# A MATHEMATICAL MORPHOLOGICAL PERSPECTIVE IN THE WORLD OF IMAGES

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Abstract— In several domains of image analysis, mathematical morphology plays a very crucial role. It was a concept that evolved in France in sixties. This theory has received little attention since then but anyhow, is now object of research in many laboratories and international conferences. The morphology provides a very coherent theoretical framework for image processing and analysis. Based on the mathematical theories of sets and topological notions, its principle lies in studying the morphological properties (shape, size, orientation and others) of the objects through non-linear transformations associated with a reference object (the structuring element). This paper presents and elucidates the basic concepts of the mathematical morphology in a rather general framework as the classical tool of analysis and segmentation of images. We will also identify some future research directions for mathematical morphology.

## 1 INTRODUCTION

Few years back in 2002, the University Consortium of Geographic Information Sciences led down the growing research challenges for long term and short term [12]. A huge amount of importance was stressed on several agendas especially spatial ontologies.

Though the development of Internet technologies has motivated the outgrowth of the Semantic Web, whose intention is to deliver well-defined web resources and make them accessible by end-users and processes, ontologies play an important role to realize this challenging goal. For modeling information with their meaning, it is one of the most suitable means. It enhances chances of successful sharing. A large body of research has investigated ontology representation and reasoning, ontology engineering and the development of ontology applications. This has led to the specification of different models for ontology design and tools for ontology engineering. Nevertheless, Spatial ontologies require specific models and tools to deal with the geographical aspects of the data. Unfortunately, little attention has been put up to now into spatial ontologies. The mathematical morphology can also be referred to as a part of the application of advanced spatial technique and spatial ontologies. In spite of having several easy to use operators involved in the mathematical morphology, it has been a topic of little attention in the world of image processing and Geographic Information Sciences.

But in the recent years, the impact of mathematical morphology has been evident by the specialist in the area of both spatial information theory and theories involved in digital image processing and analysis.

## 2. LITERATURE REVIEW

### 2.1 Mathematical Morphology and some basic operations

This methodology was initiated by G.Matheron and J.Serra for the quantitative analysis of spatial structures, at the Paris School of Mines. Mathematical morphology is a tool for extracting image components that are useful for representation and description. It's mathematical origins stem from set theory, topology, lattice algebra, random functions, stochastic geometry, etc. Hence, we say that it involves set theoretic method of image analysis providing a quantitative description of geometric structures. It is most commonly applied to digital images, but it can also be employed on surface, surface meshes, graphs, solids and many other spatial structures. It characterizes various topological and geometric continuous-space concepts such as shape, size, convexity, connectivity and geodesic distance on continuous and discrete spaces. It is based on shapes in the images not the pixel intensities that are viewed as a general image-processing framework. Generally we use it before and after image segmentation (except the case of watershed segmentation).

Two fundamental morphological operations – erosion (shrinking) and dilation (expansion) are based on Minkowski operations. There are two different types of notations for these operations: Serra/Matheron notation and Haralick/Sternberg notation. In this paper, Haralick/Sternberg notation is used which is the more often used one in case of practical applications. In this notation erosion is defined as follows (Eq. 1) (Serra, 1982):

$$X \ominus B = \bigcap_{y \in \hat{B}} X_y \,,$$

and dilation as:

$$X \oplus B = \bigcup_{y \in B} X_y$$

where, $X_y = \{x + y : x \in X\}$, $B$ and $B\hat{}$ are structuring elements and $\hat{B} = \{b : -b \in B\}$.
There are two types of composites relations; one is called morphological opening and the other as morphological closing. The main aim of opening is to remove unnecessary structures in the image like noise. Binary opening removes the small regions that are smaller than the structuring element. It is defined as erosion followed by dilation and is given as an image F opened by a SE K:

$$O(F,K) = F \circ K = (F \ominus K) \oplus K$$

Closing is used to merge or to fill the structure in an image. It is defined as dilation followed by erosion. It can fill the small holes that are smaller than the structuring element. Binary closing is an image F closed by a SE K is given as:

$$C(F,K) = F \bullet K = (F \oplus K) \ominus K$$

### 2.2 Need for Mathematical Morphological perspective

Advances in image mining and spatial analysis have led to tremendous growth in very large and detailed spatial information retrieval. Such spatial information, if analyzed with proper tool, can reveal much useful information to the human users. Henceforth we need the most efficient technique for processing of such information.

Mathematical Morphology can act as a powerful tool for solving several image related queries. The need for morphology has been evident in various fields of science and engineering as well which has been substantiated in recent years like the one in which it acts as one of the best methods to eliminate weak network lines so that there is an emergence of strongly connected subnetworks in such way that one can predict the behaviour of the network. With the help of mathematical morphology, power network images are being decimated for analytical view. It gives a quick view of the strong subnetworks in the power system [5].

