Design and Development of Head and Neck Swellings Automatic Resection Tool Based on Artificial Intelligent Technique

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Abstract--Resection of Head and Neck Swellings by current medical instruments is a time consuming task. It causes injuries in the adjacent structures. In addition, it lacks accuracy. These reasons made it essential to develop an automatic tool for the resection process. The variance and intricacy of the swelling location makes the design of such tool very difficult. The proposed tool makes use of the artificial intelligence. Support vector machine (SVM) algorithms are applied to magnetic resonance images (MRI) to perform classification of the swelling tissues and to determine its location. It also determines the coordinates of the pass from entrance of the tool to the swelling location. The tool is equipped also by a camera for in internal simultaneous imaging during the operation. In addition an aggregation cavity is used to get rid of the blood resulting from the cutting blade mismatch. This increases the efficiency and the quality of the imaging process. The tool is also equipped by a software package to enable the communication between the surgeon and the camera and cutting blade. The resection using the proposed tool improves the accuracy, reduces the operation time and minimizes the injuries to the adjacent tissues.

[G.G.N.Gouid, A.AA. Nasser, M. Z. Mostafa and D. M. El-Hennawi. **Design and Development of Head and Neck Swellings Automatic Resection Tool Based on Artificial Intelligent Technique.** J Am Sci 2013;9(12):539-546]. (ISSN: 1545-1003). http://www.jofamericanscience.org. 71

Keywords: Head and Neck Swellings, Magnetic Resonance Imaging (MRI), Support Vector Machine (SVM), intelligent control system.

I. INTRODUCTION

Presently, oncologists and otorhinolarngological surgeons face a problem of lacking control in Resection of Head and Neck Swellings (1, 2). Head and Neck Swellings can be defined as an abnormal growth of cells inside the brain or the skull, which can either be cancerous or non-cancerous (benign). Tumors that commence in brain tissues are referred to as primary tumors of the brain (3). A tumor is a mass of tissues that grows out of control of the normal forces that regulate growth (4). There are various types of tumors of which brain tumor is the cause of one quarter of all cancer deaths (5). The complex brain tumors can be separated into two categories depending on tumor origin as primary and metastatic tumors (6). Primary brain tumors are tumors that arise from cells in the brain or from the covering of the brain (5, 6). A secondary or metastatic brain tumor occurs when cancer cells spread to the brain from a primary cancer in another part of the body (4,6). Most surgical procedures performed today using classic tools are not efficient enough (7). The surgeon cannot view the desired tissue well so that the surgical process becomes difficult and more complex (8). Partial swelling resection with the microdebrider wasperformed with the Xomed swelling microresector blade at 3000 rpm in oscillation mode without Irrigation. After tissue removal via either technique, electrocautery was used for hemostasis (9). This technique involves the removal of the superior 50% to 70% of the swelling, which leaves an inferior tissue remnant undisturbed to ensure adequate velopharyngeal closure (8). We have shown that partial removal operation (swelling resection) with the microdebrider is faster than other techniques, but with less matching. This may cause injuries to the adjacent structures (7, 9). Surgeries performed using endoscopes are particularly useful for paediatric age group patients who have small oral cavities. The assessment and excision of the swelling in these cases are often difficult, because the size assessment of the swelling by conventional palpation and mirror examination is challenging (9). Moreover, it uses the classic curette, so the operator uses his both hands during the operation, as a result difficult management and decreased accuracy of the procedure (7, 9). In this paper we propose a new tool for Resection of Head and Neck Swellings (HANSR Tool), focusing on the manufacturing tool parts using a computerized controller to command motors which drive each tool a given axis. The intelligent tool operation is based on the analysis of Magnetic Resonance Images (MRI) data collected for patient with benign and malignant tumors (10, 11, 12, 13). Our aim is to achieve a high accuracy to move the tool to proper angular tumor location according to the head and neck diagram. Research tool includes a PC, motion board, servo motor drive, and 3 stepper motors, blade drive and DC motor, automatic tool-changer and general I/O card. In the present work, Research intelligent tool is utilized to perform automatic Resection of Head and Neck Swellings. This allows oncologists and ENT surgeons to control the blade motion and to see the results in real time during eradication operation. As well as giving total flexibility in the surgery without causing any injury in the adjacent structures.

