Research Paper Science

Using Potential Field Analysis into Image ArtifactDetection Field

***Marius Rogobete**	Alstom GRID, Software Development, Bucharest, Romania
Ciprian Răcuciu	Titu Maiorescu University, Science and Information Technology, Bucharest, Romania

ABSTRACT

Based on the assumption that, for specific limit conditions of visual artifact overlapping the original image, the behavior of a 2D image function representation can be approximate with a 2D potential field representation, we propose some specific potential field analysis formulas able to detect embedded visual artifact. The application developed for image artifact detection and elimination is based on the proposed algorithm here described. The whole artifact real time process of detection and elimination is applied with success on the still image of the video stream frames.

KEYWORDS image artifact; real time software; image processing; first and second gradient; potential filed analyze.

I. Introduction

Several methodologies can be used in different areas if the necessary and sufficient mathematical conditions are satisfied. The proposed methodology is extrapolated from the specific potential filed analysis into image processing area, focused on artifact analysis.



Figure 1.The original video frame with visual artifact.

The source density field σ (fig.2) could be used to generate the analyzed image (fig.1) based on solutions of Poisson equation as [2] proves.



Figure 2.The source density for total field.

The source structure (fig.2) is the result of divergence operation applied on gradient vector field (fig.3).



Figure 3. The gradient operation applied on original image.

The physical representation of visual artifact that covers a clear image could be imagined like a sum of two effects, the clear image that is the potential field intensity effect given by deeper density structure and the visual artifact being the potential field effect of a superficial density structure.

This representation is very close of a diffusion anisotropic model, which is used for image space scaling and edge detection applications[7].

The coefficient of heat conduction is replaced with a brightness gradient function using:

$$coef(x,y,t)=g(\|\Delta I(x,y,t)\|) \quad (1)$$

Then, it is used a new principle developed by Juutinen and Lakkari [5] to prove that viscosity supersolutions and p(x)-superharmonic functions of nonlinear potential theory coincide:

$$-\Delta_{p(x)}\, u(x)=-\mathrm{div}(|Du(x)|^{(p(x)-2)}Du(x)=0 \quad (2)$$

where $1<p(x)<\infty$, andthe function u is a weak solution of (2) if and only if it is a viscosity solution of (2). Based on it, Chen and Levine [1]have improved the mathematical model for image denoising, enhancement, and restoration.

Therefore, a direct classical field theory approach, as new methodology in image processing area is developed in[2]. One can see a key concept where monochrome and color images are assumed to be scalar and vectorial potential fields, respectively, more specific for electromagnetic fields representation.

The presented approach is assuming that the gravity field is a good model for specific visual transparent artifact that is analyzed.

Using typical numerical formulas for first and second gradient of potential field, the artifact is detected and then geometrical localized.

A visual artifactembedded into any imagecould be considered an effect of a superficial structureconvoluted with the deeper structure (original image) effect, thus one can consider any artifact that has the diffusion properties (semitransparent, spatial delimited) to be analyzed as a watermark.

Finally, in order to verify the gravity field model extrapolation as a specific solution, asoftware application developed for artifact detection was developed. It is using anoriginal algorithm based on first and second numerical gradient of potential field formulas, developed by Baranov [3]forgraphical representation in a rectangular grid of gravity field.For the simplicity, the image is analyzed for monochrome spectrum [8].

II. Mathematical Frame

A. The potential field

The complete expression of 3D Newtonian potential into an observation point P(x,y,z,) is:

$$V(x,y,z) = K \iiint \frac{\delta(\xi,\eta,\zeta)}{[(x-\xi)^2+[(z-\eta)^2+[(x-\zeta)^2]^{1/2}} (3)$$

that is given by the source points $\Pi(\xi,\eta,\zeta)$. The Laplace and Poisson equations show that, for an extern point of source structure, the potential field is Laplacian, but not for an inner point. This observation could be the reason for the next research work, as it offered the condition of Green theory for analytical continuation of potential field.

