mapping operator has trade-off performance of the distortion rate and quality preservation. The quality of the image should be preserved and evaluated on the various dataset.

Alessandro Artusi, et al. [2] proposed a High Order Reconstruction (HOR) technique to preserve the edge in multi-scale edge aware tone mapping. The edge-aware technique increases the quality by smoothing input images while keeping its edges intact. The proposed HOR technique focus on various factors of the performance such as altering the image structure due to changes in contrast; removes artifacts around edges; as well as reducing computational complexity in terms of implementation and associated computational costs. The proposed technique aims to reduce the changes in the image structure by using an edge-stop mechanism, whose computational cost is compared to the state-of-art method. In the 18th evaluated image shows that the proposed HOR has a higher value for the loss of contrast. This technique is not much suitable to apply for the images with high contrast (blue) due to low amplification.

Baek-Kyu Kim, et al. [3] proposed the weighted least squares (WLS) filter to preserve the detail and contrast of the image in HDR tone mapping, which preserves the global contrast in a scene by using a competitive learning neural network. The proposed method is applied before a tone reconstruction operator that preserves the color without shifting the lightness. According to the Helmholtz–Kohlrausch effect, the perception of brightness depends on the lightness, Chroma, and hue of a color. Based on the effect, the proposed method corrects the lightness of pixels according to the color of a tone mapped image. The filtering of the luminance in the image helps to measure the difference in luminance between each pixel, which is small inhomogeneous regions and larger in edge pixels. The luminance value is used to preserve edge and reduce artifacts. The local contrast is low in the HDR technique and this filter is not reliable in local tone mapping.

Yang Song, *et al*. [4] proposed an exposure condition analysis method based on the quality evaluation method for the tone-mapped HDR images. First, local exposure property analyzed for the purpose-designed HDR exposure segmentation model that used to separate image. The two new quality features such as abnormal exposure ration and exposure residual energy extracted and it is low complex. The color-based feature was also extracted and these features in the different exposure region. The quality evaluation model implemented by regression training. The ability of the model to predict the quality of tone-mapped HDR images showed in their experiment. The Pearson linear correlation coefficients are higher than 0.88; this technique has a high consistent with human visual perception.

The several methods are proposed to improve the function of the tone mapping and some limitations need to overcome. The tone mapping techniques are needed to preserve details of the image and minimize the artifacts. The computational time of the local tone mapping is needed to be decreased and preserve the quality of the image.

3. HDR IMAGE COMPOSITION

Let's take a set of images $\zeta_i = [\zeta_i^Y, \zeta_i^U, \zeta_i^V]$, i = 1, . . . , N in the luminance-chrominance space with different exposures assuming(x) ∈ [0, 1] × [−0.5, 0.5]^2 ,where x=[x1,x2] is a coordinate pixel. The main aim is to obtain a single HDR image. In our model, the luminance-chrominance channels are treated separately for chrominance channel we use saturation weighting is applied. Whereas for luminance channel a pre-calibrated responsive function is used.

3.1 Camera response function

The image a camera acquires consists of a collection of measurements we refer to as intensity values.1 At a single point in the image, an intensity value is related to the scene radiance by a nonlinear function called the camera response function. We will assume that the response is the same for each point in the image. A typical camera response has a variation across the image which is linear in scene radiance. Once the response is found, this variation may be calibrated separately and removed. By determining the response, or rather the inverse of the response, we can obtain scene radiance from image intensity.

3.2 Luminance component composition

In order to obtain camera responsive function for luminance channel a set of images of a scene with different exposures. A good number of pixels which are suitable are chosen, especially pixels having under and overexposed are chosen. From the pixels which are chosen the camera responsive function is fitted in a similar manner of HDR image composition. The camera responsive function is calculated only once and used for linearization of input values in all HDR compositions of the same device. In order to obtain the HDR luminance component, the pixel wise weighted averages of input luminance's are obtained. Gaussian functionω^Y is used as wea ighing function with sta andard deviation of 0.2 and mean of 0.5 thus making sure of a small impact of under are over-exposed pixels. The logarithmic HDR luminance component is obtained as:

$$\ln \tilde{\zeta}^Y(x) = \frac{\sum_{i=1}^{N} \omega^Y(\zeta_i^Y(X))\left(g\left(\zeta_i^Y(X)\right) - ln\Delta t_i\right)}{\sum_{i=1}^{N} \omega^Y(\zeta_i^Y(x))} \tag{1}$$

From the equation (1) value of HDR luminance is measured in logarithmic scale and camera responsive function is g. Once the natural exponential is applied the resulting values are spanned normally and positive$[10^{-4}10^{4}]$.

