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THE FUTURISTIC SCOPE OF MATHEMATICAL MORPHOLOGY AS WELL AS SOFT MORPHOLOGY--personnel view

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ABSTRACT: ***In this paper, the scope of research in future, in soft morphology is explained. There are a few areas which we can say sister areas to mathematical morphology. They also may be entered in to soft morphology. So this provide a thought to expansion of this soft morphology and its related areas.***

KEY WORDS: Mathematical morphology, Mathematical soft morphology, Soft morphology, Erosion, Dilation, Soft erosion, Soft dilation, Primitive morphological operation, equality, threshold , Multi scale morphology, soft open, soft close.

The paper is divided in to 8 sections.

1. INTRODUCTION TO IMAGE PROCESSING:

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. After that camera came in to picture. "KODAK" has entered and developed this technology.

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 its 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.

2. INTRODUCTION TO MATHEMATICAL MORPHOLOGY

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. There are some more composite operations, like thinning, thickening, skeletenization etc.

The erosion, dilation, open, close are discussed thoroughly, with properties and proofs and extensions to gray scale in 3. 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 (1,2,3,4).

The morphological operations are suitable to apply on binary images only. But later these operations are extended to gray scale images also. One method of applying these operations on gray scale images is discussed by PETROS MARAGOS etc . They have (5) proposed a method to convert a gray scale image to binary image series. This method, named as threshold superposition, has opened new doors into this area. Morphological operations may be applied on these binary images, later on, these processed binary images are integrated to get, a processed gray scale image. So, the methodology, proposed by Maragos has extended morphological operations to gray scale environment also. They have discussed the necessary mathematical background, theorems, examples etc.

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 (6) , in this area. PETROS MARAGOS (7) has discussed about morphology also. PETROS MARAGOS (8) has discussed about morphology and given theoretical analysis.

IMANTS D. SVALBE discussed about closing in 9. The morphological operations can be implemented in various directions horizontal, vertical, and diagonal. As the S.E. size is increased, so many directions are obtained. These can be implemented, taking input as one dimensional array. In this way a new type of algorithms are developed by VAN HERIC and extended by PIERRE SOILLE, etc (10). In this paper authors explained these algorithms with sufficient mathematical back ground and good examples.

SUCHEN and HARALICK proposed (11) new types of morphological algorithms recursive erosion transforms, recursive dilation transforms, recursive open transform, recursive close transform, by using recursion concept, which is an extension to mathematical morphology. For the extension of morphological operations to gray level image, efficient algorithms are designed (12) by JOSIPH (YOSSI) Gil etc by min -max values, and these are extended for getting edges of an image.

ARNOLD MEIJSTER etc (13) designed new algorithms for mathematical morphological operations. A few researchers MOTAZ A. MOHAMED, ALDO MORALES etc have given (14,15) statistical analysis of morphological operations. They have studied new composite operations (14) like close – erosion, close – open etc and smoothening and detail preservation (15) also, with respect to statistical analysis. ROBERT L. STEVENSON (16) also deals with statistical properties, with respect to morphological operations.

STEPHEN. S. WILSON (17) has given a different treatment with morphological operations, mixing with matrices. He maintained images as elements in a matrix. In another matrix, he maintained structuring elements as elements. He has processed the first matrix (which has images) by second matrix (which has structuring elements). He discussed the background theory and the corresponding mathematical analysis in detail, with a practical example, character identification. Definitely it is an unimaginable extension to mathematical morphology.

PETROS MARAGOS (18), has contributed excellent extension to mathematical morphology, by the name "DIFFERENTIAL MORPHOLOGY", introducing applications of calculus, differential equations into mathematical morphology. He discussed distance transforms, and some other signal transforms, multi scale erosion, multi scale dilation also, with sufficient mathematical back ground, in this new environment. REIN VAN DEN BOOMGAARD etc also discussed similar work (27). They discussed about solving of differential equations, by morphological operations.

PIERRE SOILLE etc (19), introduced and discussed in their paper about new morphological operations TI erosion, TI dilation, TI open, TI close (here TI: Translation Invariant). NIDHAL BOUAYNAYA and others introduced (20,21) spatially – variant morphological operations, which are of new type, in binary as well as gray level environment. They have discussed SV erosion, SV dilation, SV open, SV close in detail with properties, theorems, examples. They have discussed some more composite operations also, like skeletenization segmentation etc in SV environment.