B The first gradient of the potential field

The actual research is focused on gradient potential field applications [Ivan]with extrapolation in watermarking detection, where the image *I* is considered to be the first derivate of the virtual potential field, for x,y andz directions:

$$I_{(x)} = \frac{\partial V}{\partial x} = V_{(x)};$$

$$I_{(y)} = \frac{\partial V}{\partial y} = V_{(y)}; (4)$$

$$I_{(z)} = \frac{\partial V}{\partial z} = V_{(z)}$$

and:

$$I = \sqrt{I_{(x)}^2 + I_{(y)}^2 + I_{(z)}^2} = \sqrt{V_{(x)} + V_{(y)} + V_{(z)}} (5)$$

With the observation that

$$I_{(x)} \ll I_{(z)}; \quad I_{(y)} \ll I_{(z)}; \quad I_{(z)} \cong I$$

The horizontal gradient is

$$\Gamma = I_l = \frac{\partial I}{\partial l} = \frac{\partial^2 V}{\partial l \partial z} = V_{lz} (6)$$

where*l* is the horizontal direction on which I has the fastest variation.The components are:

$$\Gamma_{(x)} = \frac{\partial I}{\partial x} = I_x = \frac{\partial V}{\partial x \partial z} = V_{xz} (7)$$

$$\Gamma_{(y)} = \frac{\partial I}{\partial y} = I_y = \frac{\partial V}{\partial y \partial z} = V_{yz} (8)$$

and finally:

$$\Gamma = \sqrt{I_x^2 + I_y^2} = \sqrt{V_{xz}^2 + V_{yz}^2} (9)$$

The first vertical gradient is

$$I_z = \frac{\partial I}{\partial z} = \frac{\partial^2 V}{\partial z^2} = V_{zz} (10)$$

C. Second gradiend of the potential field

Most important for the present analysis is the second vertical gradient with the form:

$$I_{zz} = \frac{\partial^2 I}{\partial z^2} = \frac{\partial^3 V}{\partial z^3} = V_{zzz} (11)$$

It offers a really excellent property: it is able to separate the potential field sources, having the power to retrieve the local potential field effects from the global potential effect.

The mathematical relation is

$$I_{zz} = K\frac{\partial I}{\partial l} - \frac{\partial^2 I}{\partial l^2} \quad (12)$$

This property is explainable through the relation with the *K* curvature of isolines [3].

III. Numerical Approach

Numerical forms used for potential field gradients are specifics for several potential field types (e.g. electromagnetic field, magnetic field or gravimetric field). Whether it isn't considered the potential corresponding to the centrifugal force, then, the gravimetrical potential field form is closest of our approach, meaning that it is Laplacian, therefore it could be downward analytical continued.

A. First Gradient

The first gradientform for the elevation 0 plane, using a number of n terms on lk radiuses circles is:

$$I_z(0) = \sum_{k=0}^{n} C_k \bar{I}(l_k) \quad (13)$$

Where $\bar{I}(l_k)$are average values on circles of lk radius.

More practical, because one can approximate the first vertical gradient using the analytical continuation upward and downward at the same distances (+/-d), is the form developed by Constantinescu and Eldaien [3]:

$$I_z = \frac{\bar{I}(-d)+\bar{I}(+d)}{2d} (14)$$

With the work formula:

$$I_z = \frac{1}{d}[-13.969 * I(0) + 8.693 * \sum_{i=1}^{4} I_i(d) - 5{,}163 * \sum_{i=1}^{4} I_i(d\sqrt{2})] (15)$$

Where *d* is the grid unit.

The analytical continuation could be applied to define the geometry of the source density of the image.