3.3 Chrominance component composition

Colour saturation is taken to weight the component where are camera response function is not required to calculate the chrominance component composition. The more the colour saturation in the image, the more pixel contains more chromatic information. The chromium feature is chosen because its values are saturated when the pixel is over or underexposed. In detail, $\omega^{UV}(S) = S^{\alpha}$where $\alpha > 1$. In this method, we also recognised that $\alpha = 1.5$ is a good choice. Same weight is used for both chromatic components to guarantee the colour perseveration and compose any chromatic component $C \in \{U, V\}$ as

$$\tilde{\zeta}^C(x) = \frac{\sum_{i=1}^{N} \omega^{UV}\left(S_i(x)\right)\zeta_i^C(x)}{\sum_{i=1}^{N} \omega^{UV}\left(S_i(x)\right)}, \tag{2}$$

Saturation of $\zeta_i$is denoted by S_i.The range of $\tilde{\zeta}^C(x)$ is again in $[-0.5, 0.5]$.

3.4 Gradient value of the image

Weighted map of gradient information is created for static and dynamic scenes and at the same time to canny detection. The gradient information is extracted by the first derivatives of 2-D Gaussian filter $g(x, y; \sigma_d)$ in the x and y directions are given by $I_x^i(x, y)$[15] and $I_y^i(x, y)$[15] which are partial derivatives of images $I^i(x, y)$ along x and y axis. Two pixels in the experiment are set by standard deviation the $\sigma_d$and gradient magnitude reflects maximum change in the pixel values. The two components are calculated in the following equation

$$\tilde{\zeta}^G(x, y) = \sqrt{|I_y^i(x, y)|^2 + |I_x^i(x, y)|^2} \tag{3}$$

The use luminance, chrominance and gradient for tone mapping provide the image with proper illumination.

3.5 Algorithm

Algorithm 1.1: HDR image generation using LCGHDR technique

```
Input: image [1…n] with different exposures
output: HDR image
for each image Ci :
 if Ci is in RGB colour space then
                convert Ci into YUV space
endif
            extract Yi,Cri,Cbi values from Ci
            calculate Y,Cr,Cb component of final HDR image as per formulae using extracted values
            calculate scaling factor from extracted values
end for each
apply exponentiation on Y component of HDR image
divide Cr and Cb components of HDR image with scaling factor
return HDR image
```


4. FUSION METHOD

T which is a luminance range reduction operator will define its output as $\dot{\zeta}(x) \in [0,1]$. In terms of chromatic channel, it is the best approach. Rendering of very dark or very bright and saturated colours are not allowed by RGB gamut. This is present in real images captured in HDR images. Hence, there is nea ed for chromatic feature and hue intact in order to fit into RGB, s gamut. The scaling factor $\delta$is introduced fortwo chrominance will reduce down the saturation and there will be no change in hue. It uses RGB values which are embedded in colour space transformation and describe as follows:

The luminance, chrominance and gradient to RGB transformation matrix be $B = A^{-1}$ and define the chromatic complement image and achromatic(gray) as

by$\dot{Z}_{gray}(x), Z_{chrom}(x), \dot{Z}_{grad}(x)$[15]

The truly grey image is $\dot{Z}_{gray}(x)$,since in RGB luminance, chrominance and gradient transforms.

