Detection of Alzheimer’s disease with segmentation approach using K-Means Clustering and Watershed Method of MRI image

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Abstract. Alzheimer's disease is a common form of neurodegenerative disorders characterized by defective brain cells, such as neurofibrillary tangles and amyloid plaque that is progressive. One of the physical characteristics of someone suffering from Alzheimer's disease is shrinking of the hippocampus area of the brain. The hippocampus is the smallest part of the brain that serves to save memory. The detection of Alzheimer's disease can be done using a Magnetic Resonance Image (MRI) which is a technique of noninvasive for an analysis of the structure of the brain in the Alzheimer's patient. In this research, K-Means Clustering and Watershed method are used to segment the hippocampus area which is one part of the brain that was attacked by Alzheimer's disease. The analysis used to detect Alzheimer's is comparing the value of the threshold with the number of white pixels in the images. The data used in this research are Open Access Series of Image Studies (OASIS) database by using the image of coronal slices. Based on the our experiment result, both K-Means Clustering and Watershed method can segment the hippocampus area to detect Alzheimer's disease.

Keywords: Alzheimer's disease, MRI images, image processing, segmentation, clustering

1. Introduction
Alzheimer’s disease is a common form of an incurable neurogenerative disorder that attacks the memory of the brain slowly. The hippocampus is the smallest part of the brain that serves to save memory [1]. This area can be used to detect Alzheimer's even in the earlier stages of Mild Cognitive Impairment (MCI). MCI is a transitional condition between normal aging and dementia [2]. People who suffer from Alzheimer’s, the hippocampus will experience shrinkage. The strength of Alzheimer's attacks people over the age of 65 years [3]. Based on Alzheimer's world report [4], there are about 46 million people suffering from Alzheimer's in the world in 2015 and to 50 million people in 2017. This number is expected to increase almost 2-fold every 20 years, reaching 75 million in 2030 and 131 million in 2050. Neuroimaging data analysis has achieved much and more accuracy, which provides early and accurate detection of Alzheimer's disease. Alzheimer's disease can publish in detail using Magnetic Resonance Image (MRI). MRI is a non-innovation brain imaging technique that can display detailed anatomy of Computed Tomography (CT), Tomography Emission Computed Tomography (SPECT), and Positron Emission Tomography (PET) scan [5].
In this research used a segmentation approach in detecting Alzheimer's in the hippocampus area. The method to be used in image segmentation is binarized image using K-Means Clustering and will be compared with Watershed method can perform best segmentation method in detecting Alzheimer. The result of this research is whether one can be detected Alzheimer's or not from segmentation in the hippocampus area.

2. Methodology

2.1. Research data

The MRI scan images used are based on the Open Access Series of Image Studies (OASIS) database [6] diagnosed with Alzheimer's above the age of 60 with levels of Mild Cognitive Impairment (MCI) to Alzheimer's. In this research, MRI scans of brain used were coronal slices of Alzheimer's and MCI images with 8-bit images measuring 176 × 176 pixels.

2.2. Propose method

Initially the set of MRI scan are given as input. After getting the MRI scan image, the image to be used are coronal slices (front rear view). The slices of images will be through the process of improving image quality (preprocessing) with two methods are Mean filter, Top and Bottom Hat filtering. Because the MRI image of the Mean filter results into the blurring effect, morphology of Top and Bottom Hat Filtering are done to further clarify the image. After that the results of image quality will be processed by using the method of K-Means Clustering and Watershed. Then after getting the results from both methods, an analysis is performed for the best methods. Then the result of segmentation can be used to determine MCI or Alzheimer's with binarization approach in the feature extraction stage. Figure 1 shows the overall proposed methods that were applied in this research.

![Figure 1. Block diagram for proposed method](image-url)
2.3. Mean filter
Mean filter uses the average result of the central pixel and all its neighbors to get the new pixel intensity value. Mean filter is generally regarded as a convolution filter [7], which is the multiplication of discrete functions between the image \( f(x, y) \) and the filter \( g(x, y) \) or the sum operation of the multiplication by the operation notation (*) that multiplies image with mask (kernel). In this research use operation of Mean filter in convolution \( 3 \times 3 \) which can be defined as follows:

\[
h(x, y) = f(x, y) \ast g(x, y)
\]  
(1)

where \( f(x, y) \) is the input image and \( g(x, y) \) is convolution kernel or mask.

2.4. Top and bottom hat filtering
Top hat filtering is the difference between image input and image after having opening operation [8]. Top hat filtering is given as [9]:

\[
l_{\text{top}} = A - (A \circ B)
\]  
(2)

where\( A \) is the input image and \( (A \circ B) \) the image of the opening operation. The opening operator is defined by an erosion followed by a dilation. This filter is useful for getting global shape of an object that has varying intensity. The opening performs a dilation followed by erosion.

Bottom hat filtering is the difference between the image after undergoing closing operation and input image. A closing operator is defined by a dilation followed of an erosion. Bottom hat can be defined as follows [9]:

\[
l_{\text{bot}} = (A \cdot B) - A
\]  
(3)

where \( A \) is the input image and \( (A \cdot B) \) the image of the closing operation. The closing performs erosion followed by dilation.

The incorporation of Top and Bottom Hat Filtering is to improve image contrast and clarify the shape of the object in the image.

Because the hippocampus is small, in this research the filtering process is used so that element B is required with size \( 3 \times 3 \). The filtered image is then obtained by [10]:

\[
l_{F} = (A + l_{\text{top}}) - l_{\text{bot}}
\]  
(4)

2.5. K-Means clustering
K-Means Clustering is a method that uses learning unsupervised learning to group data into several clusters based on the similarity of characteristics possessed. The algorithm consists of the following steps to classify a data set \( x_i, i = 1, 2, 3, \ldots n \) into \( K \) clusters. \( K \) cluster used is \( K = 3 \).

