Automatic Fast Pancreas Segmentation and Classification of Abdominal CT Scans

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Abstract— Medical image segmentation is the most popular research area nowadays. In the existing system, the pancreas segmentation has been performed using the superpixel concepts. The proposed system segments the pancreas from the abdomen CT scan images with the new set of algorithms. This system uses the macro super-pixels for fast and deep labeling, segmentation process and proposes an automated bottom-up approach for pancreas segmentation in abdominal computed tomography (CT) scans. The earlier work on organ segmentation achieved only low accuracies when comparing to organs like the heart, liver, pancreas, etc. In this proposed system a complete self-learning deep analysis method is presented for pancreas segmentation. This utilizes the abdominal computed tomography (CT) scans as input. The method developed a segmentation technique by sorting image patches at different resolutions and cascading macro super-pixels. Macro superpixel segmentation, grouping both strength and likelihood features to form observed statistics in pouring random forest frameworks. At last effortless connectivity based post-processing were done. The proposed system utilizes some histogram and texture features. The method generates dynamic cascaded and macro super-pixel segmentation. For Fast organ detection SIFT (Scalable Invariant Feature Transform) algorithm is proposed. This algorithm helps to detect the descriptors from the image for fast image segmentation. This system used some CT scan images and developed segmentation algorithm using Matlab. The organ from the CT images can be segmented quickly and finally the classification task is performed over the segmented pancreas to categorize it. The classification task finds the organ into two classes such as affected or healthy pancreas.
Key words: Computed Tomography (CT) Scans, Segmentation

I. INTRODUCTION

Digital image processing is one of the fastest growing technologies around the world. It has impacted almost all the areas and has emerged as a subject of interdisciplinary study. Digital Image Processing is useful in two prime application areas first being the improvement of pictorial information for human interpretation and the other is processing of image data for storage, transmission, and representation for autonomous machine perception. The theme of digital image processing refers to processing of digital images by means of a digital computer [11]. A digital image is composed of a finite number of elements, each of which has a particular location and values. An image may be defined as a two dimensional function, f(x, y), where x and y are spatial (plane) coordinates, and the amplitude of f at any pair of co-ordinates(x, y) is called the intensity or gray level of the image at that point. When x, y and the amplitude values of f are all finite, discrete quantities, it is called as digital image. In the current scenario, there is no area of technical endeavor which is not impacted by digital image processing. Many application oriented image analyzers are available and are working satisfactorily in real environment.

II. DIGITAL IMAGE PROCESSING

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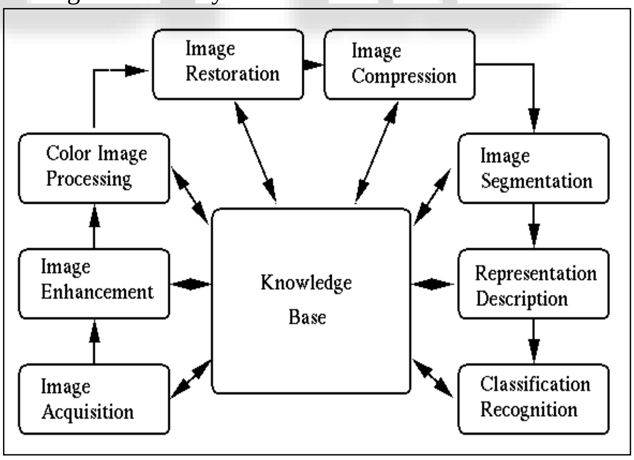

Fig. 1.0: Processes Involved in Image Processing

A. Image Acquisition

This is the first step in any image processing system shown in Figure 1.1. Acquisition could be as simple as being given an image that is already in digital form. Generally, the image acquisition stage involves preprocessing, such as scaling. This step aims to transform an optical image into an array of numerical data which could be late manipulated.

B. Image Enhancement

Image enhancement is a subjective area of image processing. This step is used to improve the subjective quality of the images. It focuses on the desired details or the features of interest in an image. Enhancement technique brings out details that are obscured, or simply highlights certain features of interest in an image.