FRANK Y. SHIH etc (22) discussed about pipeline architectures for morphological operations in recursive environment. The morphological operations have extended to fuzzy area also. Using fuzzy techniques, fuzzy morphological operations are developed. (23,24,25). ISABELLED BLOCH (24) discussed fuzzy morphological operations in depth, and their applications in pattern analysis, in his works. LOUVERDIS, G & ANDREADIS, I extended (25) these fuzzy concepts to hardware implementation, in color environment.

KRISHNA MOORTHY SIVAKUMAR, HOJN GOUTSIAS (26) extended these morphological operations to flat operations. They have designed flat erosion, flat dilation, flat open, flat close and flat structuring elements. They have applied these new morphological operations to analysis of textures. This paper provided good examples and in depth mathematical treatment for these new operations.

For elimination or minimization of noise in the images a lot of research is done. Normally a few statistical based techniques will be useful for this purpose. But morphological techniques also are useful for this purpose.

A few researchers concentrated in this area. DAN SCHONFELD etc (27) have done some research work in smoothing by morphological operations. Normally by image smoothening some useful information may be lost. But these researchers have developed algorithms, using morphological techniques, for image smoothening, without losing the important details of the image (i.e., with detail preservation). So, morphological techniques are proved to be capable for DETAIL PRESERVATION also, which is a very important IMAGE PROCESSING CHARACTERISTIC.

RONALD JONES & IMANTS SVALBE proposed (28) another method of implementation of morphological operators (Erosion, Dilation, Open, Close) and shown that the salt and pepper noise will be eliminated; (by means of their methodology). J. ALISON NOBLE has discussed about close – open, open – close (29) composite morphological operations in the context of, salt –pepper noise elimination, impulse noise elimination. [Of course he proposed these op's for texture segmentation also]. JOHAN VAN HOREBEEK and others proposed another algorithm for noise treatment, using morphological open and close operations. In 135,136,137 the discussion is done in sodar applications.

BOUAYNAYA, N; etc. (31) proposed another morphological algorithm using IDEM POTENCY and DUALTY property for elimination of speckle noise in radar images. [In this paper the importance of duality & idempotency properties are understood]. LEI, T; FAN, Y. Shown (32) elimination of impulse noise by a pair of morphological **dual** operators. They have shown that, this dual pairs provides better results for image smoothing.

In medical image processing, one object is identification of organs like kidneys, body cells, cells of blood etc. For these purposes, edge enhancement techniques and segmentation techniques are mainly useful. Morphological techniques are also very useful in this medical image processing because there are a few techniques, which will provide edges of the images and segments of the images.

SCHUPP, S etc (33) explained the role of morphological operations in medical image processing. Segmentation using morphological techniques is concentrated in this paper, and it is applied in medical image processing area, and it is explained with examples. YANK Y etc. demonstrated (34), applications of morphological techniques for the identification of cells.

BIN MANSOOR. A & others developed methodologies for diagnosis of diabetic (35) retinopathy, using morphological techniques. They have applied fuzzy morphology for this diagnosis. GAO YAN, BOLIANG WANG (36) proposed methodology for kidney identification using multi scale mathematical morphology. More than 200 test cases are studied using this algorithm. A QUINO, A; etc (37) developed an edge detection algorithm using morphological op's for identification of optic disc by processing of retina image.

3. 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.

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.

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.

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.

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.

MICHAEL A. Z MODA and LOUIS. A. TAMBURINO discussed (38) morphological operations, soft morphological operations in detail. In this paper they discussed the definitions of Erosion, Dilation on the basis of methodology like counting, which is suitable to extend to soft morphological operations, by fixing threshold values. PAULI KUOSMANERI etc. (39) have discussed about statistical properties of soft morphological ops. They discussed about noise reduction using soft morphological ops, with detail preservation, in this research paper. The above authors discussed in another research paper (40) about the relation in between soft morphology ops as well as stack filters.

SHIH, F.Y. etc. discussed (41) soft morphological properties are discussed up to some extent. Some of the properties are stated and idempotency is discussed up to some extent. They discussed about, soft morphology op's in gray scale, using threshold super position theorem. They discussed about implementation of soft morphology op's, using logic gates also. Any way, it discussed soft morphological operations in a few dimensions.

PU, C.C. discussed about (42) implementation of soft morphological op's in gray scale. They integrated super position property and stacking to extend soft morphology from binary scale to gray scale.

PAULI KUOSMANEN & JAAKKO ASTOLA (43) also discussed, statistical properties, of soft morphology op's, up to some extent, with connection to stack filters.