$b_{1,1} = b_{1,2} = b_{1,3.}$ Look for a map $\delta \geq 0$ such that,

$$\dot{Z}(x) = \dot{Z}_{gray}(x) + \delta(x) Z_{chrom}(x)[0,1]^3 + \dot{Z}_{grad}(x)$$

This is defined by$\delta(x) = \min\{1, \delta_R(x), \delta_g(x), \delta_B(x)\}$

$$\delta_R(x) = \begin{cases} \dfrac{\dot{z}^R_{gray}(x)}{-z^R_{chrom}(x)} & if\ z^R_{chrom}(x) < 0 \\ \dfrac{1-\dot{z}^R_{gray}(x)}{z^R_{chrom}(x)} & if\ z^R_{chrom}(x) > 0 \\ 1 & if\ z^R_{chrom}(x) = 0 \end{cases} \tag{4}$$

In the above formula $\delta_g\ and\ \delta_B$ are analogously. The hue of $\dot{Z}(x)$ is not influenced by δ,on the other hand the saturation is measured proportionally to it. Colours which consist in same hue at he the the the s those of HDR image $\tilde{\zeta}$ are from low dynamic the range image $\dot{Z}(x)$, as it needed to fit with RGB gamut. The LCG technique image can be stored directly in an arbitrary method for display which is changed into RGB by using matrix B.

4.1 Tone mapping

The following figure is the flow chart of TMO with respect to bitonic filter which is improved. The main goal of tone mapping(reproduction) is to compress the dynamic range of a scene to a range that will be easily displayed on physical devices only when the luminance range of the image is broader than physical devices. All tone mapping techniques can be categorising to global and local tone mapping. Global operators apply the same technique to every one pixel of an image whereas coming to local operators adapt their scales to different areas of the image. To compress the range of luminance to the range which can be displayed it is initially mapped using global tone mapping function.

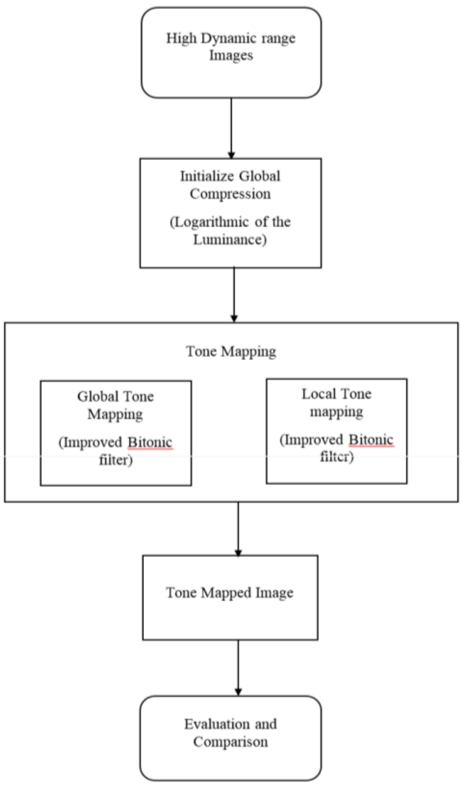

Fig. 1: Flow chart of the proposed architecture

To increase the quality of the image, "dodging and burning" technique is introduced. Which allows different exposures to each part of the image. In the automated process low contrast regions are founded by centre surrounded function. Then a tone mapping function is locally applied. While preserving overall characteristics of an image the automatic dodging and burning method enhance contrast and details of the image.

Given an HDR image, the luminance component of the HDR image in Equation (1) is decomposed as

$$Y_h(p) = Y_b(p)Y_d(p), \tag{5}$$

Where Y_b and Y_d are the base layer and the detail layer. The dynamic range of detail layer is small when compared to base layer. Using global tone mapping algorithm, the overall tone mapping algorithm is reduced to scale the base layer$Y_b$as$\hat{y}_b$.. The detail layer$Y_d$is preserved or even amplified as $\hat{Y}_d$to enhance local contrasts. The compressed luminance value Y_l is the product of $\hat{Y}_b$and$\hat{Y}_d$. The HDR image $\{R,G,B\}_h, Y_h$ and Y_l are finally adopted to generate the output LDR image$\{R,G,B\}$.

