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A BRIEF DISCUSSION ON EROSION AND DILATION IN MULTI SCALE ENVIRONMENT (A BRIEF PRACTICAL ORIENTED DISCUSSION)

Dr. Kompella Venkata Ramana
B.E, M.E, Ph.D., Associate Professor Dept of Computer Science and Systems Engineering,
Andhra University, Visakhapatnam Andhra Pradesh. INDIA

ABSTRACT: ***This paper discusses about primitive morphological operations in multi scale environment. The morphological operations are main source for defining composite morphological operations. These are applied in various image processing operations. In addition to them morphological operations are having special applications also. So the study of morphological operations in various environments will provide broad look (wide/matured look) of these operations, which throws light on understanding of these basic principles which will help in further new applications of this mathematical morphology. So in this paper morphological operations are discussed in a new dimension.***

KEYWORDS: erosion, dilation, open, close, multi scale, mathematical morphology,

I. INTRODUCTION

If we observe carefully, the human beings have the desire of recording incidents, through images. Their view may be for the purpose of future generation. Images also, played the role of symbols of languages, for communication purpose. The early cavemen documented some of the incidents through images in the caves. They documented some of the incidents of their routine life, on stones, by using primitive tools. Important incidents such as battles, routine incidents such as food habits were recorded by them, on stones. These provide record, which is historically very important, of early human civilization. The images drawn by primitive tools by Egyptians, Indians, have provided a lot of valuable information, for historians, about civilizations. After this, paints or inks were invented. The human beings started to record scenes, incidents through these paints and inks. Letter on J. B. Porta, an Italian Philosopher, during the II half of 18th century, by mean of an accidental discovery, was able to assemble a camera like equipment by mirrors and lens, which is the first step towards the modern day photography. At the same time a France scientist observed silver chloride characteristics with respect to light. After two centuries Alexander Charles extended above concept, and produced simple photo graphs. After one century, at around 1835 Henry Fox Talbot extended above concepts, using silver nitrate, extended the design of camera, and modern photography was born from this experiment, which is presented in royal society. This technology is used to record incidents of U.S. civil war, or, to record incidents of wealthy people, but not reached to a common man, due to complex chemical process, for the development of photographs till "KODAK" has entered in 1884.. Later on research is done on motion pictures by Thomas A. Edison & William Kennedy Laurie Dickson, which is foundation for modern movie technology. Actually the first step for images processing was laid during Second World War. Technical experts, who are trained specially, are used to improve quality of image. They are specially trained in object recognition, they used to identity targets, manually. So, it is first step in image processing. After invention of digital computer, digital image processing came into existence. NASA, in early 1960's, got images from Space Crafts, Ranger 7, of the Lunar Surface, in thousands. These images were processed to minimize distortions. This is initial digital I.P. work, using a computer. This work was done in NASA's JET propulsion laboratory (JPL), in California. This initial digital images processing work was very satisfactory. So, NASA continued it's funding, resulting in the development of digital image processing area. The reduction in Hardware cost, mass production of chips, reduction in memory cost, reduction in size of computers , boosted the development of Digital Image Processing area. So, researches in general have been showing interest and developed algorithms for image smoothening, edge enhancement, image compression, image segmentation, 2D to 3D conversion etc., Now a day, it is having applications from entertainment area to medical area.the detailed explanation is given in author's papers.

At the same time mathematical morphology emerged and developed separately, with some other interests and motivations. The purpose of this area is different. But later on, it is identified that the mathematical morphology is having very important applications in image processing. So, mathematical morphology is considered now, a very important branch of image processing. Actually J. SERRA (1) and MATHERON (2) are founders of mathematical morphology. They have explained all the fundamentals of mathematical morphology in their books. Actually the primitive operations are EROSION & DILATION. The composite operations are open and close. All these are explained in chapters 1 and 2. There are some more composite operations, like thinning, skeletenization etc. But the work is limited to erosion, dilation, open, close. Mr. H.J.A.M. HEIJMANS has given a detailed discussion of these operations in 4. Till now the light is thrown on the fundamentals of mathematical morphology (1,……. 4). The morphological operations are suitable to apply on binary images only. Actually, applications of morphological operations were extended by SERRA also. Later