GASTERATOS, a discussed (44) a new technique, for the realization of soft morphology op's basing upon majority gate algorithm system architecture, for implementation of soft morphology op's, is also presented. MICHAEL A. ZMUDA (45) proposed an algorithm for implementation of soft morphology ops. Normally voting logic also may be used, across neighborhoods, defined by the S.E.

But, in this algorithm instead of processing all the votes, a few votes may be chosen randomly and the service of FSM also, will be taken, in implementation of this algorithm. It is faster than conventional algorithms. Accuracy: more than 90%.

ZHAL CHUNHUI (46) designed soft morphological filter, using genetic algorithm. It is in optimized and improved algorithm. PERTTIT. KOI VISTO, etc. (47) also concentrated and discussed improved algorithms for soft morphological ops, using genetic algorithms.

M. VARDA VOULIA etc. (48) designed algorithms for small detail preservation and impulse noise suppression, using soft morphological op's [soft vector morphology] in color environment and shown better results compared to algorithm designed, based on morphological operators. [Mathematical vector morphology]. A. GASTERATOS, etc. (49) discussed about structuring element decomposition, in soft morphological environment.

A. GASTERATOS etc. (50) discussed about extension of fuzzy theory into soft morphology. G. LOUVERDIS etc. (58) also discussed about fuzzy soft morphology. These filters are less sensitive to image distortions and to small variations in the shape of the objects. Fuzzy soft morphology performs better in impulse noise removal, compared to standard morphological op's. Fuzzy soft morphology extended to edge detection also.

Soft morphological filters have entered to recursive environment also. SHIH, F.Y. & PADMAJA. P (51) PERTTI KOIVISTO etc. (54) PEI, S. etc. (55) discussed about recursive soft morphology in various contexts and environments.

In a research paper (51), the authors discussed about properties up to some extent. But, elimination of noise, as well as, detail preservation are opposite characteristics, up to some extent. A strong smoothening filter may not preserve details. But, in soft morphology, a balanced solutions maybe obtained, which will preserve details as well as suppress noise, due to flexibility in the definition of soft morphology. It is discussed by KOI VISTO, P. etc. (52).

Statistical soft morphological op's are new type of op's, which possess two types of advantages. These have properties of dealing with shape for shape preservation, due to soft morphological characteristics as well as noise cleaning properties due to statistical approach in these statistical soft morphological ops. It is introduced by STRINGA, E, etc (53). Like above methodologies, recursive order – statistic soft morphological filters/ op's, [ROSSM] balance two types of parameters. One is noise reduction. The other is detail/edge preservation. (54).

PEI, S. etc. (55) discussed these techniques and showed with examples that, these filters perform better compared to other filters like morphological filters, soft morphological filters, order–statistic soft morphological filters. A way of implementing, soft morphological op's, is discussed by LIPEND WANG etc. (56), based on graphic processing unit [GPU], reduces computing time.

Statistical soft morphology is extension to soft morphology, discussed by REGAZZONI, C.S. etc. (57), having advantages, compared to , soft morphological op's, (in image smoothening such as speckle noise handling, processing remote sensing images)

ZHENG MINGJIE etc. (59) developed directional S.E.'s for speckle noise reduction on SAR images. KOI VISTO, P; etc. (60) concentrated on detail preservation while smoothening. ZHEN JI etc. (61), designed soft morphological filter for reducing periodic noise. These results are compared with other spatial domain as well as frequency domain filters techniques.

ZHEN JI etc. (62), in another research paper, discussed about periodic noise reduction, by soft morphological filters, in another way [another algorithm].MARSHALL, S etc. (63), used soft morphological filters for elimination

of disturbance, caused by solar cosmic rays, in the images obtained by astronomy base. [Solar].

In the same way smoothening, detail preservation filters basing on soft morphology are discussed in 48,58,51,52,53,54,57, etc. papers, introducing extensions of soft morphological filters like statistical soft morphological filters, recursive soft morphological filters etc.

So many researchers entered in to edge detection using soft morphological op's.

HUANG FENG – GANG; etc. (64) discussed the role of soft morphological ops in edge detection, in noisy environment. ZHANG YING etc. (65) discussed about edge detection. They used PSO [Particle Swarm Optimization method] to choose best edge detection method, suitable to the environment of the image. SONG XIN LUO JUN etc. (66) discussed a method, which minimizes noise, preserve details & detects edges.