C. Color image processing

Color image processing has become popular because of the significant increase in the use of digital images over internet. Colors are used for extracting features of interest in an image. Color image processing can be divided into two major areas: full color and pseudo-color processing.

D. Image Restoration

Unlike enhancement which is subjective image restoration is objective and tends to be based on mathematical or probabilistic model of image degradation. It is an area that also deals with improving the appearance of an image.

E. Image Compression

Is a technique to compress or reduce the storage requirement of the image or the bandwidth required to transmit it.

F. Image Segmentation

Segmentation is a process that divides an image into its regions or objects that have similar features or characteristics. Mathematically complete segmentation of an image R is a finite set of regions R1….Rn, where the union of the regions R1 to Rn gives the original image [2]. In general, autonomous segmentation is one of the most difficult tasks in digital image processing.

G. Image Representation and Description

Representation can be of two types it can be boundary representation or it can be regional representation. Representation is just putting raw data in a form which can be used later for computer processing. Description, also called feature selection, deals with extracting attributes that result in some quantitative information of interest or are basic for differentiating one class of objects from another. Description gives the quantitative information which helps in differentiating two objects.

H. Classification Recognition

Recognition is labeling an object on the basis of its given description. In digital image processing, output of the previous step will be the input for the next so; it is necessary to produce an improved output for better recognition. In figure1.1 from image acquisition step to morphological processing generally produces the image as an output, but the steps, morphological processing, segmentation, representation, object recognition produces the image attribute as an output. So, these steps are important to improve recognition rate.

I. Wavelets

Are the foundation for representing images in various degrees of resolution.

J. Morphological processing

Deals with tools for extracting image components that are useful in the representation and description of shape.

K. Image representation

We have seen that the Human Visual System (HVS) receives an input image as a collection of spatially distributed light energy; this is form is called an optical image. Optical images are the type we deal with every day –cameras captures them, monitors display them, and we see them [we know that these optical images are represented as video information in the form of analog electrical signals and have seen how these are sampled to generate the digital image I(r , c). The digital image I (r, c) is represented as a two- dimensional array of data, where each pixel value corresponds to the brightness of the image at the point (r, c). in linear algebra terms , a two-dimensional array like the image model I(r, c) is referred to as a matrix , and one row (or column) is called a vector.

L. Image analysis

Image analysis involves manipulating the image data to determine exactly the information necessary to help solve a computer imaging problem. This analysis is typically part of a larger process, is iterative in nature and allows us to answer application specific equations. Image analysis is primarily data reduction process. Images contain enormous amount of data, typically on the order hundreds of kilobytes or even megabytes. Often much of this information is not necessary to solve a specific computer imaging problem, so primary part of the image analysis task is to determine exactly what information is necessary. Image analysis is used both computer vision and image processing. For computer vision, the end product is typically the extraction of high-level information for computer analysis or manipulation. This high-level information may include shape parameter to control a robotics manipulator or color and texture features to help in diagnosis of a skin tumor. In image processing application, image analysis methods may be used to help determine the type of processing required and the specific parameters needed for that processing. For example, determine the degradation function for an image restoration procedure, developing an enhancement algorithm and determining exactly what information is visually important for image compression methods.

M. Image segmentation

Image segmentation is a solution to a number of computer vision problems is the process of dividing an image into different regions such that each region is homogeneous. Ideally, the goal of segmentation should be to produce regions that correspond to distinct objects in the image. In a Large number of applications (in image processing, computer vision, and computer graphics), segmentation plays a fundamental role. Before applying the higher–level operations like recognition, object– based image/video compression, object tracking, scene analysis, and object–based image editing segmentation has to be performed [5, 4]. All the steps in image processing are widely been used in various applications. Image segmentation is a crucial step in image processing which has a wide variety of applications like locate tumors or other pathologies, measure tissue volume, computer-guided surgery, treatment planning, study of anatomical structure, locate objects in satellite images, fingerprint recognition etc. 5 Image segmentation is the key behind image understanding. Image segmentation is one of the most important steps leading to the analysis of processed image data. It is the prime area of research in computer vision. The output of image segmentation is used is used as an input to various applications in computer vision like shape representation and description, Shape matching and pattern recognition [11], [12], [14].

