Based on vector flexible weighted morphological image edge detection

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Abstract. The classic gray-scale morphological operator has been widely used in image filtering, edge detection, image enhancement and image segmentation, etc. Morphology theory in color image processing was still in the stage of exploration in the field of application, the application of mathematical morphology in image processing is good or not is the key to the morphological gradient operator and structural elements. In view of the two key factors the vector flexible weighted morphological algorithm is put forward to detect image edge. Firstly build the weighted structural elements, if the pixel is the edge of the image to give greater weighted value, otherwise give small weighted value. Secondly reference gray-scale morphological duality theorem, the vector flexible gradient operator meets the duality theorem of color image. Vector flexible gradient operator is proposed to apply weighted structural elements to corrosion and dilation gradient operation to extract image edge. The experimental results show that the proposed vector flexible weighted morphological operators edge detection algorithm can effectively extract image edges, keep small image edge and can remove the image noise, verify the effectiveness of the proposed algorithm.

1. Introduction

Image edge detection is to separate the edge of the target from the background of the sequence images. It is the base of target location, target tracking and scene understanding. Image edge detection has a wide range of applications in the field of monitoring, scheduling, monitoring, accident detection, automatic navigation and so on; therefore, video image edge detection technology has important research value and application significance.

Image edge detection operator detect the change of image pixel gray value, usually using first derivative extreme point or the second derivative of zero point arithmetic operation to detect edges. Edge detection algorithm is a hot spot of research, the traditional edge detection algorithm uses gradient operator to detect the edge of image, such as Roberts, Sobel, Prewitt, Canny, Laplace edge detection operator, etc. In recent years many new edge detection algorithm come forth continuously such as mathematic morphology and wavelet non-line calculate seed methods. Mathematical Morphology (MM) algorithm is also used as a tool of image processing gradually developed, especially in the aspect of edge detection and nonlinear filtering is developing rapidly. MM edge detection of image method is the key to the choice of structural elements (SEs) and gradient operator, the good or bad of SEs relationship to the extraction effect; structural elements have serious effects on quality of successive image processing.

Image edge detection using mathematical morphology operation, the effect of detection is good or bad depends on the selection of structural elements. The shape and size of structural elements decide the
direction of the edge, single structural element already cannot satisfy the application of edge detection, and symmetrical structural element weakens the edge direction changes. In order to better application of mathematical morphology algorithm for image edge detection, vector flexible morphology is effective for detecting the image edge of different directions, and can effectively suppress noise. MM gradient operator's main goal is to produce high compatibility of image edge character, then applying the matched structural elements to extract edge and remove noise. Structural elements are according to the size of the weighted factor to choose, structural elements according to the edge if doesn't exist, small weighted factor which gives structural elements, according to the size of the weighted factor to choose, if testing is the edge of the image will give a greater weighted factor structural elements.

In the paper a new edge detection gradient operator based on vector flexible weighted morphology is proposed. Vector flexible morphology operators meet the duality; weighted structural element can detect edge of the gradient effective and reserve detail of image edge, sufficiently considering mathematics morphology of removing noise.

2. Vector flexible weighted morphological edge detection algorithm

The classic gray-scale morphological operator has been widely used in image filtering, edge detection, image enhancement and image segmentation, etc. Morphology theory in color image processing was still in the stage of exploration in the field of application, in order to expand the theory of vector morphology in multichannel image processing in the application of vector morphological filtering operator, only with corrosion initiation operator has a filter function, and to expand operations starting vector morphology filter operator is difficult to effectively reduce the noise in the image, even enlarge the noise in the image. According to the basic conditions of gray-scale morphological operator meet duality theorem. Choose the strict symmetrical RGB color space, and build a pair of symmetrical characteristics of vector distance as a vector extremum of morphological operator output rule, thus satisfied duality theorem of multivariate morphological operator.

