# Brain Tumor Extraction from MRI Brain Images Using Marker Based Watershed Algorithm

Benson C. C.[1], Lajish V. L.[2], Kumar Rajamani.[3]
Department of Computer Science, University of Calicut, Kerala, India- 673 635 [1, 2]
Robert Bosch Engineering and Business Solutions[3]
bensonuoc@gmail.com[1], lajish@uoc.ac.in[2], kumartr@gmail.com[3]

*Abstract*— **Human brain is the most complex and mysterious part of human body. Many complex functions are controlled by brain. Brain imaging is a widely applicable method for diagnosing many brain abnormalities such as brain tumor, stroke, paralysis etc. Magnetic Resonance Imaging (MRI) is one of the methods used for brain imaging. It is used for analysing internal structures in detail. Brain tumor is an abnormal mass of tissue in which cells grow and multiply uncontrollably, seemingly unchecked by the mechanisms that control normal cells. The aim of this paper is to extract tumor region from the brain MRI image using watershed algorithm based on different feature combinations such as colour, edge, orientation and texture. The results are compared with the ground truth images. Here we used marker based watershed algorithm for extracting tumored region and Dice and Tanimoto coefficients are used for comparison of the results. The method proposed here is found to be producing a promising result.**

*Index Terms*—**Brain Imaging, Brain Tumor, MRI, Segmentation, Watershed, Dice Coefficient, Tanimoto coefficient.**

## I. INTRODUCTION

Human brain and spinal cord make up the central nervous system. Brain tissue is composed of several different types of cells. These include neurons and specialized cells called glial cells, such as astrocytes, oligodendrocytes, ependymal cells, and microglial. Though the brain is an important part of human body, many dangerous diseases are affecting the brain. Brain tumor is an example for such disease. The word tumor is synonym with neoplasm, which means abnormal growth of cells. A brain tumor is an abnormal growth of cells in the brain or the membranes surrounding the brain. According to the World Health Organization (WHO) there are mainly four grades of brain tumors discovered [1]. Grade 1 and 2 are slowest growing brain tumors called low grade gliomas or benign. It doesn't affect the neighboring healthy tissues. Grade 3 and 4 are highest growing brain tumors called high grade gliomas or malignant. It may be spread to neighboring cells. One of the main causes of increasing mortality among people is brain tumor. Research shows that in most of the developing counties, the number of people suffering and dying from brain tumors have increased to 300 per year during past few decades [2]. The tumor increases pressure inside the skull and so exerts pressure on the entire brain: This phenomenon is responsible for many of the symptoms of brain tumors regardless of whether they are benign or malignant.

There are about more than 100 different types of brain tumors discovered. They are generally named after the type of cell they developed from. Some of them are Astrocytoma, Oligodendroglioma, Ependymoma, Meningioma, haemangioblastomas etc. [3].

Diagnosing brain tumor diseases is a challenging task as the anatomical structure of brain is very complex. Recently there are many types of medical imaging modalities available for the diagnosing purposes. Medical imaging is the process of visualizing the interior part of the human body for clinical purposes. It is an emerging and challenging field of medical science. Brain imaging helps the doctors and researchers to view the internal part of human brain without any neurosurgery. Many imaging modalities such as Computer Tomography (CT), Positron Emission Tomography (PET), Single Photon Emission Tomography (SPECT), Magnetic Resonance Imaging (MRI) and functional MRI (fMRI) are used for brain imaging. MRI brain image analysis techniques are widely used to detect the abnormalities in the human brain [4]. MRI is basically used in the biomedical field to detect and visualize finer details in the internal structure of the body. This technique is basically used to detect the differences in the tissues which have a far better techniques compared to computer tomography. The main advantage of using MRI instead of other imaging technique is that it does not emit any harmful radiation to the human body [5].

There are various algorithms exists for the extraction of tumor part from the brain MRI image. Brain tumor cells have high proteinaceous fluid which has very high intensity. Since many of the watershed algorithms work on the basis of intensity values, we used watershed segmentation method for extracting the tumored part from the image. The intuitive idea underlying the watershed notion comes from the field of topography. Imagine our image as a lake and holes pierced in local minima. Water will fill up basins starting at these local minima, and, at points where water coming from different basins would meet, dams are built. As a result, the surface is partitioned into regions or basins separated by dams, called watershed lines [6]. The watershed algorithm is developed from this concept. It has been used in various image segmentation applications [7-12]. It is also found that the watershed algorithm is exclusively used in many medical imaging applications [13-17].