The algorithm for K-Means Clustering is following as [10]:
1. The centroid \( c_j \) is initialized using \( K \) random intensities.
2. Each of the data point \( x_i \) is clustered by grouping it into the nearest centroid.
3. The positions of \( K \) centroids are calculated when all the data points have been assigned into any of the cluster.
4. Steps 2 dan 3 are repeated until there is no further change in the cluster labels of the image.
This algorithm aims at minimizing an objective function given by:

\[ d = \sum_{j=1}^{K} \sum_{i=1}^{n} \left\| x_i^{(j)} - c_j \right\|^2 \] (5)

where \( K \) is the clusters, \( c_j \) is the centroids and \( d \) is the centroids distance to the data point \( x_i \). Then from the final cluster result where each cluster has mean value \( M_1, M_2, M_3 \) are used to compute the threshold value \( T \) given by [10]:

\[ T = \frac{M_1 + M_2 + M_3}{3} \] (6)

The given input image \( I_F(x, y) \) is converted to a binary image \( g \) as:

\[ g(x, y) = \begin{cases} 1, & I_F(x, y) > T \\ 0, & I_F(x, y) \leq T \end{cases} \] (7)

2.6. Watershed

Watershed is a method that uses a regional and edge approach. The image is represented as a topographic surface with each value in pixels representing the surface height. The flow of water will flow to the lower surface (catchment basins) so that the low surface will become the target object of segmentation. The purpose of this Watershed segmentation is to find the Watershed boundary that will separate the objects from one another. The image is the Watershed algorithm the first developed by [11]. Figure 2 shows the Watershed algorithm that were applied in this research.

2.7. Binarization approach

Binarization is a method used to extract features of an image that will change input image into binary image (0 and 1). The binarization approach was carried out to classify Alzheimer's and MCI. If the number of white pixels more than the threshold then diagnosed Alzheimer. Otherwise, if the number of white pixels less than the threshold then diagnosed MCI [12].

3. Results and discussion

3.1. Preprocessing

Preprocessing is an early stage in image processing that aims to improve image quality or eliminate noise. There are two methods performed, Mean filter and followed by Top and Bottom Hat filtering. Figure 3 shows the result of preprocessing by using Mean filter, and continued by Top and Bottom Hat filtering.

From the results of the implementation of the Mean filter obtained that the results of the Mean filter to produce blurring effect from the input image. Blurring is the smoothing of the value of neighboring pixels, the larger the size of the mask (kernel) the greater the resulting blurring effect [13]. The blurring occurs because of the neighboring value smoothing process so that the resulting value will be the same value for a given matrix size. Since the result of Mean filter gives blurring effect then continued with Top and Bottom Hat filtering method to increase image contrast to produce better quality image.
Figure 2. Flowchart watershed algorithm

Figure 3. (a) original image, (b) mean filter, (c) top and bottom hat filtering.
3.2. Segmentation

Image segmentation is the process of partitioning images into several segments or sections. In this research, segmentation is an important step to detect Alzheimer’s. Objects targeted in this research is the hippocampus (figure 4).

The results of segmentation using the K-Means Clustering and Watershed methods can equally segment the hippocampus clearly but the K-Means Clustering method produces more segmented objects.

3.3. Binarization approach

Binarization is the process of changing the color of the pixel values into two classes, such as black and white. After getting the quantity of black and white pixels on segmentation results of K-Means Clustering and Watershed, then we compared it with the threshold value to diagnosed MCI or Alzheimer’s. Binarization approach depends on the fact that the number of black pixels is much greater than white pixels in Alzheimer’s images, so we started to count the white pixels for Alzheimer’s and MCI images to get an average that can be used later as a threshold, if the number of the white pixels of a new image is greater that the threshold, then it indicates that the image is Alzheimer’s, otherwise, if the number of the white pixels is less than the threshold, it indicates that the image in MCI. The threshold value that is used in this research are 1510 for K-Means Clustering and 1198 for Watershed. Figure 4 shows the binarized image using K-Means clustering and Watershed.

From the results of the table 1 can be concluded that the method of K-Means Clustering and Watershed produce the same predictive target, all patients diagnosed Alzheimer’s. However, the results obtained on the MCI samples (patients 1 and 2) are not giving the right results. This is because MRI images in MCI and Alzheimer’s are difficult to distinguish and the difference in quality of the images between testing and training data.

![Figure 4. (a) Binarized image using K-Means Clustering, and (b) Watershed.](image)

| Patient | Number of white pixels | Actual target | Predictive target |
|---------|------------------------|---------------|------------------|
| Number of white pixels | K-Means Clustering | Watershed | K-Means Clustering | Watershed |
| 1 | 31935 | 61077 | MCI | Alzheimer | Alzheimer |
| 2 | 152501 | 185547 | MCI | Alzheimer | Alzheimer |
| 3 | 37876 | 34956 | Alzheimer | Alzheimer | Alzheimer |
| 4 | 68500 | 92549 | Alzheimer | Alzheimer | Alzheimer |
| 5 | 46757 | 80799 | Alzheimer | Alzheimer | Alzheimer |

Table 1. The result of segmentation method for five sample patients.
4. Conclusion
From the results of research that has been done, K-Means Clustering and Watershed method can be implemented for hippocampus segmentation and both methods can segment the hippocampus clearly. But K-Means Clustering can segment more objects than the Watershed method. While in terms of analysis using binerization approach to detect MCI and Alzheimer's, both methods resulted in the same detection results in diagnosing MCI or Alzheimer's patients. So that it can be concluded that in this research, K-Means Clustering and Watershed method successfully segment the hippocampus and produce the same diagnosis results in detecting Alzheimer's.

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