B. Second Gradient

The second gradient form is based on graphical determination of the tangent slope in the point l=0 and $\bar{I}(0) = C_0$, where C0 is first term of the $\bar{I}(l)$ series expression.

$$I_z = \frac{1}{d}[44I(0) + 16\bar{I}(d) - 12\bar{I}(d\sqrt{2}) - 48\bar{I}(d\sqrt{5}) (16)$$

where

$$\bar{I}(d) = \frac{1}{4}\sum_{i=1}^{4} I_i(d)$$

$$\bar{I}(d\sqrt{2}) = \frac{1}{4}\sum_{i=1}^{4} I_i(d\sqrt{2}) (17)$$

$$\bar{I}(d\sqrt{5}) = \frac{1}{8}\sum_{i=1}^{8} I_i(d\sqrt{5})$$

The problem is to recognize a very specific artifact since it appears randomly on frames, during video capture with professional camera, as it is shown on figure 1. Some image/video frames are disturbed by typical signal noisy in a way that affects the human eyes.

The artifact is lying as a blurring area, bordered by the vertical symmetry axis of the image, on the left or on the right side of it, but the blurred area is not homogenous.

Apparently, this behavior is due to an optical defect, but is really expensive to be fixed replacing the hardware modules;instead, a software solution was applied.

A potential field approach is fitting on this artifact problem, since a visual transparent watermark is equivalent to a transparent artifact.

The same characteristics are:

- Transparency
- Bordering (visual)
- A constant geometrical position (locus)
- Constant intensity over the whole video stream
  Differences:
- Randomly frames apparition
- Randomly positioning along to the geometrical locus

B. Methodology

To simplify the frame processing algorithm it is analyzed the luminance image component of the YUV format. The chrominance data are used only to compensate visually the artifact border. The luminance data reduce also the embedded resources necessary for real time processing.

As the artifact is aligned along the frame median line, arising on right or left sides, the searching matrix is limited to its neighborhood.



Figure 4. The rectangle area that contains artifact, signaled for zoom.

In the 2-nd figure there is delimited a cropped rectangle with the artifact, zoomed in the figure 5.

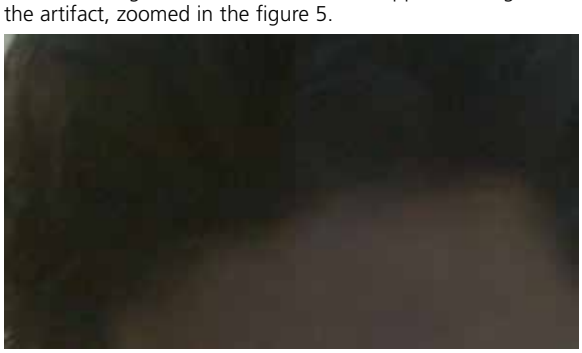


Figure 5.Zooming on artifact.

c. Classification sequency

The selected salient parameters are [9]:

- Left and Right Border Average (LBA and RBA)
- Total Average (TA)
- First Order Vertical Gradient (FVG)
- Second Order Vertical Gradient (SVG).
- Count threshold: minimum number of small
  borders detected along to the frame median that have a visual impact.
  And the processing sequence [9]:

1) Test if the TA values are located in the neighborhood range of the border artifact alignment. If at least one of them is detected continue with the classification process.
2) Test the FVG values for right side and for left side. If the detection is fitting, it continues with the classification process.
3) IF the artifact is tested:
   - For right side, then the difference FVG_{right}-FVG_{left} has to be into computed range and then the line is classified as "right artifact".
   - For left side, the FVG_{right}-FVG_{left} has to be in the computed range and then the line is classified as "left artifact".
4) The left and right classified border lines are now counted and compared with the "count threshold". If no one is over it there is no artifact, otherwise the report between the lines sides' counters is compared with the "position threshold" value; if it is over the image has an artifact on the side with larger lines counter.
5) The detected artifact homogeneity is tested and, if the number of adjacent classified lines is under the threshold value, the lines are eliminated from the artifact classification.

In figure 6 the detected border is highlighted into the zoomed image.