The rest of this paper is organized as follows: In section 2, related works are explained; in section 3, methodology of the paper is described; experimental results and evaluation have been written in section 4 and finally in section 5, conclusions are explained.

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## II. RELATED WORKS

Segmentation of anatomical regions of the brain is a fundamental problem in medical image analysis. There are many methods used for tumor segmentation. Some of them are clustering methods, threshold based methods, region growing methods, graph-cut based methods, active contour methods [18]. Many promising research works were also reported based on Markov random field model, artificial neural network, atlas-guided approaches, deformable models, and statistical segmentation methods in this area [19]. It is also proven that since the tumor cells have high intensity value, intensity based methods are more efficient than all other methods. Considering this in this present work we have used watershed based segmentation methods for tumor segmentation. In the literature we can see many types of watershed segmentation methods- Vincent-Soille watershed algorithm [20], Meyer's watershed algorithm [21], Cost-based watershed [22-24], and Topological watershed [25]. Ahmad EL ALLAOUT and M'barek NASRI proposed a novel method for extracting various brain regions from the MRI image using marker based watershed algorithm [26]. They applied morphological reconstruction for getting markers on the image. After computing the morphological reconstruction of the original image, they used the complement of the reconstructed image. Then the image is subtracted from the original image.

Pratik. P. Singhai and Siddharth A. Ladhake proposed another method of marker based watershed algorithm for detecting the tumor area form the MRI brain image [27]. They produced internal markers from the grayscale images and external markers are found by finding pixels that are exactly midway between the internal markers. Shutong Tse et al. suggested a robust method for segmentation of bright field cell images from microscopy using marker based watershed algorithm. Instead of heuristically locate where the initial markers, they used a multiphase level set marker extraction method [15, 28]. Detailed description of watershed algorithm is covered in the methodology section.

## III. METHODOLOGY

In this work marker based watershed segmentation algorithm proposed by Meyer [21] is used for segmenting tumored area from the MRI brain image.

### A. MR Image Data Set

We have used 45 samples of MRI brain tumored images provided by a Medical College hospital, for the experimental purposes. All the images taken for the experiment are axial orientation Diffusion Weighted Images (DWI) of dimension 512 x 512.

### B. General Watershed Algorithm

Image segmentation is the process of separating region of interest from an image such that each region is homogeneous with respect to some property such as intensity value of the pixels. Watershed algorithm is well recognized and efficient method of segmentation based on the idea of mathematical morphology. Watershed transform for segmentation is originally proposed by Digabel and Lantuejoul in 1977 [29] and later it is improved by Li et al. in 2003 [30]. The basic principle behind the watershed transform comes from topography. In such a topographic view, we can consider three types of points- a) Points belonging to regional minimum. A regional minimum is a minimum point which belongs to the end of the path of steepest descent, b) Points at which a drop of water, if placed at the location of any of those points, would fall with certainty to a single minimum is called as catchment basin or watershed. The pixels in a catchment basin should have the similar characteristics, c) Points at which water would be equally likely to fall to more than one minimum, is called as divide lines or watershed lines. It is used to avoid the merging of two different regions [31].

The main objective of watershed algorithm is to find watershed lines. Suppose that a hole is created on each regional minimum and let the water to rise through the holes at a uniform rate. When the water level is reached at the peak point the process is stopped. Now the landscape is divided in to different regions separated by dams or watershed lines. When applying this concept in to image segmentation, the entire image will be divided in to different regions based on the intensity values and separated by watershed lines. Fig. 1 represents the modelling of watershed algorithm.