2.1. Weighted structural element

The basic principle of weight morphology is a structural element at the edge of the original image is moving in a row, when the image x meet vector flexible operator can effectively detect the edge of the image in the target. The disadvantage of morphological gradient operator is that can only detect the image edge gradient amplitude, not to estimate the direction. To estimate the direction of the image edge must choose the appropriate structural elements and structural elements should be pluralistic direction, to give full play to the role of the mathematical morphology characteristic.

Algorithm advantage is adopted weighted structural elements, applied to the typical corrosion and expanding operations form a cascade form of operation to achieve the result of edge detection. Structural elements are the value of the standardized weight factor and factor calculated this way: Weight edge direction point value is 1, apoapsis weight value is carried out in accordance with the weighting factor $\omega > 1$ assignment, This leads to the influence of edge points is very important and to reduce the impact of the adjacent points. The rest of the weight value to calculate based on $\Delta \omega = (\omega - 1)/d$ the growth, where $d$ is the edge direction and distance from the edge direction of the farthest distance. In the horizontal and vertical direction, weighted factor grow according to $\Delta \omega$, each step start from the farthest edges direction. To take advantage of the B garages plane image smoothing, makes the pretreatment with characteristics of qualitative similarity pixel and with different pixels respectively belong to their respective regions, and make the edges more clearly. And, for some noise in the image, it can be mended by noise vague boundaries.

For example, in the structure element of $3 \times 3$ if the edge of level direction is $\omega_1 = 3$, so $B$ is $B_1$, among $\Delta \omega = 2$. If $\omega_2 = 3$, and that the same edge points of slant $45^{\circ}$ direction $B$ is $B_2$, in the same edge points have underneath lineation points and $\Delta \omega = 1$.
2.2. Vector flexible morphological operator

Due to the vector morphological operator performance mainly depends on the color space and vector sorting algorithm. The vector morphological operator is applied in the color space. Color space and vector sorting algorithm is decision vector morphological operator can satisfy the main factors of duality, according with human visual perception of color space lead to asymmetric multivariate extreme value output, in order to calculate conveniently, we chose to use the RGB color space.

Based on the definition of vector flexible corrosion morphology operation, we can define color image \( f \in \Gamma(R, \Omega_{RGB}) \), \( B \) and \( c \) respectively is structural element and core. Use structural elements \( B \) in the image \( x \) to vector flexible corrosion may be defined as:

\[
\varepsilon_{\cdot}(f)(x)(B, c, r) = \{r \odot f(a) : a \in A \} \cup \{f(b) : b \in (B \setminus A)\}
\]

(1)

In \( \odot \) said repeat operation. The same flexible vector expansion operation is defined as:

\[
\delta_{\cdot}(f)(x)(B, c, r) = \{r \odot f(a) : a \in A \} \cup \{f(b) : b \in (B \setminus A)\}
\]

(2)

Vector flexible morphological gradient operator has a better anti-noise performance, and in accordance with the definition of the morphological gradient operator. And meet the duality theorem, so that it can be unified into the vector form of operator morphology theory framework.

For the convenience of said, we unified European symmetric distance and city distance for symmetric distance \( d \), the corresponding vector morphology operator for \((\varepsilon_d, \delta_d)\), according to \((\varepsilon_d, \delta_d)\) combined with the weighted morphological theory.

The vectors of opening and closing are defined as follows:

\[
\gamma_{wd}(f) = \delta_{wd}[\varepsilon_{wd}(f)]
\]

(3)

\[
\phi_{wd}(f) = \varepsilon_{wd}[\delta_{wd}(f)]
\]

(4)

Annotation: \( wd \) represents weighted vector distance, \( f \) represents image. Opening and closing filter can be used to define various combinations filtering operator, such as vector weighted open and close \( \phi_{wd} \), vector weighted close and open \( \gamma_{wd} \).