The log function approximates the transformation performed by the retina of the HVS [17] and from this decomposition is performed in the log domain in equation

$$L_h(p) = L_b(p) + L_d(p), \tag{6}$$

Where $L_b(p)$ and $L_d(p)$ are $\log(Y_b(p))$ and$\log(Y_d(p))$, respectively. Three major function of the proposed technique are: (1) the decomposition of L_h into $L_b$andL_d, (2) the compression of $L_b$through global tone mapping and (3) the amplification ofL_d.Improved Bitonic filter is used to decompose the HDR images.

5. IMPROVED BITONIC FILTER

In order to eliminate impulsive noise median filter is commonly used whilst preserving edges well, while there is no more than one edge within the range. A rank filter is a generalization of the median where any centile can form the output. Those filters are considered as monotonic because they store signals which are monotonically increasing or decreasing, therefore, it leads to noise reduction. The shape of the window is used form the set of ranked data for two-dimensional(2D) data. For 2D image disk here we use the circular disk to ensure isotropic behaviour. If B is a Bitonic filter image and $\sigma_{B,1}^2(p')$ be variance of B in the 3×3 window,$\Omega_1(p')$ [19]. Local variances define edge-aware weighting $\Gamma_B(p')$ of 3×3 windows of all pixels as follows

$$\Gamma_B(p') = \frac{1}{N}\sum_{p=1}^{N}\frac{\sigma_{B,1}^2(p') + \epsilon}{\sigma_{B+1}^2(p) + \epsilon} \tag{7}$$

Where σ is defined as sa mall constant and the value of it is given as $(0.001 \times L)^2$. When dynamic range of input image is given as L. In order to compute $\Gamma_B(p')$ all pixels in the image are used. If value of p' is smaller than 1 then the value of $\Gamma_B(p')$ is larger than 1. IT is crystal clear that larger weights are assigned topixels at edge using $\Gamma_B(p')$. In order to prevent blocking of artifacts from appearing in final image, the value of $\Gamma_B(p')$ is smoothed by a Gaussian filter. The proposed weighting matches one features of human visual system, i.e., pixels at sharp edges are usually more important than those in flat areas.

$$r_{\omega,c}(x) = c^{th}\underset{i \in \omega}{centile}\{x_i\} \tag{8}$$

$$O_{\omega,c}(x) = r_{\{\omega\}}, 100 - c\ (r_{\omega,c}(x)) \tag{9}$$

$$C_{\omega,c}(x) = r_{\omega,c}\big(r_\omega, 100 - c\ (x)\big) \tag{10}$$

Where $r_{\omega,c}(x)$ is a rank filter, filter window is w and window length is $|\omega|$ and c is chosen centile. Robust closing and opening operations half of the required purpose, they only preserve local minima or maxima. In addition to it, it can be seen from Fig. 1 that the opening and closing operations do not store mean values of signals in the case of a noisy signal. Both drawbacks can overcome by same the means. The most appropriate output for each part of the pixel is clear by comparing each of the original pixels with opening and closed operations. Hence, we can use such a comparison to weight a combination of opening and closing operations, so instead the differences between the original signal and each of the rank-filtered pixel are smoothed with a linear filter. A Gaussian filter (i.e. a linear moving-window filter with Gaussian weights) is used for this purpose, since it is known to have good noise reduction properties. The filter length is determined experimentally to match the noise reduction from the rank filters, so that the standard deviation σ = 0*:*33*lwherel* is the window length in 1D, or the diameter of the structuring element in 2D. This smoothed error can be seen in the middle column of figure 1.

The Gaussian linear filter as$G_\sigma(x)$, this is used to weight the results of the opening and closing operations as follows:

$$\epsilon_O(x) = |G_\sigma(x - O_{\omega,c}(x)| \tag{11}$$

$$\epsilon_C(x) = |G_\sigma\big(C_{\sigma,c}(x) - x\big)| \tag{12}$$

$$b_{\omega,c}(x) = \frac{\epsilon_O(x)C_{\omega,c}(x) + \epsilon_C(x))\ O_{\omega,c}(x)}{\epsilon_O(x) + \epsilon_{C(x)}} \tag{13}$$

$\epsilon_O(x)\ and\ \epsilon_{C(x)}$are smoothed opening and closing errors and $b_{\omega,c}(x)$ is output of improved Bitonic filter.