### C. Mathematical Background of Watershed Algorithm

Let $M_j$, j= 1 to R be the different regional minima of an input image f(x, y). Assume that C ($M_j$) be the set of points in a catchment basin associated with the regional minimum $M_j$. T[n] represents the set of coordinates (p, q) of the image in which f(p, q) < n. Mathematically we can represent it as

$$T[n] = \{(p, q) \mid f(p, q) < n\} \quad (1)$$

That is T[n] is a set of coordinates of the image f(x, y) lying below the plane f(x, y) = n. min and max denote the minimum and maximum value of f(x, y). The flooding starts from the range of n = min + 1 to n = max + 1. Let $C_n$ ($M_j$) represents the set of coordinates in the catchment basin associated with minimum $M_j$ that are flooded at stage n. $C_n$ ($M_j$) can be viewed as a binary image represented as

$$C_n(M_j) = \begin{cases} 1, & \text{If } (x,y)\ \varepsilon\ C(M_j) \text{ and } (x,y)\varepsilon\, T[n] \\ 0, & Otherwise \end{cases} \quad (2)$$

C[n] represents the union of the flooded catchment basins at the stage n.

$$C[n] = \bigcup_{i=1}^{R} Cn(Mj) \quad (3)$$

$$C[max + 1] = \bigcup_{i=1}^{R} C(Mj) \quad (4)$$

From the equations we can show that C [n-1] is a subset of C [n] and C [n] is a subset of T [n]. Therefore C [n-1] is a subset of T [n]. For finding the watershed lines, we initialize C[min+1] = T [min+1]. The algorithm then recursively finds

C[n] from C [n-1]. The calculation of C[n] from C [n-1] as follows. Let H be the set of connected components in T [n]. Then for each connected component h ϵ H[n], there may be three possibilities

a. h ∩ C[n-1] is empty

b. h ∩ C[n-1] contains one connected component of C[n-1]

c. h ∩ C[n-1] contains more than one connected component of C[n-1]

Further flooding would lead to the merging of these catchment basins. One pixel thick dam can be constructed by dilating h ∩ C [n-1] with a 3 X 3 structuring element of 1s and constraining the dilation to h.

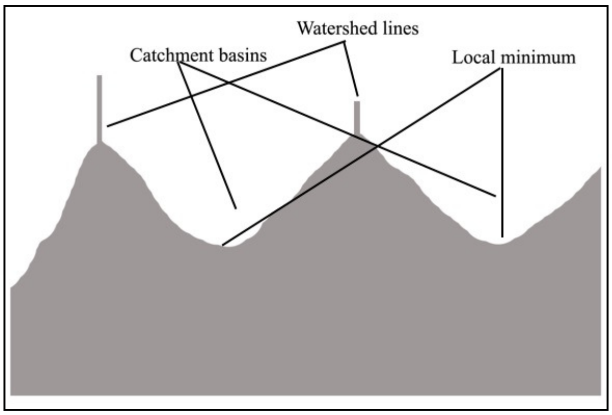
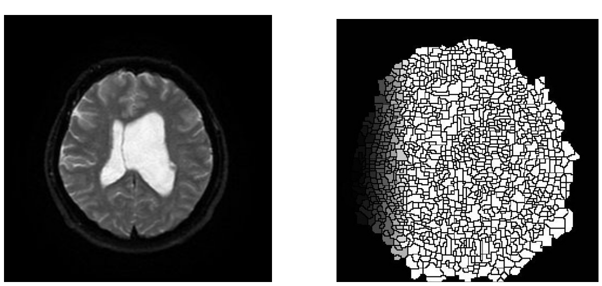



Fig. 1. Modelling of watershed algorithm

The generic problem behind the watershed algorithm is over-segmentation. It is because of the noises and other irregularities present in the image. Fig. 2 represents over segmentation of general watershed algorithm. An efficient and commonly used method to avoid the over-segmentation problem is the use of markers in the image. It is proposed by Meyer [21]. A marker is a connected component belonging to an image. There are mainly two types of markers-internal markers and external markers. Internal marker is associated with the objects of interest and external marker is associated with background. Meyer's marker based watershed algorithm is proposed in the next section.



a) Original Image b) Over segmented image

Fig. 2. Over segmentation of watershed algorithm

## IV. Meyer's Marker BASED WATERSHED Algorithm

Segmentation using watershed algorithm gives better results when we are using internal and external markers. Marker controlled watershed segmentation follows the procedure given below.

Step 1: Compute a segmentation function from the given image.

Step 2: Identify the internal markers. These are the connected components of pixels associated with objects of interest.

Step 3: Identify the external markers. These are the connected components of pixels associated with the background of the objects.

Step 3: Modify the segmentation function so that it only has minima at the internal and external marker location.