II. SYSTEM DESCRIPTIONS

The overall system of HANSR consists of Image processing for Identifying, classifying, segmentation and tumor recognition. The resection pathway control system identifies the target region and actual positions. The suction control system is used for surgical area cleaning. The aggregation control system is used for the disposal of surgery wastes. The online vision system is used for surgical area clearing and blade control system for removal operation. The system block diagram is shown in Fig. 1.

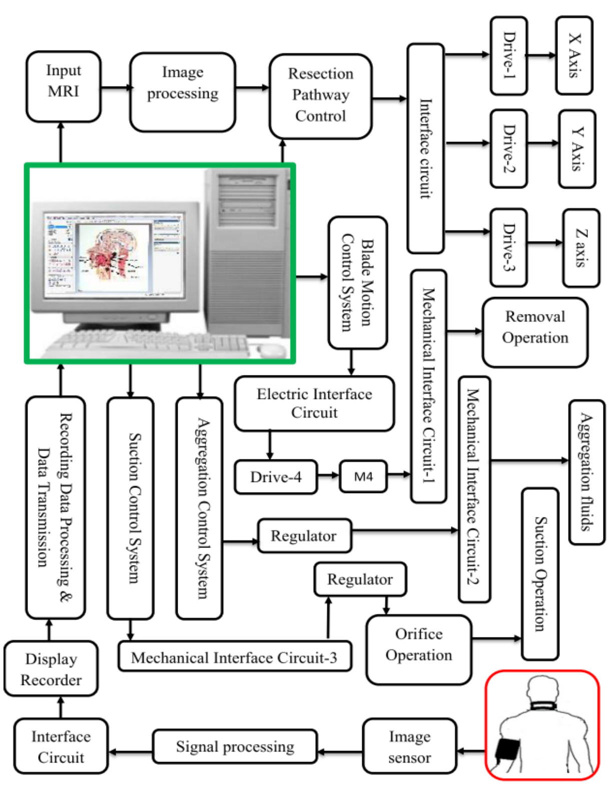


Fig. 1 Block Diagram of the System

A. Image processing

The MRI brain image segmentation and classification, of tumors are done using support vector machine (SVM) based on threshold morphology. This step identifies tumors from normal tissues. The SVM is an effective supervised classifier. It produces successful classification results especially in medical diagnosis (14). SVM follows the structural risk minimization principle from the statistical learning theory. Its kernel is to control the practical risk and classification capacity in order to broaden the margin between the classes and reduce the true costs (15). SVM has also been applied on different real world problems such as face recognition, text categorization, cancer diagnosis, glaucoma diagnosis, microarray gene expression data analysis. The proposed system used the SVM for identification and classification of brain MR image as normal or tumor affected (16).

Segmentation process

The segmentation achieves the following.

- Automatic delineation of areas to be removed.
- Delineation of tumors before and after surgical removal.
- Determining the area of the infected tumor of images.

Here, segmentation is based on the threshold morphology and the wavelet transform to increase the detection probability. The Region of Interest (ROI) is determined by thresholding the head and neck swellings image with a threshold obtained automatically to record the dimensions of the object area. Then, all clutters are removed by an area thresholding process. Consider an image (F) and a structuring element (Se), the eroded image of the image F by the structuring element Se can be obtained using the following equation:

$$F \ \Theta \ S_e = \{z \mid (S_e)_z \subseteq F\} \qquad (1)$$

Where, Z is a displacement of the structuring element.

