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Compression of high dynamic infrared image using auto aggregation algorithm

Abstract

The article presents a method of compression of High Dynamic Range of infrared image and its details enhancement. The method is based on aggregation of partial images with different ranges of pixel values generated using a weighting function. Aggregation of images could be performed according to proposed scheme with use of the optimal algorithm selected by user. Preliminary results shown that the method can reveal previously hidden details in the original image.

Keywords: infrared image, compression, enhancement, high dynamic.

1. Introduction

During infrared inspections of different industrial installations and processes a high dynamic range infrared images can be acquired. It follows from construction of contemporary infrared cameras which convert analog signals form focal plane array with resolution of 14-bit or greater. Infrared image formed in the camera and represented in gray scale exceeds sensitivity of human eye (7-bit) and typical 8-bit display devices. Displaying wide dynamic range infrared images on lower dynamic devices could hide the image details, forcing the user to change the range and level of the displayed image pixel values. High dynamic range infrared images also are not desirable from automated systems of continuous infrared monitoring point of view due to necessity of gathering and processing plenty of data. Hence, compression methods which could reduce the redundant information and enhance the image details improving its quality must be applied in infrared imagining systems. Dynamic-range compression (DRC) has been widely investigated and a number of visualization techniques have been proposed in literature [1, 2, 3, 4]. In this article a method of compression of high dynamic range infrared images based on auto aggregation of different representations of the image with nonlinearly weighted level ranges was proposed.

2. The general idea of the method

The aim of the proposed method is to compress the high dynamic range of infrared image values and enhance the visibility of image details. Due to application of the method to qualitative image analysis purposes, it was assumed that method may not preserve information about temperature values. The method consists of two main steps (Fig. 1.). First, on the basis of single radiometric image (primary image) two sets of auxiliary images (Fig. 1a) are generated. In the second step auxiliary images are joined using aggregation method (Fig 1b). As a result of these steps a final compressed image is obtained.

The auxiliary images are constructed by gradually weighting of primary image using weighting function. In order to extract some hidden details in the primary image a generation of two types of auxiliary images was proposed: Low Auxiliary Images (LAI) and High Auxiliary Images (HAI). Pixel values of these images should meet the following conditions:

$$LAI(i) \leq I_{min} + R \cdot w(i)$$
$$HAI(i) \geq I_{max} - R \cdot w(i)$$

where: I_{min} and I_{max} are respectively minimum and maximum pixel value of primary image, R is the primary image range defined as $R=|I_{max}-I_{min}|$, $w(i)$ – i-th weight, i – i-th number of auxiliary image.

Generation of auxiliary images could be treated as a some kind of primary image decomposition in pixel values domain. This operation gives us two sets called respectively low (LSSI) and high (HSSI) set of auxiliary images. Pixel value ranges of auxiliary images depend on weights which could be generated using predefined weighting function (cf. sec. 2.1.). Due to different ranges of pixel values each auxiliary image reveals different details previously invisible or weak visible in primary image. Application of appropriate aggregation scheme could preserve those information. It's worth to say that aggregation scheme could consider images from LSSI and HSSI sets independently or cross aggregation could be performed. One of many possible approaches to auxiliary images aggregation is presented in the paper (cf. sec. 2.2.).

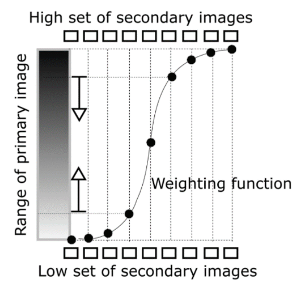

Fig. 1. Illustration of the way of generation the sets of low and high auxiliary images

2.1. Weighting function

As shown in previous author's research [5] an appropriate selection of the weighting function for purposes of auxiliary images generation is a crucial issue. A common or separate weighting function could be used for generation both low and high set of auxiliary images. For purposes of this research we decide to use one function defined in the following way:

$$w(x) = \frac{kx}{(k-x+1)} \tag{1}$$

Where $x=i/N$ – is function argument depending on i-th considered auxiliary image to total number of auxiliary images N ratio. The function values depend on k parameter which allows to weight image values in different way. An exemplary family of functions for different values of k parameter were presented in Fig. 2.