N. Applications of image segmentation

Image segmentation is a solution to a number of computer vision problems. In a Large number of applications (in image processing, computer vision, and computer graphics), segmentation plays a fundamental role. Image Segmentation has a wide range of applications such as automated detection and classification of cancerous cell; identification of crops from remotely sensed data and vision guided automobile assembly [8]. It has become increasingly important in a variety of fields such as video coding, computer vision & medical imaging as well as biometrics, pattern recognition, Image analysis and so on[20]. By considering these important applications of segmentation, this research work has motivated to select the segmentation topic.

O. Medical Image Segmentation

In the medical science, it shows how image segmentation has made many complicated things very easy and how it has helped in problem identification and cure.

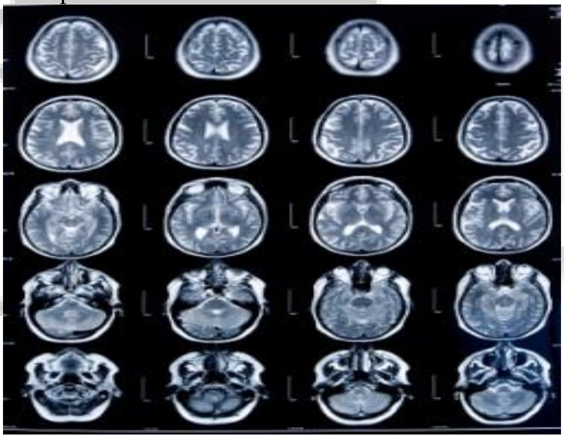

Fig. 1.1: Sample Medical Image

There are various areas in medical imaging where image segmentation has come up with very good solutions. Some of the areas are as locate tumors and other pathologies, Measure tissue volumes Computer-Guided Surgery Diagnosis, Treatment Planning and Study of Anatomical Structure.

Image segmentation helps locating tumors in guiding cancer treatment. The purpose of this is to separate the tumor region from the background region segmenting tumors (e.g.: brain tumors, breast tumors etc) is a vital process for treatment planning. Radiotherapy provides a high dose of radiation to a tumor while sparing as much as possible of the surrounding healthy tissue. A necessary first step is defining the target volume and organs at risk by manually outlining the required contours on magnetic resonance or computed tomography scans. Computer image segmentation speeds up the time consuming scanning process required for the above.

P. Remote Sensing

Remote sensing refers to the activities of recording/observing/perceiving (sensing) objects or events at far away (remote) places. Remote sensing images are normally in the form of digital images. In order to extract useful information from the images, image processing techniques may be employed to help visual interpretation, and to correct or restore the image if the correct or restore the image if the image has been subjected to geometric distortion, blurring or degradation by other factors.

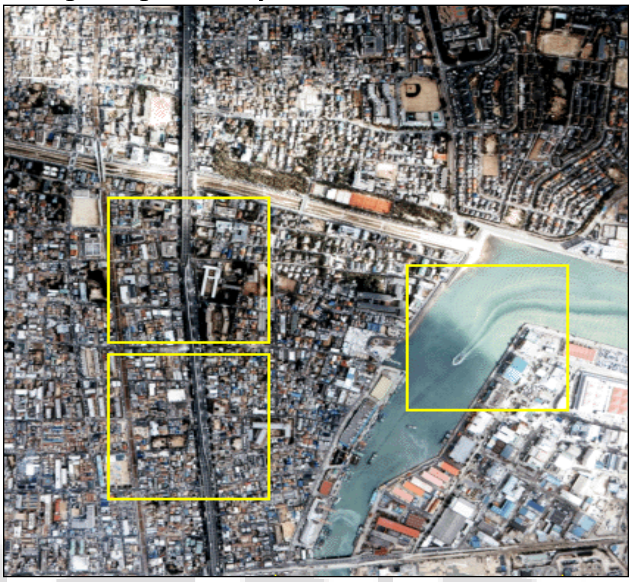

Fig. 1.2: Remote Sensing Process

The figure 1.3 shows the remote sensing sample image for city, like the above there are several applications allows the remote sensing and segmentation process.