XIAOXIN GUO etc, (67), discussed a new type of filter. They integrated soft morphology, laplacian operator as well as, nature of adaptivity. They designed, adaptive soft morphological laplacian filter, for smoothening as well as edge detection. The nature of adaptivity is achieved by, employing, 4 directional structuring elements.

Empirical mode decomposition [EMD] is a new concept in the field of signal processing. The technique, extended to analyze two dimensional data is known as bi dimensional EMD. [BEMD].

XIAOFEI YAN etc (68) proposed an edge detection method, integrating BEMD and soft morphology.

WANG TAO etc. (69) discussed an important concept they have applied soft multi – scale operations for edge enhancement in noisy environment

ST RINGA, E. etc. (70) proposed algorithm, for reconstruction of image, using soft morphology and Bayesian process and applied on SAR images. HAMID, M.S. (71) designed a multidimensional soft morphological filters in gray scale environment, using genetic algorithm for optimization for restoration. DONG YAN – ZHI etc. (72) discussed segmentation in soft morphological environment. TANLIU. Etc. (73) discussed soft morphology and top – hat tr and SPRT – PMHT for identification of targets which are small in infrared environmental images.

In some applications, like character identification, noise will be generated after shape decomposition (using morphological methods). But soft mathematical morphological methods will function excellently in this environment. It is discussed by N. SANTHI & Dr. K. RAMAR (74).

4. ITERATIVE SOFT MORPHOLOGY

It can be defined as, applying a morphological operation on an image, a few numbers of times.

4.1 CONVENTION: symbolically, $(X \ominus Y)$ means applying erosion by S.E. Y, on image X.$(X \ominus 2Y)$ means, applying Erosion by S.E. Y, on image X, twice. $(X \ominus 3Y)$ means, applying Erosion by S.E. Y, on image X, thrice. $(X \ominus NY)$ means, applying Erosion by S.E. Y, on image "X", "N" number of times ,in the same way.

$(X \oplus NY)$ means, applying dilation by S.E. Y, on image "X" ,N no of times.(X O NY) means, applying open by S.E. Y, on image "X", N numbers if times. [But it is idempotent operation].

$(X \bullet NY)$ means applying close by S.E. Y, on image "X", N number of times. [But it is also idempotent operation.] This iterative morphology will have applications in the design of composite morphological operations (Morphological Algorithms) skeletenization, thinning, thickening etc.

The applications may also be seen in structuring element Decomposition, segmentation, etc.

Iterative morphology may be extended to iterative soft morphological environment also. In iterative soft morphological environment, the following convention may be used.

$(E_{(1)})^2$: Soft Erosion, with threshold value = 1 applied, 2 times on the image.

$(E_{(1)})^5$: Soft Erosion, with threshold value = 1 applied, 5 times on the image.

$(E_{(x)})^y$: Soft Erosion, with threshold value "x", applied "y" times on the image.

$E_{(1),}$ $E_{(2),}$ $E_{(3),}$: Soft Erosion, applied with threshold values, 1,2,3 on the image.

$E_{(x),}$ $E_{(y),}$ $E_{(z),}$: Soft Erosion, applied with threshold values, x,y,z on the image.

$(D_{(1)})^3$: Soft Dilation, with threshold value "1" applied "3" times on the image.

$(D_{(2)})^4$: Soft Dilation, with threshold value = 2, applied, "4" times on the image.

$(E_{(x)})^y$: Soft Dilation, with threshold value = x, applied "y" times on the image.

$D_{(1),}$ $D_{(2),}$ $D_{(3):}$ Soft Dilation, applied with threshold values, 1, 2, 3 on the image.

$D_{(x),}$ $D_{(y),}$ $D_{(z):}$ Soft Dilation, applied with threshold values x, y, z on the image.

$(O(1, 2))^3$: Soft open applied thrice on the image, with thresholds 1,2

[Soft Erosion threshold value =1, Soft Dilation threshold value =2]

$(O(x, y))^n$: Soft open, applied 'n" times, on the image, with thresholds x, y

[Soft Erosion threshold value = x, Soft Dilation threshold value = y]

O(p, q) O(x, y): Soft Open applied twice on the image, with different thresholds.

O (p, q) O (r, s) O (x, y): Soft open, applied thrice on the image, with different thresholds.

(C (1, 2)) $^{4:}$ Soft close applied four number of times on the image, with Soft dilation threshold value = 1, Soft Erosion threshold value = 2.
[C (1, 2)] ^{n}: Soft close applied "n" number of times, on the image with thresholds 1, 2.
(C(x, y)) ^{n}: Soft close applied "n" times, on the image, with thresholds x, y.
C(p, q) C(r, s) C(t, u): Soft close applied on the image, thrice, with different thresholds.