Close range photogrammetry is a technology where each measured object is imaged on many photos taken from different camera positions. Mathematical morphology has the potential to make close range photogrammetry technology faster. With the proper configuration of morphological tools, we get exact results of many photos [3].

In the recent years, morphology has shown its need to the researchers in the realization of several topics like image enhancement, image segmentation, image restoration edge detection, texture analysis, feature generation, skeletonization, shape analysis, image compression, component analysis, curve filling, general thinning, feature detection and noise reduction.

### 2.3 Applications

It has shown directions to several research and development works across the globe by providing an easier method in several image related applications. It helps in the teeth detection of a gear using subtraction and labeling, in getting the grid identification from Biochip by detecting the size of parts and analyzing its shape (pattern spectrum) using OTSU and entropy threshold. Another important application lies in the detection of runways in satellite airport imagery, which is a multi step algorithmic process that involves White Top-hat Transformation (segmentation tool that extracts respectively dark objects from the uneven background) of the source, image threshold and reconstruction of the detected long features to get the ultimate result. Its easy-to-use mathematical techniques have helped in the medical field too. In the detection of filarial worms, this tool has been proven to be the most efficient one. In such cases, Black Top-hat Transformation of source is firstly done. Hence the reconstruction after eliminating the short structures of the skeleton gives the final result.

In advanced medical image processing, morphology helps to segment the vertebra and ribs. The other striking applications of morphology are related to the edge detection, which is based on binary dilation, binary erosion and image subtraction [10].

Reduced noise Morphological Gradient Edge Detector, Erosion Residue Edge Detector, Dilation Residue Edge Detector, and Morphological Gradient Edge Detector are the several notable morphological edge detection techniques. By implementing edge detection using morphology, the edges and parts of the architectural monuments and industrial objects can be possibly detected. Mobile mapping systems is a technology where morphology helps to extract edges and detects characteristic objects in mobile photogrammetry systems to make maps that have been taken from sources like an image taken from a car or moving physical object. [20]

The specific objects (like road signs) can also be extracted easily by its use by diminishing the area of interest. Morphology can detect defects in the sewer pipes by applying median filters for the removal of unnecessary noise. Then after using linear closing by reconstruction, the features not similar to the geometry of pipe cracks can easily be taken care of. After performing these steps, author produces the digital model of the defects after improving the cracks. [19]

## 3. GLOBAL PROSPECT OF MATHEMATICAL MORPHOLOGY

We all know that nowadays, remote sensing satellites are the fastest growing sources of geographical information. The unmanned lunar mission satellites like Chang'e 1 of China and Chandrayaan 1 of India were really commendable. The main objective of these satellites was to study the three-dimensional images of the lunar surface. A reliable tool for the better analysis of such three-dimensional images would always be useful for such global researches needed for the spatial information retrieval. . Such a tool always supports the main theme behind this study in a better and easier way in order to deal with the retrieved spatial information pertaining to the satellite by analyzing the received images properly. These kinds of problems are easily solved by the mathematical morphology where very few simple mathematical operations can be combined to implement various different kinds of image processing techniques (gradients, distance images, skeletons, noise removal, contrast enhancement, filling). Its basic aim is to analyze the shape and the forms of the objects.

The entire world has seen a series of unprecedented development in the past year in the ways in which a common human being interacts with the Geographic Information System

(GIS) in several developed as well developing countries.

The development in the GIS can be foreseen by the popularity of Google Earth and its contemporaries like Microsoft's Virtual Earth, NASA's World Wind, *etc.*). Today, a school going kid can generate a bee by using a simple user interface within few seconds of instruction, a task that would previously have required an exposure of more than a year to commercial off-the-rack GIS in a university course. Eventually, it is evident that we are moving very fast from a concert pianist model of GIS as a tool confined to experts, to a school going kid model where the power of GIS is available to all including the layperson of this field. Nevertheless the huge concern about this powerful and complex technology in the hands of inexperienced users cannot be denied [12].

So it is clear that a common man needs more and more user-friendly techniques to play with any of such technologies like the GIS that may lead much faster and easier processing of the geographical data.

For such cases as well mathematical morphology acts as a beneficial tool for automated GIS data acquisition form scanned thematic maps that would give the GIS a newer outlook. Although the people do so interest in the popular GIS services, measures should be taken that common people become more and more attracted and aware with the GIS. The future research direction should mainly focus on making GIS more and more user friendly using the best available tool particularly mathematical morphology so that this easy –to-use technique may be designed in such a way that it becomes not only confined to the specialist of the area but also to the general public. We hope to see this morphology as a tool for analysis of images of the Geographical Information Science by the common users as well.

