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International Journal of Current Research
Vol. 8, Issue, 05, pp.31590-31596, May, 2016

INTERNATIONAL JOURNAL OF CURRENT RESEARCH

ISSN: 0975-833X

RESEARCH ARTICLE

EQUALITY IN SOFT EROSION, SOFT DILATION AND SOFT CLOSE IN MULTI SCALE ENVIRONMENT

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ARTICLE INFO

Article History:
Received 18th February, 2016
Received in revised form
25th March, 2016
Accepted 18th April, 2016
Published online 30th May, 2016

Key words:
Mathematical morphology, Mathematical soft morphology, Soft morphology, Erosion, Dilation, Soft erosion, Soft dilation, Primitive morphological operation, Equality, Threshold, Iterative morphology, Multi scale morphology, Soft open, Soft close.

ABSTRACT

In this paper, equality is established and discussed among soft erosion, soft dilation and soft close in multi scale environment. Soft erosion and soft dilation will exist for various thresholds. So soft open and soft close also exist for various thresholds. If definition for soft erosion and soft dilation are studied (5), then some type of equalities are viewed among soft morphological operations. So equality may be established in between soft erosion and soft dilation in multi scale environment (47). open and close are composite operations. So soft open and soft close are also composite operations which will exist at various thresholds. Equality may be viewed among all soft morphological operations. As part of that, in this paper equality may be established in between soft erosion, soft dilation and soft close in multi scale environment. A very important point is that equality does not exist in mathematical morphology but will exist in soft mathematical morphology.

Citation: Kompella Venkata Ramana, 2016. "Equality in soft erosion, soft dilation and soft close in multi scale environment", *International Journal of Current Research*, 8, (05), 31590-31596.

INTRODUCTION

The human beings have the desire of recording incidents, through images. It has started from early cavemen also. Later, so many techniques, to get the images and so many techniques, to process the images are developed. After assembling of computers, image processing was expanded. In 1964 G. Matheron was asked to investigate the relationships between the geometry of porous media and their permeability. At the same time, J. Serra was asked to quantify the petrography of iron ores, in order to predict their milling properties. (Serra-Image Analysis and Mathematical Morphology; Matheron - Mathematical Morphology) At the same time a centre was developed to study mathematical morphological techniques in Paris school of mines, France. Mathematical morphology can provide solutions to many tasks, where image processing can be applied, such as in remote sensing, optical character recognition, Radar image sequence recognition, medical image processing etc., In mathematical morphological operations, Erosion and Dilation are primitive operations (Robert *et al.*, 1987; Heijmans and Ronse, 1990). Open and close are composite operations.

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Dilation: - These operations may be defined in so many ways. Different researchers defined this operation in different ways.

Def. 1:- Let A and B be subjects of E^N (where N is Space) the dilation of A by B, is denoted by $A \oplus B$ and is defined by $A \oplus B = \{C / C = a + b \text{ for some } a \in A \text{ and } b \in B\}$

Def 2:- $A \oplus B = \bigcup_{b \in B} (A)_b$ Where A is the image and B is the structuring element.

Here $(A)_b$ means, translation of A by b, defined as

$(A)_b = \{C / C = a + b;\ a \in A\}$

Def 3:- $(I \oplus S)[x, y] = 1$ if $|I \cap S'_{(x, y)}| \geq |$
= 0 otherwise.
Here, I is the image
S: structuring element

S' : reflection of S about the origin

[If S.E. is having origin, at its centre point then S= S' .]

I (x, y) denotes image pixel value at the coordinate (x, y)
|Z| denotes the cardinality of the set Z;

$S_{(x, y)}$: S translated by the displacement {x,y}.

Erosion: This morphological operation also defined in so many ways, by different researchers.

Def 1):- The erosion of A by B is denoted by A B, and is defined by
A B = {x/x +b A for every b B} Here x E^N when E^N= N space.
Def 2):- A B = {x/ for every b B, there exists and a A, such that x=a-b}
Def 3):- (I S) [x, y] = 1 If |I $S_{(x, y)}$|= |S|
= 0 other wise
Here I is image and S is S.E. I(x, y) denotes image value at coordinate (x, y)
|Z| denotes the cardinality, of the set Z.
$S_{(x,y)}$: S translated by the displacement (x, y)

OPEN: It is a composite morphological operation. Open can be defined by the two primitive morphological operations, dilation and erosion operations.