4.2 BRIEF DISCUSSION ON ITERATIVE SOFT MORPHOLOGY:

Iterative morphology means, applying one morphological operator, on an image a few no of times. These morphological operators may have same S.E or different S.E's or same S.E with different dimensions. Iterative morphology is having its own importance. It is having so many applications in so many areas.
Iterative morphology appears in skeletonization process. In an algorithm for skeletonization erosion has to be applied, a few no of times. In thinning also, iterative morphology will appear. A Structuring Element has to be applied so many times, on an image; [Each time the Structuring Element, will be rotated]. Same case in thickening also. Thickening also uses iterative morphological concept.
In some situations, multi scale iterative concept will appear. In multi scale skeletonization
S.E. will be applied at various dimensions, each time upon an image, to get skeletons at various dimensions.
There is an area in mathematical morphology , called S.E. decomposition. A S.E. will be divided into series of mini S.E,'s. All these S.E.'s will be applied on the image one after the other as a series or these can be applied on the image simultaneously in parallel computing environment. Any way structuring element decomposition deal with iterative morphology. The S.E. may be decomposed into mini S.E's, with dimensions in increasing order. So, S.E decomposition can be in iterative environment and multi scale environment also.
This iterative morphology can be applied for segmentation also. A few researchers proposed an algorithm for hand verification also. A few researchers discussed methodology for segmentation technique, which is suitable to apply on sequence of images of traffic scene using this iterative morphology. AUPIGITER. R. also discussed segmentation using iterative watershed algorithm in 3D environment, which is suitable for medical image processing. A few researchers discussed segmentation using watershed algorithm, to be applied in medical area, using iterative erosion technique. Another set of researchers discussed methodology for smoothing (for the treatment of impulse Gaussian noises) using iterative close – open technique. A researcher proposed algorithm for determination of centroids using iterative morphology. It has entered in to cluster analysis also. A few researchers discussed about applications of iterative morphology in medical image processing, regarding neurological analysis which is very important. There are so many applications, where iterative morphology may be applied. All the above works are explained in the author's other papers which are given in reference. Some related wok is done in 19 and 20.

5. MULTISCALE 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.
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 (75). MING – HUA CHEN & PING – GAN YAN explained (76) Erosion, Dilation, Open, Close in multi scale environment, with diagrams (results), mathematical analysis, as well as symbolic conventions.
PAUL. T. JACKWAY etc. (107) 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. This paper discussed the back ground. theory, in one angle, relating to MSMM.
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 (77). The same authors KUNWANG etc. proposed another algorithm for edge detection (78) 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. (79).
ZENG PINGPING etc. proposed another algorithm, for edge enhancement (80) in multi scale morphological approach, using order morphology also, which is suitable

to apply in noisy environment also. ZHEANHUA LI; & others (81) discussed another technique for edge enhancement, in MS morphological environment.

WENJUAN ZHANG & others, proposed another methodology for edge enhancement by combining MSMM and WAVELET transform. In this methodology, they have separated low and high frequency components, by WAVELET transform. They have applied MM techniques, MSMM techniques on low and high frequency components. These O.P.'s are integrated. It is a better method compared to, MM based or WAVELET transforms based edge detection methods, in noise environment. (82).

XOAKAI – JIAN; etc. (83) proposed another edge detection algorithm, in MS MM environment, using WAVELET transform also. CHAO LI; etc. proposed an adaptive algorithm for edge detection using multi – structure and MS MM environment. (84). PANCHAO WU & others proposed another algorithm, for edge detection in noisy environment using MS MM & WAVELET transforms.

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. (86).

GAO LI etc (87) 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 (88).

HAI LONG HUANG etc. proposed an algorithm for suppression of noise and preserve edges using multi share and multi scale mathematical morphology environment (88). 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. (89)

ZHANG ANU & others have proposed another algorithm (90) for identification of weak edges in Oct images using MSMM environment, XINGHUI ZAANG etc. (91) proposed another algorithm for edge detection in color image environment, using MSMM. QING LIU etc. proposed another edge detection algorithm (92) in MSMM environment. Here, as the first step, noise is eliminated by applying open close filter in multi – scale environment. Later, edge detection algorithm is applied in MSMM environment. So, image smoothening and edge detection is done in MSMM environment. So, image smoothening and edge detection is done in MSMM environment by this algorithm, is very efficient. This algorithm is very efficient in noise elimination and nation and complex border detection. WANG TAO & WEINA (93) proposed another edge detection algorithm in MSMM environment. Another algorithm for smoothening is discussed using MSMM. (94). XU, YANLEI; ZHAO, JIYIN discussed (95) another algorithm, for edge detection, using MSMM, in noisy environment. DANTING YUHUA CHAI, ZHAO, etc. proposed (96) an algorithm for smoothening using MSMM. XIANGZHI BAI etc. (97) proposed a new type of algorithm, for image enhancement using multi scale top-hat transform.