Step 4: Calculate the watershed transform of the modified segmentation function.

## V. Proposed Method

Segmentation of the tumored area from the MRI brain images is one of the most challenging and complicated tasks in the medical image processing. Although watershed algorithm is an efficient method for medical image segmentation, it suffers from over segmentation problem. It is due to the noises and other unwanted effects in the image. For resolving this problem, we used marker based watershed algorithm for the segmentation of tumored area. We applied an atlas based approach for the detection of internal and external markers. In atlas based approach prior information about the image is used for marker identification [32]. We implemented marker based watershed algorithm in an interactive tool kit, Ilastik. Ilastik is an open source software that combines interactive machine learning, active learning, and the ability to cope with complex textures within a convenient and unified user interface [33]. The internal and external markers are manually marked in the image with the help of prior information about the tumor.

We used different combinations of features for the segmentation purpose. The combinations are:

- Color and Edge
- Orientation and Texture
- Color and Orientation
- Color and Texture
- Edge and Orientation
- Edge and Texture

Six combinations of features are used for watershed segmentation. Each combination includes two features. We excluded more than two features combinations since they produce the same results. All the segmentation process is implemented in Ilastik interactive toolkit. These results are then compared with the manually marked ground truths created using with ITK Snap tool. It is also an open source software that contains innovative tools for manual outlining and quality control [34].

Here we used Ilastik toolkit for watershed segmentation and ITK Snap tool for ground truth creation. The comparison procedure is implemented using Matlab.

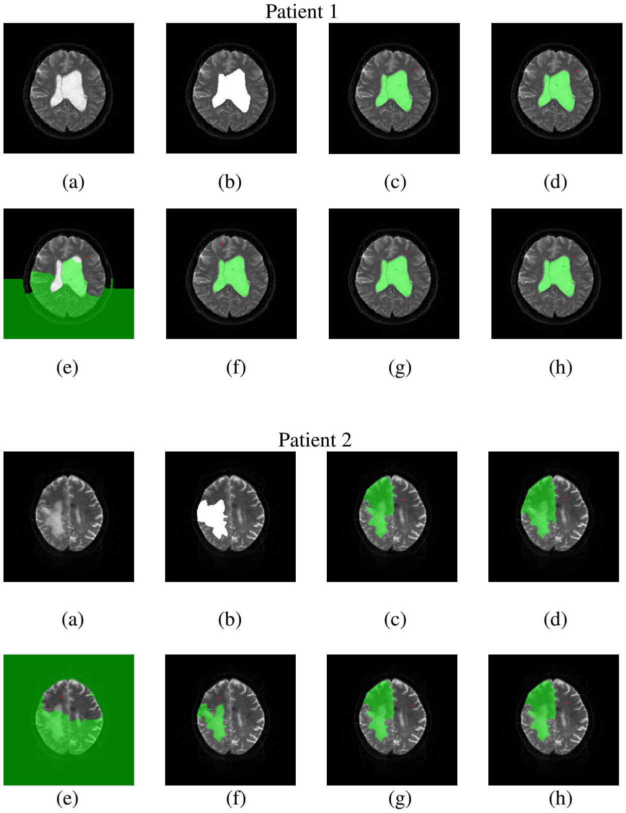
## VI. Results and Discussion

The experimental results obtained from the applied watershed algorithm on various sample images based on the different combinations of features are shown in the figures. In the figure.3, first row of images are the four original image samples collected from the hospital. Second row of images are the ground truth image crated using ITK Snap tool. Experimental results using different combinations of features are given in the following rows. The accuracy of the results is calculated using Dice [35] and Tanimoto [36] coefficients. These are two standard measures used to compare the segmentation accuracy. The table 1 and 2 shows accuracy of the algorithm using different combination of features.

$$\text{Dice Coefficient} = \frac{2\,|A(S) \cap A(G)|}{|A(S)| + |A(G)|} \quad (5)$$

$$\text{Tanimoto Coefficient} = \frac{|A(S) \cap A(G)|}{|A(S)| + |A(G)| - |A(S) \cap A(G)|} \quad (6)$$

Where A (S) represents area of the tumor that we have calculated using proposed algorithm and A (G) represents area of tumor that we marked as ground truth.