## 4. Conclusion

In this paper, the applications and effectiveness of mathematical morphology has been presented. The way, in which it is beneficial in dealing with many image-related problems, through various cited examples was brought forth in a lucid manner. We saw the strength and versatility of this technique through the review of previous research works in this domain.

It has been rightly remarked by a famous researcher "though mathematical morphology is a powerful tool for many image analysis, it is not that famous because it is not useful or it is not used so it is not famous, may be because it involves too many mathematical theory!" but we saw the aspect in which it can be dealt with several image queries.

Hence, we conclude on this note of discussion that in spite of not gaining ample recognition, Geographic Information Sciences and image processing evidenced the efficiency of morphology and the time has come to prove its enduringness to the critics.

The crux of the matter is that we can await some more precise results in the world of images in the near future where the differences between the morphological and non-morphological operations will be well known to us.

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## REFERENCES/BIBLIOGRAPHY

1. Wyne Hsu, Mong Li Lee, Ji Zhang, **"**Image Mining: Trends and Developments", Journal of Intelligent Information Systems Volume 19, Issue 1 (July 2002).
2. William Green, "Edge Detection Tutorial." Internet:http://www.pages.drexel.edu/~weg22/edge.html, 2002.
3. M. Kowalczyk , P. Koza, P. Kupidura , J. Marciniak, "APPLICATION OF MATHEMATICAL MORPHOLOGY OPERATIONS FOR SIMPLIFICATION AND IMPROVEMENT OF CORRELATION OF IMAGES IN CLOSE-RANGE PHOTOGRAMMETRY", The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences. Vol. XXXVII. Part B5. Beijing 2008
4. Adrien Bousseau, "Mathematical Morphology a non exhaustive overview", pages 2-14.
5. Radhakrishnan, B. D. S.Sagar, and B. Venkatesh,*"* Morphological Image Analysis of
Transmission Systems*"*IEEE TRANSACTIONS ON POWER DELIVERY, VOL. 20, NO. 1, JANUARY 2005.
6. Pierre Soille, Morphological Image Analysis. Springer-Verlag, 2003.
7. Rafael C. Gonzalez, Richard E Woods. Digital Image Processing. Prentice Hall, second edition, 2002.
8. Milan Sonka et. al. Image Processing, Analysis and Machine Vision. PWS Publishing, second edition, 1999.
9. Edge Detection using mathematical morphology, Neil Scott, RESEARCH CENTRE FOR INTEGRATED MICROSYSTEMS- UNIVERSITY OF WINDSOR, June 15th, 2007.
10. LIXU GU, SEMINAR SERIES ON ADVANCED MEDICAL IMAGE PROCESSING, LIXU GU, Robarts Research Institute London, Ontario, Canada, September 13, 2002
11. L. Najman, Using Mathematical Morphology for Document Skew Estimation, Laboratoire A2SI, Groupe ESIEE Cit´e Descartes, BP99.
12. Michael F. Goodchild, University of California, Santa Barbara, GEOGRAPHICAL INFORMATION SCIENCE FIFTEEN YEARS LATER, pages 2-4
13. Center of Mathematical Morphology (http://cmm.ensmp.fr/index_eng.html) at Ecole des Mines de Paris.
14. Morphology Digest (http://www.cwi.nl/projects/morphology) edited by Henk Heijmans, Centre for Mathematics and Computer Science, Amsterdam, The Netherlands
15."Image analysis and mathematical morphology" by J. Serra (call# TA1632.S47 v.2 1988)
16. STEFANO SPACCAPIETRA, NADINE CULLOT, CHRISTINE PARENT, CHRISTELLE VANGENOT, "On Spatial Ontologies"
17. Celine Hudelot, Jamal Atif, Isabelle Bloch, "A Special Relation Ontology using Mathematical Morphology and Description Logics for Spatial Learning"
18. Ole Christian Eidheim," Introduction to Mathematical Morphology", Department of Computer and Information Science, NTNU
19. Shivprakash Iyer, Sunil K. Sinha J., 2005. Automated condition assessment of buried sewer pipes based on digital imaging techniques. Indian Institute of Science, Sep.–Oct., 85, 235–252
20. Tao, C.V., 1998. Mobile Mapping Technology for Road Network Data Acquisition 1. Journal of Geospatial Engineering, Vol. 2, No.2, pp. 1-13. Tokyo, Japan.
21. Michael F. Goodchild, "CHALLENGES AND OPPORTUNITIES", pages 1-10