Def: Open can be defined as, Erosion on the image, followed by Dilation. Open can be represented as, "O" symbol. B O K means image "B" is opened by the structuring element "K"
B O K = (B K) ⊕K

CLOSE

It is also a composite morphological operation.

Def:- "Close" can be defined as, dilation on the image, followed by, erosion.

Close can be represented as ● symbol.

B ● K means, image "B" is closed by the S.E., "K".B ● K = (B⊕K) K.

Soft morphology

In mathematical morphology, some type of the concept "All" will play major role. In Erosion, the O.P. will be "1", if all elements of the sub image are equal to 1, otherwise, the output will be "0". In dilation, the O.P. will be "0", if all elements of the sub image are equal to "0". Otherwise the output will be "1". This "All" concept, will cause some type of inconvenience. So some type of flexibility is introduced, in the form of threshold value. So, this morphology with threshold is defined as soft morphology. So, this soft morphology is having a few advantages, which the mathematical morphology operations don't have. So, the Soft Morphology can be considered as extension to mathematical morphology. Even though mathematical morphological operators are efficient, they suffer with a few drawbacks as specified above. In addition to above, some more comments are………. In primitive morphological operations, erosion, one or two mismatched pixels of image prevent the structuring element from fitting perfectly. It is the basic morphological operation, quantifies the way in which, the structuring element fits into the image. Erosion is an "All or nothing" transformation, implemented using bitwise "and". So, erosion will be sensitive to noise.

In primitive morphological operations, dilation, isolated pixels, even though, they are irrelevant to the image's content, significantly affect the output of the transformation. The net effect is an increased number of large spurious particles, increasing the confusion in the dilated image. So, noise will be added, which may be named as additive noise (Michel A. Zmoda and Louis, 1996).

But, many applications require more tolerance to noise than is provided by erosion and dilation. Soft morphological operators possess many of the characteristics, which are desirable, perform better in noisy environments. (Michel A. Zmoda and Louis, 1996)

So, the soft morphological filters, improve the behavior of standard morphological filters, in noisy environment. The soft morphological filters are better compared to mathematical morphology in small detail preservation and impulse noise. In soft morphology, it preserves details, by adjusting its parameters (Koivisto *et al*., 1996). It can be designed in such a way that, it performs well in removal of salt – and – pepper noise as well as Gaussian noise, simultaneously (Lipeng Wang and Hanbin Wang, 2011).

Koivisto and others discussed soft morphological filters (Koivisto *et al*., 1996) in a different way.

The idea of soft morphological operations is to relax, the standard morphological definition, a little, in such a way that, a degree of Robustness is achieved, While, most of the desirable properties of standard morphological operations are maintained. The soft morphology was introduced by KOSKINEN etc, and developed by researchers.

DISCUSSION ON DEFINITION

In some papers, researchers proposed soft morphology using two sets of structuring elements.

A) The core
B) The soft boundary [7,8,9 etc].

But, in some papers [5 etc.] they proposed soft morphology, by counting logic. They have done the counting of ones, in the particular sub image, chosen. Then they have applied threshold value, for soft Erosion and soft dilation.

Soft dilation was defined as (5)

$(I\oplus S^{(m)})$ [x, y] = 1 If |I $S_{(x,y)}$ |≥m
= 0 otherwise.

Here "m" is threshold value where 1≤ m ≤ |S|. |S| is the cardinality of S.

Soft Erosion may be defined as

$(I \quad S^{(m)})[x,\ y] = 0$ If $|\bar{I} \quad S_{(x,y)}| \geq m$
$= 1$ otherwise. $\bar{I}$ = inversion of I; m= threshold $\leq |S|$.

[The exact definition, given in "5", is slightly modified, according to the requirement, but without changing the meaning. Here the main assumption is origin is at central place of the structuring element and structuring element is assumed to be a square grid.]. Here "m" is threshold value.

Soft open and soft close are defined by above soft erosion and soft dilation..some convention is discussed in the next section.

Multi scale soft morphology

Discussion on multi scale soft morphology

In the process of understanding the objective world, the appearance of an object does not depend only on the object itself, but also on the scale that the observer used. It seems that appearance under a specific scale does not give sufficient information about the essence of the percept, we want to understand. If we use a different scale, to examine this percept, it will usually have a different appearance. So, this series of images and its changing pattern over scales reflect the nature of the percept.