Identification process

The identification system consists of two stages to perform both the training of the input images models and the evaluation of the testing image sets, which are feature extraction and identification as shown in Fig.2. (17). If we consider firstly the feature extraction stage, we can find that this stage is concerned with converting an input training image into a series of vectors, which contain the discriminative information for the main image features.

There are a lot of identification techniques that can be used such as Vector Quantization (VQ), Artificial Neural Networks (ANNs), k-Nearest neighbor (k-NN) ,Markov Random Fields (MRFs), Gaussian Mixture Models (GMMs), Hidden Markov Model (HMM) and Support Vector Machine (SVM) (18, 19). The identification step in all image identification systems is in fact a feature matching process between the features of any new image and the features stored in the database. In this paper, the SVM technique will be used.

The proposed approach has two phases; a training phase and a testing phase. In the training phase, features are extracted from each image of a database of head and neck swellings images. These features are used to train an SVM. Features are extracted from the patient every incoming image in the testing phase, and a decision is made through feature matching and decision making step to decide if there is a swelling or not.

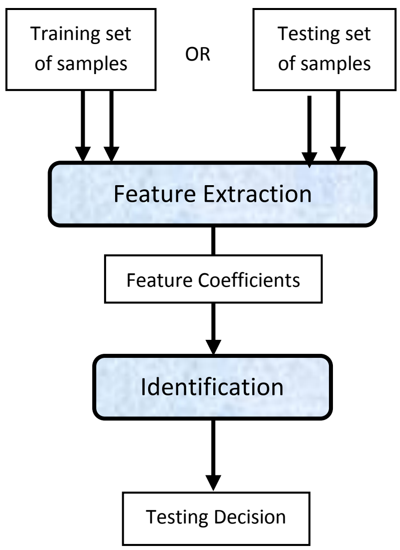


Figure2. The identification system

B. Resection Pathway Control System

Motion control is one of the main factors that affect the automatic operation (20, 21). These swellings are located in complicated regions of the head and neck diagram. Motion control tries to access the desired location of the tumor to be removed without causing any lacerations of the adjacent structures (22). The intelligent HANSR tool employs a program that allows the blade tool itself to autonomously determine the action required to move the blade into the tumor position.

Motion control system of HANSR tool is based on MACH3 and ARTCAM algorithms. These algorithms can handle 3D and 2D images to directly access the tumor position or to guide the blade towards it. In addition to putting the blade into the right place, the right amount of force and torque at the right time is essential for efficient head and neck swellings resection operation.

MACH3 algorithm

In this study, MACH3 2.0 is used to control the motors and interface between the user input and the driver circuit. It enables motor control from manual input or programmed blade control. MACH3 generates step pulses and direction signals to perform the steps defined by a G-Code part program and sends them to the I/O ports. The MACH3 software automatically generates controller code for the basic system set-up parameters such as distances and speeds. The editor is used to provide a programmable environment to create blocks or lines of code.

ArtCAM algorithm

ArtCAM algorithm can be generated by the G-code of HANSR blade path from inserted 2D or 3D MRI images. The G-code standard set of instructions for programmed machining is used, generated from standard CAD/CAM packages. Also, this algorithm has been designed to give a smooth motion control of the HANSR blade.

The ArtCAM algorithm is used here as an identifier for the tumor location from the brain MRI images. In addition, the Calculation technique for the tool path motion direction in computed tomography images is based on oncologists' and ENT surgeon's experience. After that, testing of this path should be performed using a test image set to verify the efficiency of the constructed path. This allows oncologists and ENT surgeons to access the location of the tumor in head and neck during eradication operation as shown in Fig. 3.