6. EVALUATION METRICS

From researchers, we collect data sets. In adjusting parameters of tone mapping perceptual quality assessment method is developed for HDR.TMQI that provides a single quality score for TMIs is proposed recently. In order to dilute detail loss in dark and bright regions, we use patches under normal light condition. So TMQI can inadequately show the detail loss in dark or bright regions whose areas may be small compared to the areas under normal light conditions. To overcome this, we used an additional metric for detailness in the dark and bright regions that are detailness metric.

The evaluation metrics of TQMI are followed from [21] and TMQM is followed from

$$TMQM = TMQI.DS \tag{14}$$

When,

$$DS = \frac{DS_{under}.\sum_{(i,j)\in U} VS(i,j) + DS_{over}.\sum\_((i,j) \in U) VS(i,j)}{\sum_{(i,j)\in U} VS(i,j) + \sum_{(i,j)\in 0} VS(i,j)}$$

One more old evaluation metric is PSNR (peek signal to noise ratio) shows the quality of the image and is given by

$$PSNR = 10log\left(\frac{d}{MSE}\right) \tag{15}$$

$$MSE = \frac{1}{MN}([f(x,y) - r(x,y)])$$

The MSE represents the average of the squares of the "errors" between our actual image and is an expensive operation, we use MSE for PSNR calculation.

$$PSNR = 20log\left(\frac{d}{\sqrt{MSE}}\right) = 20\ log\left(\frac{d}{RSE}\right)$$

Fig. 2: series of images with different exposure levels taken as input

7. EXPERIMENTAL RESULTS

Using MATLAB(R2017b) the experiment is conducted where the system specifications must be 3.0 GHz processor and 4 GB ram. In the same environment efficiency analysis is performed for all methods. From the available HDR photographic survey website the input images are collected. The output image is a perfectly illuminated image which is took for evaluation. In terms of signal to noise ratio (SNR), this method is evaluated. Each set of images have fifteen similar images captured with different exposures. The HDR techniques used for the 10 set of images and obtain the image with proper illumination.

There are 106 images used as input images for evaluation. As illuminance, chrominance and gradient values extracted from images. Based on the feature value

(a) **(b)** **(c)**

Fig 3: (a) Output of our proposed technique (LCGHDR with IBTM) (b) Output using Durand technique (c) Output using Reinhard technique.

Table 1: Comparison of BAR, AEE and LCGHDR

Number of scenes	Methods	Number of shots	% Lost	$\sum_{i=1}^{N} T_i(s)$
1	Durand	3	1.61	0.301
	Reinhard	2	1.61	0.025
	LCGHDR	2	1.61	0.014
2	Durand	3	0	0.301
	Reinhard	2	0	0.101
	LCGHDR	2	0	0.85
3	Durand	3	0	0.301
	Reinhard	2	0	0.04
	LCGHDR	2	0	0.021
4	Durand	3	0	0.301
	Reinhard	2	0	0.05
	LCGHDR	2	0	0.032
5	Durand	3	0	0.301
	Reinhard	2	0	0.034
	LCGHDR	2	0	0.015
6	Durand	3	0	0.301
	Reinhard	2	0	0.025
	LCGHDR	2	0	0.012

8. CONCLUSION

The combination of LCGHDR pipeline with Improved Bitonic Filter Tone Mapping technique generates pleasant noise free high dynamic range images. Since LCGHDR technique to produce HDR luminance map takes less time than the available methods like Reinhard, Durand, Drago etc. The IBTM technique produces noise-free tone mapped HDR images and our method uses both of these techniques making it surpass the existing methods in terms of time complexity and noise ratios. But this method takes slightly more memory than existing methods. Since we have implemented this technique in Matlab, it is possible to reduce the memory intake by the method if it is implemented in a native language like CPP.

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