The S.E. dimension can be anything. It depends upon situation, requirement, and context etc. It can be $^1/_1, ^2/_2, ^3/_3, ^4/_4, ^5/_5, ^6/_6, ^7/_7, \ldots\ldots\ldots$

In some situations, particularly square grid is chosen, it can be $^3/_3, ^5/_5, ^7/_7, ^9/_9, ^{11}/_{11}, ^{13}/_{13}, \ldots\ldots\ldots$

For example, it can be

$$\begin{pmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{pmatrix} \text{OR} \begin{pmatrix} 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 \end{pmatrix} \text{OR} \begin{pmatrix} 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 & 1 & 1 \end{pmatrix}$$

The S.E.'s, having series, and in increasing size [like mentioned above] is called multi scale S.E.'s and the morphological approach (operations) dealing with multi scale S.E.'s is called multi scale morphology. As the size of the S.E. is more, its impact upon image will be more. For example, amount of expansion by applying dilation operation is more on an image, if we apply $^5/_5$ S.E., compared to amount of expansion of image, by dilating by $^3/_3$ S.E.

If Multi Scale Soft Morphology and iterative soft morphology are combined, a new area Multi Scale iterative Soft Morphology Emerges. [MSISM]

Review on multi scale soft morphology

Till now, some amount of research is done in this area, and it is applied in so many areas. In mathematical morphology also, a new area multi scale mathematical morphology is developed, and applied in so many areas like smoothening, edge enhancement, analysis of radar imagery, remote sensing, medical image processing etc. PETROS MARAGOS entered into multi scale morphology, in addition to other areas. He explained about changes of shapes, as the scale is changed. He explained the applications of MSMM, and back ground mathematics. He explained about application of MSMM in skeletenization also. He extended these concepts to gray scale, also (Petros and Maragos, 1989). Ming – Hua Chen & Ping – Gan Yan explained (Ming *et al*., 1989) Erosion, Dilation, Open, Close in multi scale environment, with diagrams (results), mathematical analysis, as well as symbolic conventions. KUN WANG etc. proposed an algorithm, for edge detection in the presence of Gaussian noise & salt – pepper noise in multi scale morphological environment. The experimental results are better than that of conventional algorithms (Kun Wang *et al*., 2007). The same authors KUNWANG etc. proposed another algorithm for edge detection (Kun Wang *et al*., 2007) which will function better in Gaussian, salt - paper noise environment, in MS morphological approach.

KIM WANG and others discussed an edge detection algorithm, in multi scale environment, which is suitable to apply on brain MRI, in noisy environment. (Kim Wang *et al*., 2007). Runway detector plays a very important role in synthetic vision system, which is helpful for pilots. But the infrared image constructed in this situation which will help pilot, will have heavy noise and bad contrast. Suitable to this situation, a multi scale morphological edge detector is proposed, which will help the pilot, for his, environmental awareness. So, MSMM is having, its applications, in aviation areas also. YANG SHANMIN and others discussed above MSMM concept (Yang Shanmin *et al*., 2010). GAO LI etc (2010) proposed an adaptive algorithm for edge detection of a color image (In HIS space) in MSMM environment. CHEN JIN LONG, etc. proposed another methodology for edge detection in multi structure and multi scale mathematical morphology environment (Chen Jin Long *et al*., 2010). ZHANG ANU & others have proposed another algorithm (Zhang Ang *et al*., 2011) for identification of weak edges in Oct images using MSMM environment, XINGHUI ZAANG etc. (Xingh uI Zhang and Jiuying Li, ?) proposed another algorithm for edge detection in color image environment, using MSMM.

Another algorithm for smoothening is discussed using MSMM. (Morphology based symbolic image modeling, 1988). XU, YANLEI; ZHAO, JIYIN discussed (Xu, Yanlei and Zhao, Jiyin, 2008) another algorithm, for edge detection, using MSMM, in noisy environment. JIAN–HUI TAN etc. proposed (Jian *et al*., 2010) a new type of process using MSMM for smoothening of infrared imagery. It will have complexity due to noise. Using this methodology, they protected details also. These MSMM techniques are extended to segmentation also. DEBAY LE, J. etc (2005) extended MSMM for segmentation using adaptive technique and MARC DROSKE etc. also (2007) used MSMM for segmentation. (Huang *et al*., 2007) H UANG, R. etc. discussed extension of MSMM to 3D. They discussed and designed algorithm for volume segmentation. For this purpose, they have designed spherical S. E.'s at various sizes. LETITIA, S; etc. applied MSMM for road segmentation from satellite aerial images (Letitia and Monie, 2008).