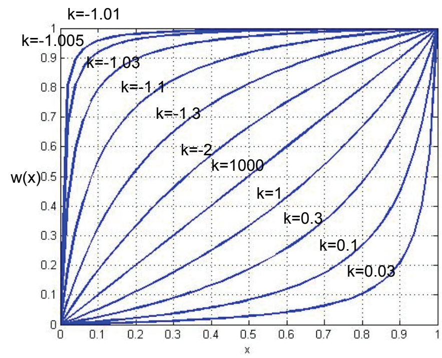

Fig. 2. Exemplary plots of weighting function for different values of k parameter

2.2. Auto aggregation of infrared image

Auto aggregation is based on image fusion approach, that in the case of proposed technique is consisted only in a step of image merging. As the main goal of the image merging (aggregation) is to preserve and emphasize important but slightly visible image details, while simultaneously blurry or redundant information is supressed. The key issue is to select valid aggregation method. Methods in spatial, transformation, gradient and other domains were proposed in literature. Previous authors work [5] shown that aggregation method influences quality of results. Additionally, even slight changes in aggregation method parameter or fusion rule can led to generation of images with unacceptable quality. Aggregation methods in spatial domain are most common due to their simplicity and the lowest computational cost. Unfortunately results generated by those methods (mainly Laplace transform based hierarchical approaches) give poor quality or are affected with unwanted artefacts (halo effect, omission of important regions, preservation of noise). Moreover those methods introduce spectral distortions into output image. To overcome those drawbacks, two aggregation schemes were proposed.

A DWTF-GDF method is based on two fusion methods, applied on different aggregation scheme stages. At the first stage, where auxiliary images are merged, a hierarchical method utilizing discrete wavelet transformation (DWT) was applied [7]. The DWT fusion (DWTF) methods provide computationally efficient image fusion techniques.

In this method image is transformed at each level of decomposition into four bands, where details are generated by applying low-pass filtering to the image and approximation is obtained by downscaling and high-pass filtering. The number of filtration steps depends on the number of levels of decompositions, which is limited by image size. In proposed approach DWTF is performed several times, according to the number of images in input data set. The output partial images (LI or HI) is generated in an iterative manner, where consecutive input images are merged with intermediate images (iLAI_x or iHAI_x, Fig. 3).

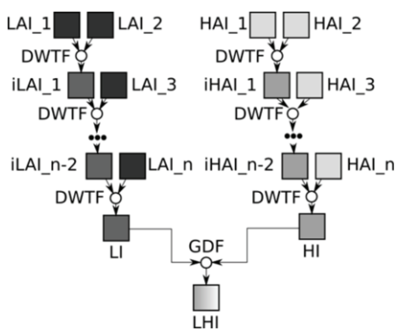

Fig. 3. Flowchart of proposed DWTF-GDF auto aggregation scheme

On final aggregation stage, where LHI image is obtained from partial aggregated LI and HI images, gradient domain fusion algorithm (GDF) was used. The selected algorithm operates in the YCbCr color space, where Y is luminance, and Cb and Cr are blue-difference and red-difference chrominance components. According to that at the very beginning conversion from RGB (or grayscale) to YCbCr is performed. In this method two fusion paths are used: luminance fusion, followed by chrominance fusion. At the end aggregated image of all three channels is generated [8].

A GDF-GDF method was also verified, as an alternative for the DWTF-GDF approach (Fig. 4). In this approach, at both stages GDF method was used. There is no need to perform iterative aggregation, because GDF can be feed with many input images, so the whole set can be merged at once. It is a great benefit of this method.

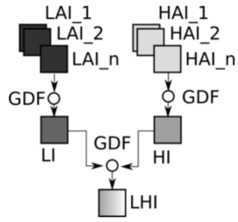

Fig. 4. Flowchart of proposed GDF-GDF auto aggregation scheme

3. Example of application of the method

The proposed method was tested using infrared image (Fig.5) recorded during inspection of industrial installation in a power plant. Image was recorded in radiometric format which allow calculation the temperature values of image pixels. The image resolution is 320×240 px and showing a scene with industrial objects whose temperatures values were scattered in a wide range (from 20°C to 140°C). In the original image indicated areas where image details are not visible due to high dynamic range of image values.

Fig. 5. Original image taken into consideration during the research

Using the original image and a weighting function (1) the low (LSSI) and the high (HSSI) sets of auxiliary images were generated. In order to investigate an influence of weighting function shape the following values of k parameter was taken into consideration k={1000, −1.01, −1.03, −1.1, −1.3,}.

For each function the auxiliary image sets consisted of respectively 16, 32, 64 and 128 images were generated.