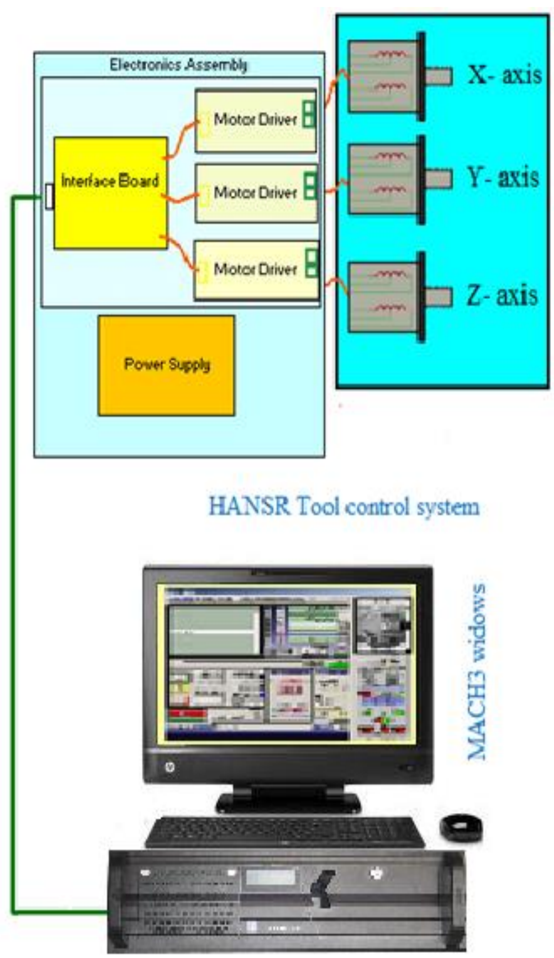


Figure 3. HANSR tool path motion direction control sytem.

Stepper motor

A stepper motor is an electromechanical device which converts electrical pulses into discrete mechanical movements. The shaft or spindle of a stepper motor rotates in discrete step increments when electrical command pulses are applied to it in the proper sequence. The motors rotation has several direct relationships to these applied input pulses (23). The stepper motor used in this research has 200 steps per revolution. This indicates that the step angle is 1.8 degrees.

Stepper motor driver circuit

The drive circuits are used to drive the two phase bipolar X,Y and Z stepper motors. The five-wire, five-phase unipolar stepper motor can easily be controlled from a personal computer (PC) with one MOSFET per winding. The output lines from the PC interface circuit are buffered using a 4050 non-inverting buffer chip. Each buffered signal line is connected to a MOSFET. A control signal on the base is amplified and then drives the second MOSFET. The resulting circuit can not only switch large currents, but it can do so with a very small controlling current. The diagram of stepper motor driving section is showed in Fig.4. It uses *Parallel Port of PC* pins on the PC interface to drive the motor. These pins are connected to transistors Q_1, Q_2, Q_3 and Q_4 respectively. Using these pins, the proper transistors are turned ON and OFF to achieve clockwise (CW) or counter clockwise (CCW) rotation. A reverse shunting diode is connected between the emitter and the collector to protect the transistor from reverse voltages.

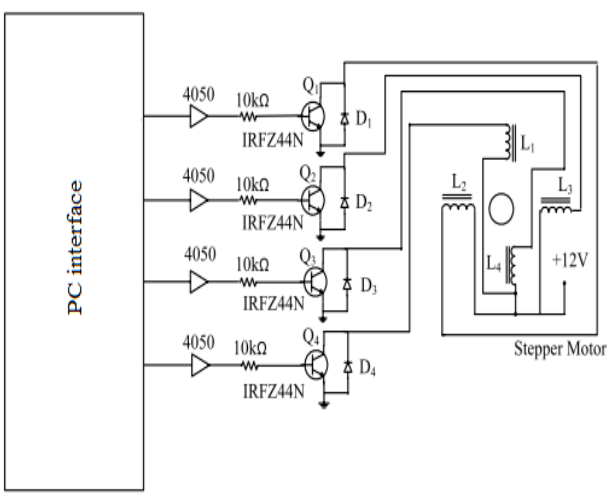


Figure 4. Diagram of Stepper Motor Driving Section

Stepper motor interface circuit

Parallel port *of PC* is a standard I/O interface for all PCs. Today, there exists at least one parallel port for various applications such as connection of a printer or a hard-key. In Table 1, the base hardware addresses of the parallel ports are given.