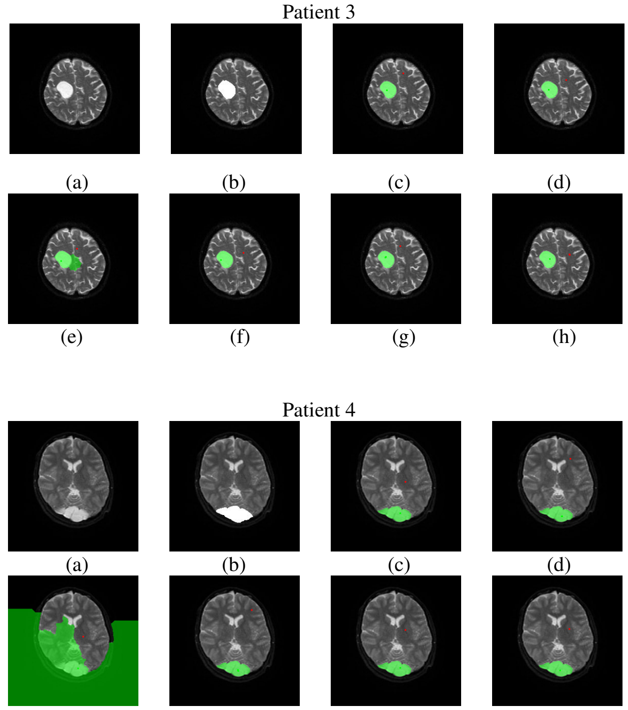




Fig. 3. Results after applying watershed segmentation with different combinations of features on patient 1. (a) Original image, (b) Ground truth image, (c) Color and Edge, (d) Orientation and Texture, (e) Color and Orientation, (f) Color and Texture, (g) Edge and Orientation, (h) Edge and Texture.

| Patient / Features | Patient 1 | Patient 2 | Patient 3 | Patient 4 |
|---|---|---|---|---|
| Color & Edge | .9398 | .9241 | .9183 | .9140 |
| Orientation & Texture | .9398 | .9241 | .9183 | .9140 |
| Color & Orientation | .7393 | .6222 | .8966 | .7135 |
| Color & Texture | .9398 | .9241 | .9183 | .9140 |
| Edge & Orientation | .9398 | .9241 | .9183 | .9140 |
| Edge & Texture | .9398 | .9241 | .9183 | .9140 |

Table. 1 Results comparison using Dice coefficient

| Patient / Features | Patient 1 | Patient 2 | Patient 3 | Patient 4 |
|---|---|---|---|---|
| Color & Edge | .8864 | .8314 | .8489 | .8417 |
| Orientation & Texture | .8864 | .8314 | .8489 | .8417 |
| Color & Orientation | .5864 | .5516 | .8125 | .5547 |
| Color & Texture | .8864 | .8314 | .8489 | .8317 |
| Edge & Orientation | .8864 | .8314 | .8489 | .8417 |
| Edge & Texture | .8864 | .8314 | .8489 | .8417 |

Table. 2 Results comparison using Tanimoto coefficient

Table.1and 2 shows the results after comparing the output of the algorithm using different feature combinations. All the combinations except color and orientation features produce same accuracy results. The proposed feature combination method of watershed segmentation algorithm gives more accurate results than other methods [2, 27, 37-39] in the literature.

## VII. Conclusion and Future Enhancements

Tumor identification and segmentation from MRI brain images are the most challenging task for a clinician. In this work marker based watershed segmentation algorithm is implemented with different combinations of features. Each combination produces prominent results. From the table, it is evident that the color and orientation features cannot be considered for the watershed segmentation purpose. All other combinations yield the same result. By comparing the other methods, the proposed method using combination of features gives better results. Here we manually identified the markers for the algorithm. Future work is to identify the markers automatically and segment the tumored area based on the automatically identified markers.

## References


[1] Kleihues P, Burger PC, Scheithauer BW, "The new WHO classification of brain tumours", Brain Pathol 3 (3): 255-68, 1993.

[2] Anam Mustaqeem, Ali Javed and Tehseen Fatima, "An Efficient Brain Tumor Detection Algorithm Using Watershed & Thresholding based Segmentation", International Journal of Image, Graphics and Signal Processing, September 2012.