Q. Biometric Images

Biometrics refers to methods for uniquely recognizing humans based upon one or more intrinsic physical or behavioral traits. Examples include fingerprint recognition, face recognition, iris detection and voice recognition. A facial recognition system is a computer application for automatically to recognize a face by capturing the emission of heat patterns that are generated by the vascular system of the face [18]-[19]. It is typically used in security systems to search for criminals and terrorists, to prevent voter fraud in elections, as a security measure in ATM's. Fingerprint recognition refers to methods for uniquely recognizing humans. Fingerprint recognition is used as a form of identity access management. It is also used to identify individuals in groups that are under surveillance.

Fig. 1.3: Biometric Images

A biometric system is essentially a pattern recognition system that recognizes a person by terminating the authenticity of a specific physiological and/or behavioral characteristic possessed by that person. Although biometric emerged from its extensive use in law enforcement to identify criminals (e.g. illegal aliens, security clearance for employees for sensitive jobs, fatherhood determination, forensics, and positive identification of convicts and prisoners), it is being increasingly used today to established person recognition in a large number of civilian application. Iris recognition is considered to be the most reliable biometric authentication system. Segmentation and detection of iris poses a number of challenges like inferior image quality, occlusion of eyelids and eyelashes hence 100% accuracy cannot be achieved [10].

R. Agricultural Image Mining

Image segmentation plays a very important role in agriculture; it helps in finding whether the crops grown are healthy. It also finds if there is any type of disease in the crops grown. After the detection it helps the agricultural researchers to find the type of the disease the crops are suffering.

Fig. 1.4: Image Processing in Fruit Detection and Disease Classification

S. Manufacturing

Image segmentation is also used while manufacturing the medicines. It checks for any broken pills while manufacturing and gives alerts about the same. Not only in the medical but in manufacturing of many more products image segmentation reports the faults in manufacturing.

III. IMAGE SEGMENTATION APPROACHES

In image segmentation process, the image is divided into its constituent parts, which is going to discuss in this section. Image segmentation approaches can be broadly grouped into the five different categories such as Region Based Methods, Edge Based Methods, Thresholding or Histogram based techniques, Morphology based and Hybrid Techniques. Image segmentation algorithms are generally based on the two basic concepts that are similarity and discontinuity with respect to the intensity values.

A. Region Based Methods

The principal approach in similarity based partitioning, an image is partitioned into regions that are similar according to the set of predefined criteria and the principal approach behind the second approach is to partition images based on the abrupt changes in the intensity values. Region based methods are based on continuity. These techniques divide the entire image into sub regions depending on some rules like all the pixels in one region must have the same gray level.

Edge detection is an important issue for complete understanding of an image. The most usual classical methods search for several ways to perform an approximation to the local derivatives and they marks the edge by searching the maximum of these derivatives. In this chapter, discussion about all techniques is given.

B. Edge or Boundary based Technique

Segmentation Methods based on Discontinuity find for abrupt changes in the intensity value. These methods are called as Edge or Boundary based methods. An edge is a vector variable with two components magnitude and orientation, where x Edge magnitude – gives the amount of the difference between pixels in the neighborhood (the strength of the edge). x Edge orientation- gives the direction of the greatest change, which presumably is the direction across the edge detection is the problem of fundamental importance in image analysis. According to John canny there are three criterions should be well taken care of while edge detection. One is High probability of marking the real edge point and low probability of marking non edge points second one is the points marked as edge points should be as close as possible to the center of the true edge There should be only one response to a single edge i.e. double line for edges should not be detected Edge detection techniques are generally used for finding discontinuities in gray level images. Edge detection is the most common approach for detecting meaningful discontinuities in the gray level. Image segmentation methods for detecting discontinuities are boundary based methods. It reduces the complexity of image allowing more costly algorithms like object recognition, object matching, object registration or surface recognition from stero-images to be used.

C. Thresholding based Techniques

Thresholding is one of the most important approaches to image segmentation. Suppose that the gray-level histogram corresponds to an image, f(x, y), composed of light objects on a dark background. Furthermore, suppose that the object and background pixels have gray levels grouped into two dominant modes. One obvious way to extract the objects from the background is to select a threshold T that separates these modes. Then, at any point (x, y) for which $f(x, y) > T$ is called an object point; otherwise, the point is called a background point. If three or more dominant modes characterize the image histogram (for example, two types of light objects on a dark background), it is sometimes possible to segment the image by multilevel thresholding.