TABLE 1. PARALLEL PORT ADDRESS TABLE

Name of the Port	Data Port	Status	Control
LPT1	378h	379h	37Ah
LPT2	278h	279h	27Ah
LPT3	3BCh	3BDh	3BEh

There are three types of I/O interface in the parallel port namely data port, status port and control port.

- Data Port : There exist eight digital output terminals that are accessed by data ports.
- Status Port : There exist five digital input terminals, of which one of them is inverted, that are accessed by status ports.
- Control Port : There exist four digital output terminals, of which three of them are inverted, that are accessed by control ports.

All ports are defined at TTL (Transistor-Transistor Logic) logic levels (An electrical "high" on the pin is TTL high, +2.4 to +5 volts. An electrical "low" is TTL low, 0 to +0.8 volts.). Data port is driven by the high impedance octal D-type flip-flop (74LS374). This IC can source 2.6 mA while it can sink 24 mA. As these values are relatively low, it may be necessary to amplify the outputs for specific applications. Control port pins are driven by the 7405 inverter IC which may supply 1 mA up to 7 mA. In Fig. 5, the block diagram of the parallel interface is given.

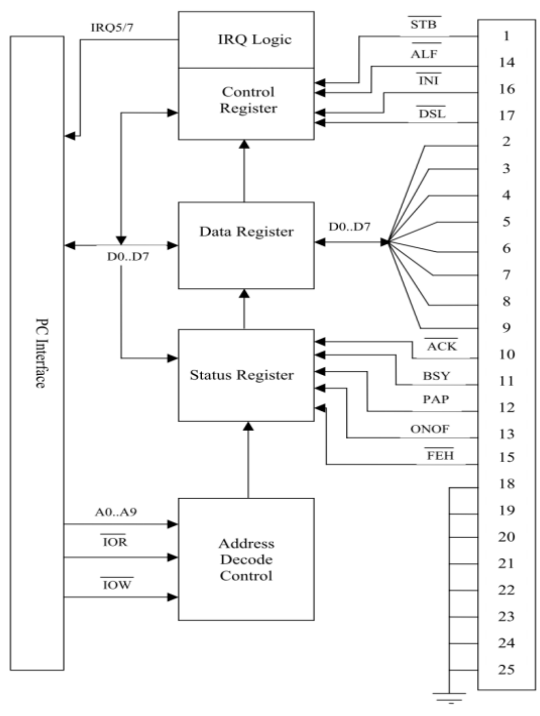


Figure5. Block diagram of the parallel port interface

C. Suction control system.

It is a small control unit in the base tool for surgical area cleaning; it is used to clear the bloody field during the operation by suction tube which is a metal tube that connects suction orifice with external suction device. Orifice and tube of suction unit are made of stainless steel metal to overcome corrosion. We can clear bloody field from removed swelling through suction tube without inserting external suction tube. Suction unit can be controlled by one on/off switch, so that the surgeon can easily control the operation.

Safety divider and aggregation unit

Safety Divider is safe casement metal cylindrical form that is located on sides of blade to prevent remove the undesired tissues. An aggregation unit is used to enable the disposal of surgery wastes.

D. Blade control unit

Blade control unit is used to ensure the removal of the swelling tissues without causing any injury in the adjacent structures. In the automatic resection of head and neck tumor it is important to identify the blade velocity and direction, in addition to precise control on the movement in the path way of the tool to the tumor. This ensures the access to the tumor without causing any lacerations the adjacent tissue structure during surgery.

E. Vision unit

It is a small unit supplied with a small vision sensor (TV camera). This unit is used to monitor the surgical area on line. This is a C-MOS sensor (CCTV video camera) with self-interface circuit. C-MOS camera is angled at 25° relative to the arm axis so the apex of the arm can be imaged. Also, we can use stand for camera fixation on HANSR tool frontal framework. This stand must be perpendicular to the location of operation to obtain perfect vision.