[3] S. Cha, "Update on Brain Tumor Imaging: From Anatomy to Physiology", American Journal of Neuroradiology, March, 2006 27: 475-487.

[4] Sudipta Roy, Atanu Saha and Samir K. Bandyopadhyay, "Brain Tumor Segmentation and Quantification from MRI of Brain", Journal of Global Research in Computer Science, Vol.2 No. 4, April 2011.

[5] R. G. Selkar, M. N. Tahakare and B. J. Chilke, "Review on Detection and segmentation of brain tumor using watershed and thresholding algorithm", IORD Journal of Science & Technology. Vol.1, Issue II, Jan-Feb 2014.

[6] Laurent Najman and Michel Couprie, "Watershed algorithms and contrast preservation", Discrete Geometry for Computer Imagery, 2003, France. Springer, Discrete Geometry for Computer Imagery, 2886, pp. 62-71, Lecture Notes in Computer Science.

[7] Amandeep Kaur, Aayushi, "Image Segmentation Using Watershed Transform", International Journal of Soft Computing and Engineering (IJSCE), Volume-4, Issue-1, March 2014.

[8] Thodeti Srikanth, Prof P.Pradeep Kumar, Ashwin Kuma, "Color Image Segmentation using Watershed Algorithm", (IJCSIT) International Journal of Computer Science and Information Technologies, Vol. 2 (5) , 2011, 2332-2334.

[9] Lamia Jaafar Belaid1 and Walid Mourou, "Image Segmentation: A Watershed Transformation Algorithm", Image Anal Stereol 2009; 28:93-102.

[10] V. Grau, A. U. J. Mewes, M. Alcañiz, R. Kikinis, and S. K. Warfield, "Improved Watershed Transform for Medical Image Segmentation Using Prior Information", IEEE Transactions On Medical Imaging, Vol. 23, No. 4, April 2004.

[11] Vincent, L., Soille, P, "Watersheds in digital spaces: An efficient algorithm based on immersion simulations", IEEE Trans. on PAMI 13 (1991) 583–598.

[12] Malik Sikandar Hayat Khiyal, Aihab Khan, and Amna Bibi, "Modified Watershed Algorithm for Segmentation of 2D Images", Issues in Informing Science and Information Technology, Volume 6, 2009.

[13] Mariela A. Gonzalez, Teresita R. Cuadrado, Virginia L. Ballarin, "Comparing marker definition algorithms for Watershed segmentation in microscopy images", JCS&T Vol. 8 No. 3 October 2008.

[14] Shengzhou Xu, Hong Liu, Enmin Song, "Marker-Controlled Watershed for Lesion Segmentation in Mammograms", Journal of Digit Imaging (2011) 24:754–763.

[15] Xiaopeng Wang, Shengyang Wan and Tao Lei, "Brain Tumor Segmentation Based on Structuring Element Map Modification and Marker controlled Watershed Transform", Journal Of Software, Vol. 9, No. 11, November 2014.

[16] Ahmed Wasif Reza, C. Eswaran and Kaharudin Dimyati, "Diagnosis of Diabetic Retinopathy: Automatic Extraction of Optic Disc and Exudates from Retinal Images using Marker-controlled Watershed Transformation", Journal of Med Syst (2011) 35:1491–1501.

[17] Devaki. K. and V. Murali Bhaskaran, "A Novel Approach To Detect Fissures In Lung CT Images Using Marker-Based Watershed Transformation", Journal of Computer Science 10 (6): 896-905, 2014.

[18] Mohammed Sabbith Hamoud Al- Tamimi, Ghazali Sulong, "Tumor Brain Detection through MR Images: A Review of Literature", Journal of Theoretical and Applied Information Technology, April 2004, Vol. 62, No. 2.

[19] M. A. Balafar, A. R. Ramil, M. I. Saripan, S. Mashohor, "Review of Brain MRI Image Segmentation Methods", Springer, Artif Intell Rev (2010), 33:261-274.

[20] Vincent, L., Soille, P, "Watersheds in digital spaces: An efficient algorithm based on immersion simulations", IEEE Trans. on PAMI 13 (1991) 583–598.

[21] Meyer, F, "Un algorithme optimal de ligne de partage des eaux" In: Actes du 8`eme Congr`es AFCET, Lyon-Villeurbanne, France (1991) 847–859.