JIAN–HUI TAN etc. proposed (98) 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. They have taken the help of NN (Neural Net works) also. So, in this paper, MSMM & NN are integrated. JIE KANG etc. used (99) CB (Contour Bougie) morphology in MSMM environment for speckle noise treatment, in SAR (Synthetic Aperture Radar) images, for maintaining detail preservation also.

These MSMM techniques are extended to segmentation also. DEBAY LE, J. etc (100) extended MSMM for segmentation using adaptive technique and MARC DROSKE etc. also (101) used MSMM for segmentation. (102) 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 (103).

JIANN–JONE CHEN etc. extended the MSMM to 3D segmentation, using **dual** (MS morphological) concepts (104).

SHU LI; etc. (105) designed water sheds segmentation algorithm, using MSMM, and applied to cell image segmentation, and got quality results. XU YING SHA; etc (106) proposed another water shed algorithm for segmentation of remote sensing images, in MSMM environment. It shows good results, by avoiding, over segmentation.

PAUL. T. JACKWAY etc. (107) 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.

J. ANDREW BANGHAM, etc. (108) discussed about decomposition, in MSMM environment using the sieve decomposition theorem / method, with good B.G. FU LIU etc. (109) discussed the methodology for identifying obstacles in lunar, using water shed method, based on MSMM. Here, for this purpose, open close operators is used, in multi scale environment. It gives better results, compared to traditional watershed method. TIE XIANG WEN etc. (110) proposed an algorithm to choose the suitable scale in multi – scale morphological top – hat

transformation [this transformation is used in pattern recognition].
SHUWEI LI etc. (111) 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. (112) 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 (113), suitable for ECG analysis, in impulse noise environment using MSMM. DAWEI QI (114) proposed another algorithm, for medical analysis environment. JI – LE HU; etc. (115) 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.
ZA BI HI, S.M etc. (116) discussed application of MSMM for retinal vessel segmentation. DAWEI QI etc (117), HAI YAN GU; etc (118), WEIPING HOU etc (119) discussed the applications of MSMM in wood analysis they have done wood decay estimations, defect identification of wood, etc. RUJIANG HAO etc. (120) used MSMM open operation for identification of defects of the rolling beatings. YING ZHANG etc. (121) used MSMM to do analysis of results of turbine rotor experiment. In noise environment also, it provides good results [strong edges].