Weight morphology improves the noise resistance of gradient operator in some extent, but because of the morphological gradient operator is the difference in expansion operator and corrosion operator. And the output of the weighted morphological operator does not rely on expansion and corrosion, only by calculating the vector distance as the output vector gradient. Based on the idea of weighted morphological operator the performance of the morphological gradient operator is improved, unifying the theory to morphology theory framework, combining section 2.1 of the flexible morphological operator, based on the vector flexible weighted morphological gradient operator is proposed in this paper.

\[
g_{wd}(f)(WB, c, r) = |\delta_{wed}(f)(WB, c, r) - \varepsilon_{bed}(f)(WB, c, r)|
\]

(5)

In formula (5) \( r \) repress the parameters of flexible operator, \( WB \) and \( c \) respectively repress weighted structural element and core. Flexible morphological gradient operators have a better anti-noise performance, and comply with the definition of the morphological gradient operator. And because the flexible morphological gradient meet duality theorem, so it can be unified into the vector form of operator morphology theory framework.
3. Simulation experiment

In order to verify the superiority of vector weighted morphology, in the simulation experiment, choose standard test images “Lena”, selects the salt and pepper noise model. We use morphological filtering operator is verified the superiority of the proposed vector dual morphological operators. The vector flexible weighted morphological gradient operator is verified performance in multi-channel image edge detection.

The vector flexible weighted morphological edge method has obvious advantage, firstly the operator to extract the edge of the at the same time can effectively restrain the noise of the image, by speckle index to inspect the performance of morphology filter algorithm, Canny algorithm, the results as shown in table 1; Primary detect the edge details as shown in figure 1 and 2.

| noise intensity | noise image | classical morphology | canny | the proposed algorithm |
|-----------------|-------------|----------------------|-------|------------------------|
| speckle index   | 0.3212      | 0.4673               | 0.5892| 0.0312                 |
| mean square error| 0.0831      | 0.0058               | 0.0069| 0.0039                 |

From the table 1: de-noise performance of the proposed algorithm is better than the classical morphology and Canny edge detection algorithm. Table 1 shows that at different levels under noise environment, vector weighted morphology has the low speckle index and low mean square error, especially when the parameters of flexible operator bigger ($r = 3$), operator is not sensitive to the change of the noise, the filtering performance is no big change. As shown in table 1, the vector flexible weighted ($r = 3$) is almost straight and level, obviously higher robustness. While the remaining operators performance rapidly reduces with the increase of noise intensity. The proposed algorithm high robustness, therefore, not easily affected by noise parameters.

Figure 1(a) is original image, (b) ~ (d) separately is Robert edge image, LOG edge image and classical morphological edge image, (e) is the proposed edge image result. Figure2 (a) is classical morphology edge image and (b) is the proposed algorithm.

Several kinds of commonly used edge detection methods are compared. As shown in figure 1 for the simulation test results. By the above simulation results it can be seen that using Sobel operator for edge
detection, the overall effect is better, but for the details, such as hat texture) can't reflect well. LOG operator, although details extract is better, but the overall effect is not good, appears over-segmentation phenomenon. And the proposed approach can extract the edge details well; also can maintain the overall effect is good. Image edge detection results show that this algorithm can extract the image edge, the edge of the tiny extraction effect is obvious, at the same time also can reduce the noise of the image and the false edge less.

The algorithm based on the use of selected dual weighted structural elements to judge whether the pixels of the image belongs to the edge. If the pixels of the image belong to the edge of the image, structural elements give big weighted factor, whereas small weighted factor. The algorithm can produce high matching image edge, less false edge, the edge of the extract clearer and tiny edge can be extracted. So the proposed algorithm based on vector flexible weighted morphology is effective for image edge extraction. Vector flexible weighted morphological gradient operator is using the edge of a group of structural elements to judge and enhanced, highlight the edge of the small and remove the image noise.

Conclusion
Based on vector flexible weighted morphology algorithm is proposed to detect image edge. Weighted morphological operator meet duality theorem and the vector morphology theory with classical morphology theory unifies, and expand the classical mathematical morphology operators directly to the vector morphological operation, the vector weighted morphology gradient operator is constructed. These new operator is applied to the gradient edge detection; the experimental results show that the proposed algorithm has high performance. Edge detection at the same time also can highlight the tiny image edge and reduce the false image edge. Using the proposed algorithm can remove the image noise; get clear image edge, the application prospect of clear.

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