STERNBERG concentrated in this area. In depth study was done (the theoretical analysis) by J.A.M HEIGMANS in this area. PETROS MARAGOS has discussed about morphology also. PETROS MARAGOS has discussed about morphology and given theoretical analysis. For elimination or minimization of noise in the images a lot of research is done. The researchers developed algorithms for smoothening with detail preservation and for edge enhancement also. some resesrchers developed morphological algorithms for elimination of salt and pepper noise ,and impulse noise also. It has entered into medical area also the detailed references are available in the other papers of author.(6 to 18). The mathematical morphology has entered in to some more areas like soft morphology, fuzzy morphology, flat morphology etc. some of the work done by the author in soft morphology is referred in references.

II. DEFINITIONS

The primitive morphological operations are dilation and erosion. By means of these operations only, all the remaining morphological operations may be defined. These two morphological operations play the role of bricks, for a house.

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

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

Def 2:- $A \oplus B = U (A)b$

$b \in B$ 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}.

2.1.2. Properties of dilation.

Dilation is commutative

$A \oplus B = B \oplus A$

Dilation is associative

$A \oplus (B \oplus C) = (A \oplus B \oplus C$

Dilation is translation invariant.

$x \oplus B = (A \oplus B)\ x.$

Dilation is having "Increasing" property.

$A \subseteq B \Rightarrow A \oplus D \subseteq B \oplus D$

$A \subseteq B \Rightarrow D \oplus A \subseteq D \oplus B$

Dilation is extensive, when origin belongs to S.E. [extensivity means that, dilated result contains the original image]

$(A \cup B) \oplus C = (A \oplus C) \cup (B \oplus C)$

$A \oplus (B \cup C) = (A \oplus B) \cup (A \oplus C)$

$(A \cap B) \oplus C \subseteq (A \oplus C) \cap (B \oplus C)$

$(A \oplus (B \cap C)) \subseteq (A \oplus B) \cap (A \oplus C)$

2.1.3. Characteristics of Dilation:

Normally an image may have hills (peaks), valleys, holes, Islands etc., different types of parts. Dilation will influence each part and in a distinct way.

- By applying dilation, the size of the hill will be increased.
- By applying dilation, the size of the valley will be decreased (reduced).
- The hole size will be reduced.
- The island size will be enhanced.
- The corners of the image will be smoothened.
- The size of the image will be enhanced.
- It may connect neighboring particles (islands)

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

2.2.1 Def 1):- The erosion of A by B is denoted by $A \ominus B$, and is defined by

$A \ominus B = \{x / x + b \in A$ for every $b \in B\}$ Here $x \in E^N$ when $E^N =$ N space.

Def 2):- $A \ominus B = \{x /$ for every $b \in B$, there exists and $a \in A$, such that $x = a - b\}$

Def 3):- $A \ominus B = \{x /\ (B)\ x \subseteq A\}$. Here A is image, B is S.E.

Here $x \in E^N$ $(B)_x$: Translation of B by "x"

Def4):- $A \ominus B = \bigcap_{b \in B} (A)_b$

Here "A" is the image and B is the S.E.

$(A)_b$: Translation of A by b

Def 5):- $(I \ominus S)[x, y] = 1$ If $|I \cap S_{(x, y)}| = |S|$
$= 0$ 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)

2.2.2. Properties of Erosion

Erosion is Non – Commutative

$A \ominus B \neq B \ominus A$

Erosion is Non – Associative

$A \ominus (B \ominus C) \neq (A \ominus B) \ominus C$

Erosion is translation invariant

$(A)_x \ominus B = (A \ominus B)_x$

D) Erosion is having "INCREASING" property.

$A \subseteq B \Rightarrow A \ominus D \subseteq B \ominus D.$

$A \subseteq B \Rightarrow D \ominus A \supseteq D \ominus B.$

Erosion is anti–extensive when origin belongs to S.E.

[Original image contains the Eroded IM when origin $\in$ S.E].