[22] Meyer, F."Topographic distance and watershed lines" Signal Processing 38 (1994) 113–126 Special issue on Mathematical Morphology.

[23] Najman, L., Schmitt, M." Watershed of a continuous function" Signal Processing 38 (1994) 99–112 Special issue on Mathematical Morphology.

[24] Lotufo, R.A., Falcao, A.X., Zampirolli, F.A." Ift-watershed from gray-scale marker", In: SIBGRAPI'02, Fortaleza-CE, Brazil (2002) 146–152.

[25] Couprie, M., Bertrand, G." Topological grayscale watershed transform" In: SPIE Vision Geometry V Proceedings. Volume 3168. (1997) 136–146.

[26] Ahmad EL ALLAOUT and M'barek NASRI, "Medical Image Segmentation by Marker Controlled Watershed and Mathematical Morphology",The International Journal of Multimedia and Its Applications (IJMA), Vol.4, No.3, June 2012.

[27] Pratik. P. Singhai and Siddharth A. Ladhake, "Brain Tumor Detection Using Marker Based Watershed Segmentation from Digital MR Images", International Journal of Innovative Technology and Exploring Engineering, Vol.2, Issue.5, April 2013.

[28] Shutong Tse, Laura Bradbury, Justin W.L. Wan, Haig Djambazian, Robert Sladek and Thomas Hudson, "A combined watershed and level set method for segmentation of brightfield cell images", Proc. SPIE 7259, Medical Imaging 2009: Image Processing, 72593G (March 27, 2009); doi:10.1117/12.811747.

[29] H. Digabel and C. Lantuéjoul, “Iterative algorithms”, in Proceedings of the 2nd European Symposium on Quantitative Analysis of Microstructures in Materials Sciences, Biology and Medicine, pp. 85–99, Caen,France, October 1977.

[30] Li, H., Elmoataz, A., Fadili, J. and Ruan, S. “An improved image segmentation approach based on level set and mathematical morphology”, Proceedings of the Third International Symposium on Multispectral Image Processing and Pattern Recognition, volume 5286, pp. 851-854,2003.

[31] Rafael C. Gonzalez, Richard E. Woods, “Digital Image Processing”, Chapter 10, third edition, PHI Publications, 2008.

[32] Neeraj Sharma and Lalit M. Aggarwal, “Automated medical image segmentation techniques”, J Med Phys. 2010 Jan-Mar; 35(1): 3–14.

[33] C. Sommer, C. Straehle, U. Köthe, and F.A. Hamprecht, “ilastik: Interactive Learning and Segmentation Toolkit”, 8th IEEE International Symposium on Biomedical Imaging (ISBI 2011), in press.

[34] P.A. Yushkevich, J. Piven, H. Cody, S. Ho, J.C. Gee, G. Gerig, “User-guided level set segmentation of anatomical structures with ITK-SNAP”, Insight J., 1 (2005) (special issue on ISC/NA-MIC/MICCAI Workshop on Open-Source Software).

[35] Lee R. Dice, “Measures of the Amount of Ecologic Association between Species”, Ecological Society of America, 26(3), 297–302, 1945.

[36] T.T. Tanimoto, “An elementary mathematical theory of classification and prediction”, IBM Report (November, 1958), cited in: G. Salton, Automatic Information Organization and Retrieval (McGrawHill, 1968) p. 238.

[37] Xiaopeng Wang, Shengyang Wan and Tao Lei, “Brain Tumor Segmentation Based on Structuring Element Map Modification and Marker controlled Watershed Transform”, JOURNAL OF SOFTWARE, VOL. 9, NO. 11, NOVEMBER 2014.

[38] Hui Zhu, Bofeng Zhang, Anping Songa and Wu Zhang, “An Improved Method to Reduce Over-segmentation of Watershed Transformation and its Application in the Contour Extraction of Brain Image”, 2009 Eighth IEEE International Conference on Dependable, Autonomic and Secure Computing.

[39] Swe Zin Oo and Aung Soe Khaing,” Brain Tumor Detection And Segmentation Using Watershed Segmentation And Morphological Operation”, International Journal of Research in Engineering and Technology, Volume: 03 Issue: 03, Mar-2014.