JIANN–JONE CHEN etc. extended the MSMM to 3D segmentation, using dual (MS morphological) concepts (Jia nn *et al*., 2009). SHU LI; etc. (2010) designed water sheds segmentation algorithm, using MSMM, and applied to cell image segmentation, and got quality results. XU YING SHA; etc (2011) proposed another water shed algorithm for segmentation of remote sensing images, in MSMM environment. It shows good results, by avoiding, over segmentation. SHUWEI LI etc. (2011) proposed method, to generate DTM and to maintain the terrain details, based on MSMM [here DTM means, Digital Terrain Model]. MSMM is having, application in medical area also. (Divyendu sinha and Charles R. Giardina, 1990) DA WEI QI etc. shown an application in medical I.P. for edge detection in noisy environment, which gives better results, compared to traditional pictures. FEI ZHANG etc., given another algorithm (Xia oli wane and Gilles Bertrand, 1992), suitable for ECG analysis, in impulse noise environment using MSMM. DAWEI QI (Kyeong *et al*., 1996) proposed another algorithm, for medical analysis environment. JI – LE HU; etc. (Lei Chen *et al*., 2005) proposed another algorithm, in ECG analysis, which provided suitable and good decisions, at critical points. It is a decision making algorithm regarding heart using MSMM.

Some relevant concepts are discussed in 38,39,40 which are related to soft mathematical morphology.

Equality in soft erosion, soft dilation and soft close in multi scale environment

Close may be defined as composite operation on dilation and erosion.

Soft close may be defined as composite operation on soft dilation and soft erosion.

$$\left(I \bullet S^{(m,n)}\right) = \left(\left(I \oplus S^{(m)}\right) \quad S^{(n)}\right)$$

Here ● for close.   For erosion. ⊕ For dilation.

In soft erosion and soft dilation they can be defined by thresholds. So m, n will have different values, depending upon structuring element size.

For $3/3$ m, n will vary from 1 to 9.

For $5/5$ m, n will vary from 1 to 25.

For $9/9$ m, n will vary from 1 to 81.

In the same way depending upon the structuring element size the values of m and n will vary.
$\left(I \bullet S^{(m,n)}\right)$ Can be represented as $C(m,n)$, means soft close of image by threshold values m and n.

$\left(I \oplus S^{(m)}\right)$ may be represented as $D(m)$ where $D(m)$ means soft dilation of image I by threshold value m.

In the same way, $\left(I \quad S^{(n)}\right)$ may be represented as $E(n)$ where $E(n)$ means soft erosion of image I by threshold value n.

$3/3$ Structuring Element

$C(1,1) = D(1)E(1)$	$C(2,1) = D(2)E(1)$
$C(1,2) = D(1)E(2)$	$C(2,2) = D(2)E(2)$
$C(1,3) = D(1)E(3)$	$C(2,3) = D(2)E(3)$
$C(1,4) = D(1)E(4)$	$C(2,4) = D(2)E(4)$
$C(1,5) = D(1)E(5)$	$C(2,5) = D(2)E(5)$
$C(1,6) = D(1)E(6)$	$C(2,6) = D(2)E(6)$
$C(1,7) = D(1)E(7)$	$C(2,7) = D(2)E(7)$
$C(1,8) = D(1)E(8)$	$C(2,8) = D(2)E(8)$
$C(1,9) = D(1)E(9)$	$C(2,9) = D(2)E(9)$

……………
……………
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$C(8,1) = D(8)E(1)$	$C(9,1) = D(9)E(1)$
$C(8,2) = D(8)E(2)$	$C(9,2) = D(9)E(2)$
$C(8,3) = D(8)E(3)$	$C(9,3) = D(9)E(3)$
$C(8,4) = D(8)E(4)$	$C(9,4) = D(9)E(4)$
$C(8,5) = D(8)E(5)$	$C(9,5) = D(9)E(5)$
$C(8,6) = D(8)E(6)$	$C(9,6) = D(9)E(6)$
$C(8,7) = D(8)E(7)$	$C(9,7) = D(9)E(7)$
$C(8,8) = D(8)E(8)$	$C(9,8) = D(9)E(8)$
$C(8,9) = D(8)E(9)$	$C(9,9) = D(9)E(9)$

In general, $C(m,n) = D(m)E(n)$ where $m, n = 1$ to 9.