$(A \cup B) \ominus C \supseteq (A \ominus C) \cap (B \ominus C)$
$A \ominus (B \cup C) = (A \ominus B) \cap (A \ominus C)$
$(A \cap B) \ominus C = (A \ominus C) \cap (B \ominus C)$
$(A \ominus (B \cup C)) = (A \ominus B) \cap (A \ominus C)$

2.2.3. Characteristics of Erosion

- By applying Erosion, the size of the peaks will be reduced.
- The Erosion will increase the size of the valleys.
- If there are any holes, in the image, the size of the holes will be increased.
- The size of the Islands will be reduced.
- The shape of the corners will not be changed.
- By Erosion, the size of the image will be reduced.
- It will disconnect some particles (islands)

III. MULTI SCALE ENVIRONMENT

3.1 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 $\frac{1}{1}, \frac{2}{2}, \frac{3}{3}, \frac{4}{4}, \frac{5}{5}, \frac{6}{6}, \frac{7}{7}, \ldots\ldots\ldots$

In some situations, particularly square grid is chosen, it can be $\frac{3}{3}, \frac{5}{5}, \frac{7}{7}, \frac{9}{9}, \frac{11}{11}, \frac{13}{13}, \ldots\ldots\ldots$

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 $\frac{5}{5}$ S.E., compared to amount of expansion of image, by dilating by $\frac{3}{3}$ S.E.

3.2 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.

MING – HUA CHEN & PING – GAN YAN explained Erosion, Dilation, Open, Close in multi scale environment, with diagrams (results), mathematical analysis, as well as symbolic conventions.

PAUL. T. JACKWAY etc. provided one type of analysis in MSMM. They discussed how to relate the results of one scale with the results at different scale. They have provided this analysis with good examples, using Erosion/Dilation morphological operations. 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. The same authors KUNWANG etc. proposed another algorithm for edge detection 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.

ZENG PINGPING etc. proposed another algorithm, for edge enhancement (112) in multi scale morphological approach, using order morphology also, which is suitable to apply in noisy environment also. ZHEANHUA LI; & others discussed another technique for edge enhancement, in MS morphological environment.

PANCHAO WU & others proposed another algorithm, for edge detection in noisy environment using MS MM & WAVELET transforms. GAO LI etc 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. HAI LONG HUANG etc. proposed an algorithm for suppression of noise and preserve edges using multi share and multi scale mathematical morphology environment. HAI LONG HUANG etc. proposed an algorithm for suppression of noise and preserve edges using multi share and multi scale structure elements using different directions and sizes of S.E.'s. These MSMM techniques are extended to segmentation also. DEBAY LE, J. etc extended MSMM for segmentation using adaptive technique and MARC DROSKE etc. also used MSMM for segmentation. 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.

PAUL. T. JACKWAY etc. provide another type of analysis in MSMM. Naturally a few questions arise in MSMM, like how to relate the results of one scale with the results of other scale. This type of analysis is provided in this paper by Erosion/Dilation operations with good examples. MSMM is having, application in medical area also. 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, suitable for ECG analysis, in impulse noise environment using MSMM. DAWEI QI proposed another algorithm, for medical analysis environment. ZA BI HI, S.M etc. (148) discussed application of MSMM for retinal vessel segmentation.. DAWEI QI etc HAI YAN GU; etc WEIPING HOU etc discussed the applications of MSMM in wood analysis they have done wood decay estimations, defect identification of wood, etc. RUJIANG HAO etc. used MSMM open operation for identification of defects of the rolling beatings. YING ZHANG etc. used MSMM to do analysis of results of turbine rotor experiment. In noise environment also, it provides good results [strong edges].The detailed references and explonations are available in my other papers, which are given in reference.

IV. RESULTS AND DISCUSSIONS

The importance of multi scale morphology is explained in the above section. So, the primitive operations of mathematical morphology--erosion and dilation are taken and they are discussed in multi scale morphology point of view. The concept is very simple. But some of the important points are eloborated practically with the help of a few images and some important observations are given. In this section, the results of experiments are presented. Actually two diagrams are taken, a Semi circle shape and a dumbbell shape. On these images various morphological operations are applied. The output is got in the form of tables, diagrams and graphs, around 1000 pages. But here some important as well as samples outputs are presented , relevant to this work.

Images: In this section, the Semi circle and dumbbell images are presented.

Semi-circle dumbbell

4.1. Erosion in multi scale environment:

The erosion operation is applied in multi scale environment on semi circle and dumbbell images. In this paper the results applied on semi circle are only presented. In Fig – a , the semi-circle images are presented in multi scale environment.