This is generally less reliable than its single-level thresholding. Great care must be taken with illumination because it plays a crucial role in establishing the shape of the histogram in the resulting image. Once derivative is calculated, the next stage is to apply a threshold, to determine where the results suggest an edge is present. The lower the threshold, the more lines will be detected, and the results become increasingly susceptible to noise, and also to picking out irrelevant features from the image. Conversely a high threshold may miss subtitle lines, or sections of lines. A commonly used compromise is thresholding with hysteresis. This method uses multiple thresholds to find edges, now by using the upper threshold to find the start of a line.

Once have a start point, trace the edge's path through the image pixel by pixel, marking an edge whenever above the lower threshold criteria is satisfied. The process should stop marking the edge only when the value falls below lower threshold. This approach makes the assumption that edges are likely to be in continuous lines, and allows us to follow a faint section of an edge that have previously seen, without meaning that every noisy pixel in the image is marked down as an edge. In Image Segmentation, the image is composed of a number of constant intensity objects in a well-separated background. The image histogram is usually considered as being the sample probability density function (PDF) of a Gaussian mixture and, thus, the segmentation problem is reformulated as one of parameter estimation followed by pixel classification.

D. Morphology Based Techniques

Morphology is biological term refers to study of form and structure, in imaging, the term is not used so generically. Morphological operators often take a binary image and a structuring element as input and combine them using a set operator (intersection, union, inclusion, complement). They process objects in the input image based on characteristics of its shape, which are encoded in the structuring element. The mathematical details are explained in Mathematical morphology. Usually, the structuring element is sized 3×3 and has its origin at the center pixel. It is shifted over the image and at each pixel of the image its elements are compared with the set of the underlying pixels. If the two sets of elements match the condition defined by the set operator (e.g. if set of pixels in the structuring element is a subset of the underlying image pixels), the pixel underneath the origin of the structuring element is set to a pre-defined value (0 or 1 for binary images). A morphological operator is therefore defined by its structuring element and the applied set operator.

E. Hybrid Techniques

The aim of this technique is to offer an improved solution to the segmentation problem by combining techniques of the previous categories. Most of them are based on the integration of edge and region based methods. There are two ways the edge and region integration can be performed. There are two ways we can integrate the region based and edge based techniques. Perform edge detection on the input image then region detection on the output from the first step; this gives us the finally segmented output image. In some hybrid techniques the image is initially partitioned into regions using surface curvature sign and, then, a variable-order surface fitting iterative region merging process is initiated. While in some, the image is initially segmented using the region-based, split-and-merge technique and, then the detected contours are refined using edge information. Initial image partition is obtained by detecting ridges and troughs in the gradient magnitude of image through maximum gradient paths connecting singular points. Then, region merging is applied through the elimination of ridges and troughs via similarity/dissimilarity measures. The aim of this technique is to offer an improved solution to the segmentation problem by combining techniques of the previous categories.

IV. IMAGE CLASSIFICATION

In image classification, an image is classified according to its visual content. For example, does it contain an airplane or not. An important application is image retrieval - searching through an image dataset to obtain (or retrieve) those images with particular visual content. The goal of this session is to get basic practical experience with image classification. It includes: (i) training a visual classifier for five different image classes (aeroplanes, motorbikes, people, horses andcars); (ii) assessing the performance of the classifier by computing a precision-recall curve; (iii) varying the visual representation used for the feature vector, and the feature map used for the classifier; and (iv) obtaining training data for new classifiers using Bing image search.

A. Training and testing an Image Classifier

1) Stage A: Data Preparation

The data provided in the directory data consists of images and pre-computed feature vectors for each image. The JPEG images are contained in data/images. The data consists of three image classes (containing aeroplanes, motorbikes or persons) and `background' images (i.e. images that do not contain these three classes).