5/5 Structuring Element

$C(1,1) = D(1)E(1)$
$C(1,2) = D(1)E(2)$
$C(1,3) = D(1)E(3)$
$C(1,4) = D(1)E(4)$
$C(1,5) = D(1)E(5)$
$C(1,6) = D(1)E(6)$
$C(1,7) = D(1)E(7)$
$C(1,8) = D(1)E(8)$
$C(1,9) = D(1)E(9)$
$C(1,10) = D(1)E(10)$
$C(1,11) = D(1)E(11)$
$C(1,12) = D(1)E(12)$
$C(1,13) = D(1)E(13)$
$C(1,14) = D(1)E(14)$
$C(1,15) = D(1)E(15)$
$C(1,16) = D(1)E(16)$
$C(1,17) = D(1)E(17)$
$C(1,18) = D(1)E(18)$
$C(1,19) = D(1)E(19)$
$C(1,20) = D(1)E(20)$
$C(1,21) = D(1)E(21)$
$C(1,22) = D(1)E(22)$
$C(1,23) = D(1)E(23)$
$C(1,24) = D(1)E(24)$
$C(1,25) = D(1)E(25)$

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$C(25,1) = D(25)E(1)$
$C(25,2) = D(25)E(2)$
$C(25,3) = D(25)E(3)$
$C(25,4) = D(25)E(4)$
$C(25,5) = D(25)E(5)$
$C(25,6) = D(25)E(6)$
$C(25,7) = D(25)E(7)$
$C(25,8) = D(25)E(8)$
$C(25,9) = D(25)E(9)$
$C(25,10) = D(25)E(10)$
$C(25,11) = D(25)E(11)$
$C(25,12) = D(25)E(12)$
$C(25,13) = D(25)E(13)$
$C(25,14) = D(25)E(14)$
$C(25,15) = D(25)E(15)$
$C(25,16) = D(25)E(16)$
$C(25,17) = D(25)E(17)$
$C(25,18) = D(25)E(18)$
$C(25,19) = D(25)E(19)$
$C(25,20) = D(25)E(20)$
$C(25,21) = D(25)E(21)$
$C(25,22) = D(25)E(22)$
$C(25,23) = D(25)E(23)$
$C(25,24) = D(25)E(24)$
$C(25,25) = D(25)E(25)$

In general, $C(m,\ n) = D(m)E(n)$ where $m, n = 1$ to 25.

7/7 Structuring Element

$C(1,1) = D(1)E(1)$ …………… $C(1,14) = D(1)E(47)$
$C(1,2) = D(1)E(2)$ …………… $C(1,15) = D(1)E(48)$
$C(1,3) = D(1)E(3)$ …………… $C(1,16) = D(1)E(49)$
…………… …………… ……………
…………… …………… ……………
…………… …………… ……………
$C(49,1) = D(49)E(1)$ …………… $C(49,47) = D(49)E(47)$
$C(49,2) = D(49)E(2)$ …………… $C(49,48) = D(49)E(48)$
$C(49,3) = D(49)E(3)$ …………… $C(49,49) = D(49)E(49)$

9/9 Structuring Element

$C(1,1) = D(1)E(1)$ …………… $C(1,79) = D(1)E(79)$
$C(1,2) = D(1)E(2)$ …………… $C(1,80) = D(1)E(80)$
$C(1,3) = D(1)E(3)$ …………… $C(1,81) = D(1)E(81)$
…………… …………… ……………
…………… …………… ……………
…………… …………… ……………
$C(81,1) = D(81)E(1)$ …………… $C(81,79) = D(81)E(79)$
$C(81,2) = D(81)E(2)$ …………… $C(81,80) = D(81)E(80)$
$C(81,3) = D(81)E(3)$ …………… $C(81,81) = D(81)E(81)$

In general, $\boldsymbol{C(m,n) = D(m)E(n)}$ where $m, n = 1$ to 81**.**
In the same way the results will be obtained for 11 / 11, 13 / 13, 15 / 15, 17 / 17, …..

General case

So, in general,

$C(m,n) = D(m)E(n)$

where $m, n = 1$ to k.

Where $k = 9$ for $3/3$ structuring element,

$k = 25$ for $5/5$ structuring element.

$k = 49$ For $7/7$ structuring element,

$k = 81$ for 9 x 9 structuring element

$k = 121$ For $11/11$ structuring element and so on.

Conclusion

In this paper a fundamental rule called EQUALITY is discussed in multi scale and iterative environment. It will fill up gap, on the fundamentals of mathematical soft morphology. Till now applications are discussed in various papers by various researchers, but fundamental properties are not touched. so discussion of fundamental property in this context ,will lead to development and expansion of this area, which will lead to excellent applications.

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