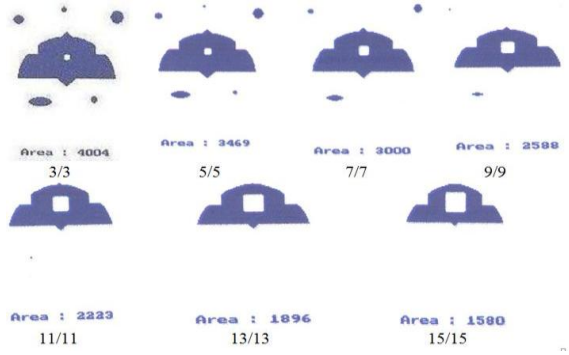

Fig – a Eroded Images in multi scale environment

scale	Area
3/3	4004
5/5	3469
7/7	3000
9/9	2588
11/11	2223
13/13	1896
15/15	1580

Table - 1

The Table 1 will provide the areas of images in multi scale environment

4.2 Dilation in multi scale environment:

The dilation operation is applied in multi scale environment on semi circle. In Figure-b …, semi circle are presented in multi scale environment.

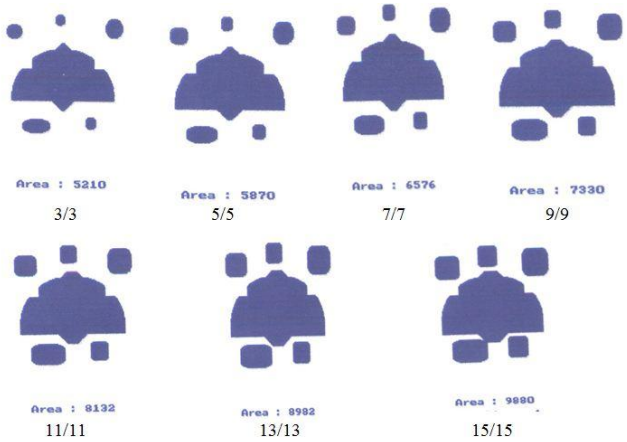

Fig – b: Dilated Images in multi scale environment

Scale	Area
3/3	5210
5/5	5870
7/7	6576
9/9	7330
11/11	8132
13/13	8982
15/15	9880

Table –2: The areas of images in multi scale environment. (Dilation)

4.3 Observations:

EROSION:

1) By erosion, in multi scale environment, the size of the image is decreased, as the structuring element size is enhanced.
2) The size of the holes are enhanced.
3) The size of the islands are increased gradually.
4) Gradually the sizes of peaks are also reduced. It can be described as the peaks will be smoothened more, as the size of the structuring element is enhanced.
5) Overall the image will be smoothened, as the structuring element size is enhanced.

DILATION:

1) By dilation, in multi scale environment, the size of the image is enhanced, as the structuring element size is enhanced.
2) The size of the holes are reduced. Even they may disappear, if the hole size is sufficiently not large enough.
3) The size of the islands are decreased gradually. From a structuring element size , even they have disappeared also.
4) Gradually the sizes of peaks are enhanced.
5) Overall the image will be smoothened , as the structuring element size is enhanced.

V. CONCLUSIONS

In this paper erosion and dilation are studied with reference to size of the image, peaks, valleys, holes etc. This paper will give fundamental discussions on fundamental characteristics only. But these fundamental properties are not touched by any researcher in this way. Even though the concept is simple, it is discussed practically, in detail. Here detailed practical study is presented. It will lead to good understanding of this area.

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BIO DATA

The author Kompella Venkata Ramana has done his B.E (E.C.E) and M.E (COMPUTER ENGINEERING) and Ph.D from ANDHRA UNIVERSITY, VISAKHAPATNAM, INDIA. He has started his carrier as LECTURER in N.I.T. (W). Later he shifted to ANDHRA UNIVERSITY. At present he is working as ASSOCIATE PROFESSOR in the department of computer science &systems engineering in ANDHRA UNIVERSITY. His areas of interest are Image Processing, Formal languages and Automata theory, compiler design and Systems Programming. He has written books on the above areas. He has experience of more than twenty five years in teaching and guided more than one hundred Thesis in M.Tech. Level, majority of them are in image processing.
He has done his Ph.D in computer engg.(image processing…mathematical soft morphology.)