The arm HANSR's intelligent, autonomous grasping system was made possible by using image processing that utilizes a C-MOS camera. In this control approach, the arm HANSR tool determines the position of a target object and automatically moves to grasp it. Target identification from an image captured with the C-MOS camera is followed by sending the image and data to a PC using an interface circuit. The vision control unit allows oncologists and ENT surgeons to access the location of the tumor in head and neck during eradication operation to see the results in real time as well as giving total flexibility in the tumor removal operation. This is very important because the tumor has to be removed without causing any lacerations in the adjacent structures during entry or exit from the tumor area.

III. SYSTEM OPERATION

The HANSR prototype tool has three degrees of freedom with the span of the motion120 mm length in both X and Y axes and 40 mm in the Z direction. Three stepper motors are used to control the motion. The rational blade is shown in Fig 6. In order to rotate the blade in real time we can use the mechanical drive, which consists of rack and gearbox. The rack is a rectangular prism with gear teeth machined along one side. It could be considered a gear wheel with an infinite pitch circle radius. This rack is connected between gearbox and the blade to convert rotational motion into rectilinear motion of the blade. One stepper motor is used to control the desired movement of the blade. A reduction gear is located between the stepper motor shaft and the rack to reduce the speed and to increase the motor cutting torque. This provides matching of the blade motion with motor speed. A MACH3 algorithm is used to drive the four motors. When the operation starts, the blade moves forward to the target position and then moves upward to the tumor location. Then the tool blade rotates in order to pick up the tumor tissues for the blade after catching the desired tumor tissue from the operation area or tumor location, the blade moves downward and moves backward to the operating area.

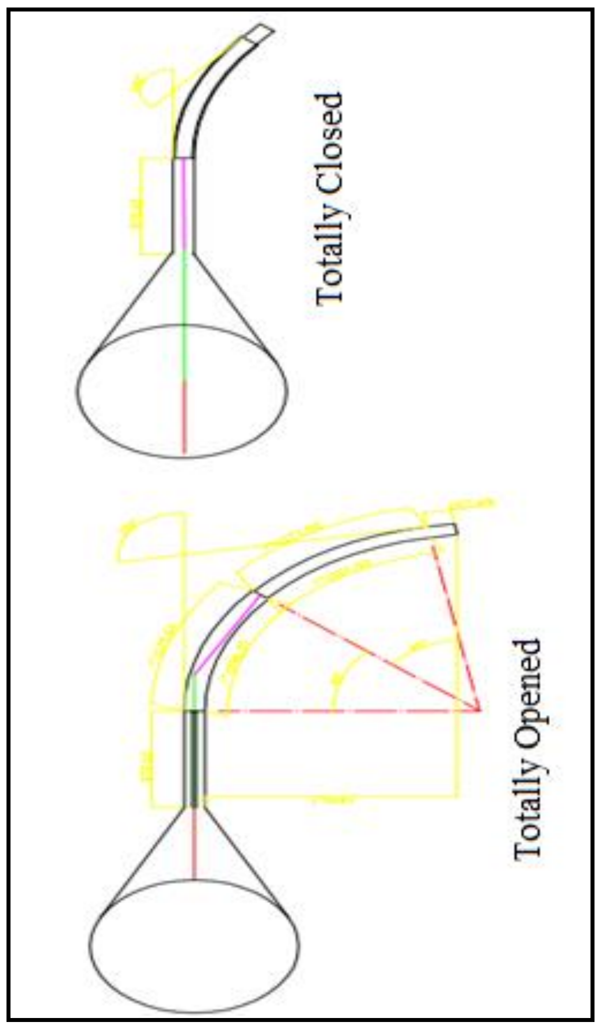


Figure 6. HANSR tool operation

IV. EXPERIMENTAL RESULTS

The proposed intelligent tool utilizes a combination of different techniques and is composed of several steps including segmentation and identification. We first perform segmentation of brain tumors in MR images. Segmentation technique is implemented in MATLAB. This technique has been tested on datasets of real brain MR images consisting of normal and tumorous brain images.