2) Stage B: Classify the test images and assess the performance

The intent of the classification process is to categorize all pixels in a digital image into one of several land cover classes, or "themes". This categorized data may then be used to produce thematic maps of the land cover present in an image. Normally, multispectral data are used to perform the classification and, indeed, the spectral pattern present within the data for each pixel is used as the numerical basis for categorization. The objective of image classification is to identify and portray, as a unique gray level (or color), the features occurring in an image in terms of the object or type of land cover these features actually represent on the ground.

V. OBJECTIVES OF THE PROPOSED SYSTEM

The proposed system aims to provide a hybrid segmentation approach for pancreas with the consideration of veins and its spatial features. Additionally the system has the following specific objectives.

The objective of this work is

1) To develop a unified framework for better segmentation of CT scan images with vein spatial data analysis.
2) To detect the descriptors from the image for fast image segmentation, SIFT algorithm is used.
3) To classify the image patches at different resolutions, the dynamic cascading and macro super-pixel segmentation is generated.

4) The classification accuracy improvement with minimum training samples is another objective of the proposed system.
5) To evaluate and check the robustness and accuracy of this framework.

VI. RESULTS AND DISCUSSIONS

From the analyses of the problem in medical data there were problem like image segmentation and classification. To solve the issue the proposed system segments the pancreas with the considerations of spatial relationships of splenic, portal and superior mesenteric veins with the pancreas. The proposed system uses macro super-pixels for fast and deep labeling and SIFT based segmentation process. The proposed system is an automated bottom-up approach for pancreas segmentation with the consideration of optimal features in abdominal computed tomography (CT) scans. The method generates dynamic cascaded and macro super-pixel segmentation information's by classifying image patches at different resolutions.

Image from Dataset	Method	Jaccard	Dice	Tanimoto
Dataset1	Proposed Method	0.8007	0.889	0.800
	FCM-SC	0.333	0.499	0.333
Dataset2	Proposed Method	0.5507	0.710	0.550
	FCM-SC	0.5097	0.675	0.509

Table 4.0: Comparative analysis of results obtained based on similarity measures Jaccard, Dice and Tanimoto

Extracted pancreas area using proposed method is also very close to the ground truth compared to the FCM-SC approach as shown in Table 1.0. Plots of average values of similarity measures obtained for both the methods are shown in Figure 3.0 where results of proposed method are found to be better than other compared method. As observed from Table 1.0, major difference was observed in the results of TPR (sensitivity) for both the methods.

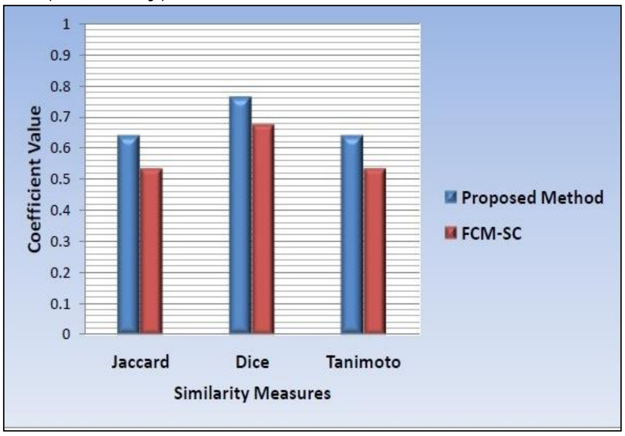

Fig. 4.0: Plot of average values of similarity coefficients for proposed method and FCM-SC Method

The proposed system effectively detects the pancreas from the abdomen CT images with effective feature selection. The best feature selection is performed using the SIFT and Macro super pixel concepts. The classification process is performed after the pancreas segmentation. In phase-I pancreas images are segmented using super pixel segmentation technique. In phase-II the proposed macro super pixel segmentation technique will be implemented and compared with existing system. The macro super pixel based segmentation will show better performance when compare to existing system.