Figure 6.Artifact border detected by application.

6) The correction of the classified lines is done using an algorithm with experimental parameters, in order to have a linear degradation of the edge border values. Therefore, the difference between the processed pixels and non-processed adjacent pixels is not enough significant, in terms of human eyes observation (Figure 7).

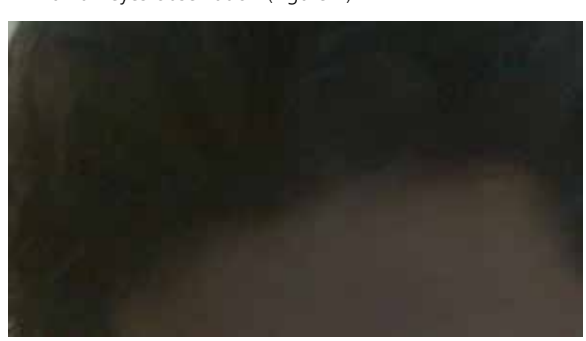


Figure 7. The border attenuation processed by application.

The algorithm detectsthe specific artifacts in 100% of its apparitions.

7) Finally the corrected image matrix is saved out (figure 8).



Figure 8.Processed frame, with the attenuated artifact.

The result of the divergence operation applied on gradient vector field (fig.10) of the corrected frame (fig.8) is presented in the figure 9.



Figure 9.The source density ofcorrected field.



Figure 10. The gradient operation applied on corrected image.

V. Conclusion

Using numerical formulas based on first and second gradient of potential field, and adjusting the parameters in order to compensate specific mathematical conditions, an interesting solution was developed initially for visual artifact detection, but that works properly also for artifacts which can be approximated with visual watermarks.

The original formula was implemented on embedded platform of the professional video camera having 100% success on artifact detection.

The correction of the detected artifact is using a parameterized border attenuation algorithm that reduces the border slope to 1/8 of the initially value, in order to obtain an optimal visual quality of the processed image, as the comparison between image gradients (figure 3 and figure 10) proves.

REFERENCES

[1] Y Chen, S Levine, M Rao, "Variable Exponent, Linear Growth Functionals in Image Restoratiom", SIAM J. Appl. Math., 66(4), 1383–1406, July 2006. | [2] H Endo, S. Hayano, Y Saito, T Kunii, "Image Processing by Field Theory", XII-th International Symposium on Electrical Apparatus and Technologies SIELA 2001, Bulgaria, 31 May – 1 June 2001 | [3] M Ivan, , Magnetic Prospecting (in Romanian), University of Bucharest, 1996 | [4] W Jiao, Y Fang, G He, "An Integrated Feature Based Method For Sub-Pixel Image Matching", The International Archives of the Photogrammetry, 2008 - Citeseer | [5] P Juutinen, T Lukkari, M Parviainen, "Equivalence of Viscosity an Weak Solutions for the p(x)-Laplacian", Ann. Inst. H. Poincare Anal. Non Lineaire 27(6), 1471-1487, 2010 | [6] T Kobayashi, N Otsu, "Image feature extraction using gradient local auto-correlations", Computer Vision–ECCV 2008, 2008 - Springer | [7] P Perona, J Malik, "Scale-Space and Edge Detection Using Anisotropic Diffusion", "Transactions on Pattern analysis and machine Inteligence", Vol. 12, pp. 629-640, IEEE, July 1990. | [8] M Rogobete, C Răcuciu, E. Rădoi "Original Methodology and Algorithm able to Identify Visible Noisy in Image and Video Stream", International Conference for Education and Creativity, 7th Edition, Bucharest, 2013 | [9] M Rogobete, C Răcuciu, "First and second order image statistics in specific image artifact detection", International Conference on Innovative Technologies, IN-TECH 2012 | [10] Y Wang, P Moulin, "Optimized feature extraction for learning-based image steganalysis", Information Forensics and Security, IEEE, 2007 | | |