Fig. 7 shows some of the test images collected from publicly available sources. Once the classification is done, the malignant brain images are further segmented for extraction of tumor regions from these brain MR images. The obtained experimental results from the proposed technique are given in Fig.8. Secondly, the identification experiments have been conducted on different types of head and neck swellings images.

In these experiments, we used a SVM MATLAB toolbox with different kernel functions, linear, polynomial, and sigmoid and RBF. The linear kernel type has been adopted in this paper, because it gives better performance and higher recognition rates than the other kernel types.

$$\text{Recognition Rate} = \frac{\text{the nnmber of correction identification}}{\text{the total number of identification trails}} \quad (2)$$

We carried out seven experiments in the presence of noise to test the robustness of the proposed image identification approach. The data base here is generated from 20 different head and neck swellings images with different dimensions, shapes and types. These images have been used in the training phase of the SVM. The features have been extracted from the original image signals and/or their discrete transforms. The features used in the experiments are 13 MFCCs and 26 polynomial coefficients forming features vector of 39 coefficients for each frame of the head and neck swellings image signal.

The images used in the training phase, have also been used in the testing phase with degradations by different types of noise. The degradations considered in this paper are additive white Gaussian noise (AWGN), impulsive noise and speckle noise with and without blurring of the images.

In the testing phase, similar features to those used in the training phase are extracted from the degraded images and are used for matching. A comparison study between all these extraction cases for the above degradation cases are carried out. From this comparison, it is clear that the features extracted from the DST of images contaminated by AWGN, features extracted from the image signals plus the DCT of image signals contaminated by impulsive noise and features extracted from the image signals plus the DST of image signals contaminated by speckle noise give better performance than the others as shown in Figs. 9 to 11.

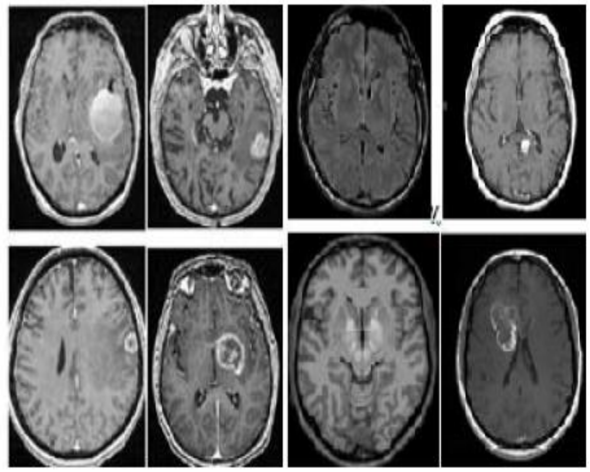
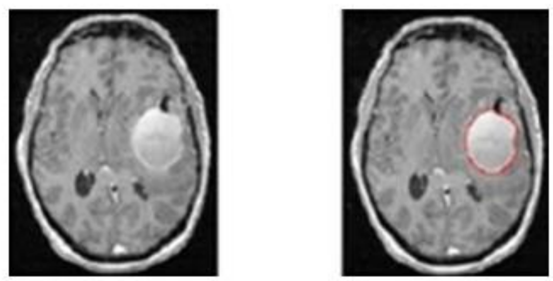


Fig. 7: MRI image dataset



(a) (b)