VII. FUTURE WORK

However, the frameworks created till today do not apply in case of CT pancreas with vein image (having any type of edges and lines). Hence, this research work concentrates not only on segmentation of Medical images but also on unifying it under one roof. Thus it gives a combined or a unified Framework of segmentation which can take as input different types of pancreas and medical images. This system will utilizes histogram and texture features. The method generates dynamic cascaded and macro super-pixel segmentation information's by classifying image patches at different resolutions. In future for Fast organ detection WASIFT (Weighted Adaptive Scalable Invariant Feature Transform) algorithm can be used. This algorithm helps to detect the weighted descriptors from the image for fast image segmentation. Using this system, the organ from the CT images can be segmented quickly. With the consideration of additional features of other organs and classifying those images into different classes with high precision will be performed in the future work. The future work will use semi-supervised classification techniques to reduce the time of training process. Using the above, the accuracy can be improved and time can be reduced.

REFERENCES

[1] AHARON, M., ELAD, M. and BRUCKSTEIN, A.M. (2006) K-SVD: an algorithm for designing over complete dictionaries for sparse representation. IEEE Transactions on Signal Processing, 54, pp. 4311–4322.
[2] Amal Farag, (2015)"A Bottom-up Approach for Pancreas Segmentation using Cascaded Superpixels and (Deep) Image Patch Labeling".
[3] Amal Farag, Le Lu et al, (2014)"A Bottom-Up Approach for Automatic Pancreas Segmentation in Abdominal CT Scans.
[4] Anders Lindbjerg Dahl, (2011)"Learning Dictionaries of Discriminative Image Patches".
[5] ASHBURNER, J. and FRISTON, K. J. (1997) Multimodal image co-registration and partitioning - a unified framework. NeuroImage, 6(3), pp. 209-217.
[6] BUADES, A., COLL, B. and MOREL, J.M. (2005) A non-local algorithm for image denoising. IEEE International Conference on Computer Vision and Pattern Recognition, 2, pp. 60–65.
[7] ELSHERIF, M. and ELSAYAD, A. (2001) Wavelet packet denoising for medical image enhancement. IEEE Transaction Inf. Theory, 10, pp.180-184.

[8] FRISTON, K.J. (2000) Voxel-based morphometry the methods. NeuroImage, 11, pp. 805–821.
[9] GERIG, G., KUBLER, O., et al., (1992) Nonlinear anisotropic filtering of MRI data. IEEE Transactions on Medical Imaging, 11, pp. 221–232.
[10] GULERYUZ, O.G. (2003) Weighted over complete denoising. Proceedings of Asilomar Conference on Signals and Systems, 2, pp. 1992-1996.
[11] Holger R. Roth, Amal Farag et al, (2015) "Deep convolutional networks for pancreas segmentation in CT imaging".
[12] Holger R. Roth, (2015) "DeepOrgan: Multi-level Deep Convolutional Networks for Automated Pancreas Segmentation".
[13] KAUR, M. K. and MITTAL, R. (2014) An Efficient Scheme for Brain Tumor Detection of MRI Brain Images Using Euclidean Distance. Journal of Emerging Technologies in Web Intelligence, 6(4), pp. 429-434.
[14] MASROOR, M. A. and DZULKIFLI, M. (2008) Segmentation of brain MR images for tumour extraction by combining k means clustering and Perona-Malik anisotropic diffusion model. International Journal of Image Processing, 2(1), pp. 27-34.
[15] MURESAN, D.D. and PARKS, T.W. (2003) Adaptive principal components and image denoising. IEEE International Conference of Image Processing, 1, pp. 101–104.
[16] K.NARASIMHANA, (2010) "Medical Image Feature, Extraction, Selection And Classification".
[17] Shimizu, T. Kimoto, H. Kobatake, S. Nawano and K. Shinozaki. "Automated pancreas segmentation from three-dimensional contrast-enhanced computed tomography." Int. J. Comput. Assist. Radiol. Surg., 2010.
[18] WIRTH, M., FRASCHINI, M. and LYON, J. (2004) Contrast enhancement of micro clasifications in mammograms using morphological enhancement and non-flat structuring elements. IEEE Symposium on Computer-Based Medical Systems.
[19] YAROSLAVSKY L.P., (1985) Digital Picture Processing - An Introduction, Springer Verlag.
[20] ZONG XULI; LAINE, A.F. et al., (1996) De-Noising and contrast enhancement via wavelet shrinkage and nonlinear adaptive gain. Proceedings of SPIE, 2762, pp. 566-5.