Finally for the research purposes a 20 sets of low and high auxiliary images were subjected to further processing with use of described below aggregation algorithms.

At the first level of processing, a wavelet based algorithms were used. Based on previous author research, as well as literature review three combination of parameters were used:

- wavelet DB2, fusion rule mean (for details and approx.),
- wavelet sym4, fusion rule mean (for details and approx.),
- wavelet sym4, fusion rule max (for details and approx.).

Decomposition was made into five levels. At second level, low and high auxiliary images were aggregated, gradient domain transform was used.

During aggregation considered different combinations of images obtained with use of weighting function parameters. Sets with different number of images were also combined.

Results of aggregation were evaluated visually. It allows us specify the best combination of processing parameters.

The most promising results obtained using DWTF-GDF scheme with Sym4 wavelet and fusion rule Max as well as with use GDF-GDF aggregation schemes. Exemplary image obtained with use of this schemes are presented in Fig. 7 and Fig. 8. In the first case even that images are blurred there are visible almost all details. Observed that weighting function parameter has very small influence on images content. A small number of images taken for aggregation caused images more blurred. In the case of application of GDF-GDF aggregation algorithm resulted image also preserved most of details and is not blurred (Fig. 8) however there is some space for improvements, while in several places interesting content remain hidden and invisible for human observer.

Images obtained with use DWTF-GDF scheme with DB2 wavelet and fusion rule Mean for different weighting function parameters are presented in Fig. 8 and Fig. 9

Fig. 6. Exemplary aggregated image using DWTF-GDF scheme with wavelet Sym4 and fusion rule Max, weighting function parameter k=−1.01, number of images in considered LSSI and HSSI sets N=128 (PSNR = 15.30)

Fig. 7. Exemplary aggregated image using GDF-GDF scheme (PSNR = 18.10)

In case of aggregation using parameters Sym4–Max obtained images confirmed small influence of value of weighting function k parameter. When fusion rule Mean was used the k parameter has influence but the influence of wavelet type is not visible. It can be also noticed, that application of Mean rule lead to images, with different content, result strongly depends on the type of input data. In resulting images, various areas of low dynamics are revealed, but only dark (cold) or bright (warm) ones separately. In the cases of Sym4 and DB2 with Mean fusion rule number of aggregated images has minimal influence on content of final image.

Analysing PSNR (Peak Signal-to-Noise Ratio) for selected images it can be seen that this type of measure work well for images that are similar to input images. It is calculated globally, so results of images of low dynamics, as well as for those with regions of low and high dynamics are similar. Different measure, taking into consideration structural information or human perceptual abilities could be a better choice for objective algorithm selection.

The complexity of algorithms depends mainly on the number of auxiliary images. Taking into consideration only the aggregation stage, times for DWTF-GDF varies significantly (Tab. 1).

Fig. 8. Exemplary aggregated image using DWTF-GDF scheme with wavelet DB2 and fusion rule mean, weighting function parameters LSSI: k=−1.1, N=64 HSSI: k=1000, N=64 (PSNR= 9.10)

Fig. 9. Exemplary aggregated image using DWTF-GDF scheme with wavelet Sym4 and fusion rule Mean, weighting function parameters: LSSI: k=1000, N=64 HSSI: k=−1.01, N=64 (PSNR = 5.11)

For GDF-GDF approach times are much shorter, and are not so strong bounded to number of auxiliary images. There was no research made on possibility of GDF method FPGA implementation. Nevertheless at this stage none of evaluated algorithms can be applied in real time.

Tab. 1. Algorithms execution times

No. of auxiliary images	16	32	64	128
DWTF-GDF (s)	13	27	55	114
GDF-GDF (s)	5.3	5.5	5.7	6.3

4. Conclusions

The method presented in the paper is on the preliminary stage of development, but even in this phase it is possible to compress high dynamic range of the infrared image simultaneously revealing details previously hidden on the original image. Obtained results strongly depend on applied aggregation scheme. Obtained results show the direction of further research which will be focused on optimization of weighting function parameter as well as improvements in aggregation scheme. First of all a simplification of image fusion algorithm will be take into consideration in order to speed up aggregation processing time. Open problem is assessment of image quality. Visual comparison is not effective solutions thus it its necessary to find objective image quality indicator. In the future research application of objective metrics like HDR visual detection predictor (HDR-VDP-2.2) and HDR video quality metric (HDR-VQM) is planned.

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