Fig. 8: (a) Original image, (c) Segmented image

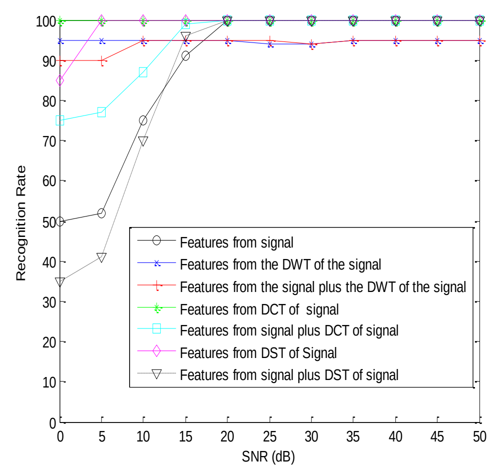


Figure (9): Recognition rate vs. SNR for MFCC feature extraction methods from blurred images contaminated by AWGN

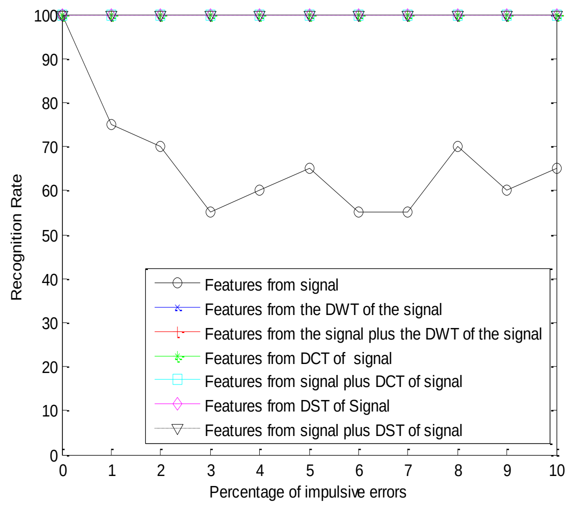


Figure (10): Recognition rate vs. the percentage error for MFCC feature extraction methods from images contaminated by impulsive noise.

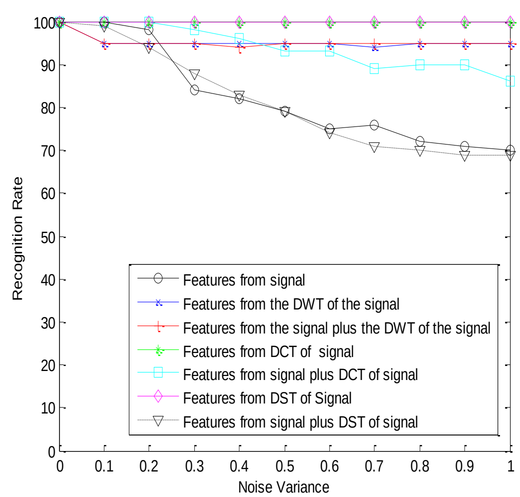


Figure (11): Recognition rate vs. the noise variance for MFCC feature extraction methods from images contaminated by speckle noise.

V. Conclusion

In the present work, a research intelligent tool is utilized to perform automatic resection of head and neck swellings based on intelligent technique. The design sequence of the current system is described and parameters of four driving stepper motors are calculated. This tool will allow oncologists and ENT surgeons to access the surgical area with an online vision as well as giving total flexibility that will help physicians to perform an accurate surgery. This is the technique that causes minimum injury or damage to the healthy tissues adjacent to the swelling site during entry or exit from the target area.

Acknowledgment

I can't find the suitable words to express about my deepest grateful to Prof. Abed Elmeneam A.A. Nasser for his constant professional support, excellent expertise and motivating discussions throughout this work.

I would like to express special thanks my advisor Prof. Mohamed Z. Mostafa and Prof. Deiaa M. El-Henawy. For his invaluable a device and encouragement during this research.

A special dept of gratitude and cordial appreciation is paid to Dr. Ahmed Geneid for his constant professional support, excellent expertise and motivating discussions throughout this work.

I also want to thank dr. ahmed sallam and eng. Ashraf sallam for their great assistance, continuous support and encouragement.

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12-11-2013