6. FUTURE SCOPE

A lot of scope for research exists in this area. The reason is that Soft Morphology can be applied in any area, where image processing may be applied (especially mathematical morphology is applied), But with less complexity and more advantages and flexibility of design.
6.1 Duality and equality are discussed in 134. In addition to duality and equality, some more properties like idempotency, extensivity, increasing etc., may be discussed. Open, Close are composite operations. The discussion of properties may be extended to other composite operations like skeletenization, thinning, thickening etc. Some more composite operations are designed for special applications, like Close–Open, Open–Close, Close–Erode etc. For these composite operations also, properties may be studied.
6.2 .1 The study is done assuming square grid structuring element. But, study may be extended to other structuring elements like circular, Triangular, Linear etc. The study is done, assuming origin at central place of square. But study of properties may be extended to, having origin, to other places (Pixel positions) also.
6.2.2 The soft morphology is extended to Fuzzy logic and Fuzzy soft morphology has emerged. Statistical soft morphology is also a new area, extension to soft morphology. A lot of scope for research, is existed in these areas, because detailed study of properties are not done in these areas. Especially the equality is a new property, followed by soft morphological operations. So equality may be studied in fuzzy soft morphology and statistical soft morphology also.
Duality also may be studied in the above areas. The other properties like idempotency, extensivity, increasing etc., also may be studied .
6.3 Mathematical Morphology is extended and so many new types of mathematical morphological operations are designed. For example Recursive transforms (Recursive erosion transform, Recursive dilation transform, Recursive open transform, Recursive close transform), translation invariant morphological operations (TI erosion, TI dilation, TI open, TI close), spatially – variant morphological operations (SV erosion, SV dilation, SV open, SV close), Flat morphological operations (Flat erosion, Flat dilation, Flat open, Flat close), are proposed by different researchers. These can be extended to soft morphological environment and properties may be studied in depth.
6.3.1 So recursive soft erosion , recursive soft dilation, recursive soft open, recursive soft close may be defined and their properties like equality,duality,idempotetency, etc. properties may be studied. In addition to them they can be studied in various image processing applications like smoothening,edge enhancement etc.
All the above concepts may be extended to iterative, multi scale as well as iterative multi scale environment. In these environments, the possible properties may be studied, because the iterative and multi scale morphology are having wide applications.
6.3.2. In the same way we can design TI soft erosion, TI soft dilation, TI soft open, TI soft close also. Again they can be studied in various applications as well as various properties point of view.
6. 3.3. In the same way we can design SV soft erosion, SV soft dilation, SV soft open, SV soft close also. Again they can be studied in various applications as well as various properties point of view.
6. 3.4. In the same way we can design Flat soft erosion, Flat soft dilation, Flat soft open, Flat soft close also. Again they can be studied in various applications as well as various properties point of view.
6.4 PETROS MARAGOS etc. (5) have proposed a method, threshold super position, to convert a gray scale image to a series of binary images. This opened new doors to research into gray soft morphological scale domain of images. So applying soft morphological operations, on these images, we can get soft morphological gray scale images. So, the duality and equality may be studied on soft morphological gray scale images. In addition to them the remaining properties also may be studied on these images. In addition to these, the gray scale images may be studied in multi scale as well as, iterative soft morphological environment. Really, it will open wide scope of research in this area.

6.5 There is a lot of scope for research for structuring elements in soft morphology. This is explained in sections 6.5.1 and 6.5.2.

6.5.1 STEPHEN. S. WILSON (17) work may be extendable using soft morphological structuring elements in the second matrix. This will give good extension to soft morphology.

6.5.2 Research is not much done in structuring element decomposition in soft morphological environment. In pattern restoration, the morphological operations role is very efficient (138). Suitable idempotent morphological operations will be chosen for this purpose. So, research can be done on idempotent soft morphological operations, and these can be applied in this context for better results. Structuring element decomposition will give good performance. This structuring element decomposition can be done in soft morphological environment also and iterative morphology and multi scale morphology may be applied for this purpose (extension of work 139).

6.6 Skeletanization discussed in multi scale structuring element environment (117), may be extended to soft morphological environment. Multi scale skeletanization (123) may be extendable to soft morphological environment. So many algorithms are proposed for skeletanization (116, 117, 118,…,133). These can be extended to soft morphology and equivalencies of skeletons and duals of skeletons may be studied and duals of skeletons constructed by soft morphological operations may give new dimensions or new scope for research in this area.

6.7 Morphological operations are applied in image smoothening for detail preservation (27), removal of salt and pepper noise (28) and for the same purpose Close—Open, Open—Close composite operations are discussed (29). Any way some more researchers developed algorithms using mathematical morphological operations for image smoothening. All these algorithms may be studied in soft morphological, multi scale soft morphological domains.

6.8 Applying of dual pairs for noise elimination is studied in 31, 32 for better results. These can be extended to soft morphology and multi scale soft morphology. Dual pairs can be constructed for statistical soft morphological as well as Fuzzy soft morphological operators and above methodology (31, 32) can be extended to these areas also. Especially idempotency and duality properties are used for speckle noise removal in radar images (31). These can be studied in soft morphological domain and multi scale soft morphological domains.

6.9 The mathematical morphology provide algorithms for edge enhancement. The methodologies are

A) (Original image – Eroded image)
B) (Dilated image – Original image)
C) (Dilated image – Eroded image)

In the above methodologies multi scale soft morphological filters may be applied. Comparison may be done in between (Original image – Eroded image) & (Original image – Eroded image^d).

Example: $(I - E(1)) \& (I - E(1)^d)$
$(I - E(2)) \& (I - E(2)^d)$
$(I - E(3)) \& (I - E(3)^d)$
……
……
$(I - E(n)) \& (I - E(n)^d)$

n will be dependent basing upon size of the structuring element. Study may be done in between (Dilated image – Original image) & (Dilated image^d – Original image).

Example: $(D(1) - I) \& (D(1)^d - I)$
$(D(2) - I) \& (D(2)^d - I)$
$(D(3) - I) \& (D(3)^d - I)$
……
……
$(D(n) - I) \& (D(n)^d - I)$

Even statistical morphological filters, statistical soft morphological filters, Fuzzy morphological filters, and Fuzzy soft morphological filters also may be applied.

This type of thinking will give very broad scope for research and to study the results. In this approach, unimaginable findings also may be obtained, which may have excellent applications in medical and some other important areas.

For example GAOYAN, BOLIANG WANG proposed algorithms using multi scale morphological techniques for kidney result analysis (36). By extending these experiments to multi scale soft morphological domain and applying dual operations and comparisons, we get some more results for doing kidney analysis or disease analysis. Medical area is using morphological techniques for analysis of various deceases (Like – 35 – Diabetic retinopathy, 37 – Retina analysis etc.,). All these may be repeated and studied using soft morphological operations and their dual operations and the output results may be compared, for better results and better analysis. This discussion is providing wide scope of research in this area. The researchers may concentrate in this area which can be a very good collaborative work in between medicine as well as computer science.

6.10 The analysis of shape of an image, change of the size of the image, change of connection of main image with islands etc. are discussed when morphological operations are applied on images. But impact of soft morphological operations, multi scale soft morphological operations is not discussed. Research can be done in this orientation. Especially the impact of dual soft operations on images may be studied, like a comparative study. The same type of study may be extended to multi scale soft morphology, Fuzzy soft morphology, statistical soft morphology etc.

6.11 Research in Edge enhancement in noise environment is done in multi scale environment (77, 78, 79, 80, 81 etc.,). It can be extended to soft morphological environment and multi scale soft morphological

environment. In this environment dual soft morphological operations, may be applied, one after the other or individually on the images and these results may be studied. Till now, studies are done in combining frequency domain techniques and multi scale mathematical morphological techniques for better edge enhancement in noisy environment (82, 83, 84). But soft morphological and multi scale soft morphological operations may be combined with frequency domain techniques. Duals of soft morphological operations also may be applied and studied, in this context.

6.12 All the edge enhancement algorithms (86, 87,…., 92) developed till now in mathematical morphology and multi scale mathematical morphology may be extended to soft morphology, multi scale soft morphology and specially dual operations may be studied for special analysis, and for extension of research.

In the same way smoothing is done using in mathematical morphology and multi scale mathematical morphology techniques (96, 98, 99 etc.,). These works may be extended to soft morphology, multi scale soft morphology environments. After applying an operation its duals also may be applied and the results may be compared.

6.13 The segmentation is discussed basing upon mathematical morphology and multi scale mathematical morphology techniques (102, 103, 104, 105, 106, 107 etc.,). These may be extended to again soft morphology, multi scale soft morphology environments. After applying an operation its duals also may be applied and the results may be compared, and comparative study may be done. Multi scale mathematical morphology algorithms (113,…, 115) applied in medical analysis may be extended to soft morphology and multi scale soft morphology areas.

6.14 In the same way for wood analysis also (the wood analysis is done by morphological methods) the research may be extended to soft morphology and multi scale soft morphology.

Multi scale mathematical morphology has entered into mechanical engineering applications also for identification of defects of the rolling bearings, analysis of results of turbine rotor experiment. So it can be extended to soft morphology and multi scale soft morphology domain also. The soft morphology or multi scale soft morphology operations and its duals may be applied, separately and jointly and the results may be analyzed.

6.15 In sodar also image processing is applied for smoothening of signal.(135,136,137).

So the soft morphological operations also may be applied for smoothening in this context. It can be applied in multi scale environment on sodar signal and better signal may be obtained for a particular S.E. size as well as threshold value also. Other (soft)morphological operations also may be applied (like flat(soft) erosion, flat(soft) dilation,.....TI(soft) erosion, TI(soft) dilation.....SV (soft) erosion, SV (soft) dilation.....)

In total we can say, wide scope for research is opened in the above specified areas.

In this paper the scope for the future of research is discussed in soft morphology.

The probable developments are discussed.

7. CONCLUSION

In this paper some work related to morphology,soft morphology ,fuzzy morphology, and other morphologies like flat, SV, TI are reviewed. Now the extensions are explained. It means how soft morphology may be applied in other areas or soft morphology definition may be clubbed with other definitions and where they can be applied with reference to the previous work. It means it gives a lot of ideas for further extensions. Really for a scholar, it gives some idea for his research work, who is having some idea of image processing.

In this paper some review of work is given as well as new ideas are also given .So it will give detailed and depth idea for expansion.

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