Head and Neck Swellings Resection Control Using Intelligent Control Based on Mach3 and Artcam Based on MRI Image

G.G.N.Geweid[1], A.A.A. Nasser[2], M.Z. mostafa[3] and D.M.El-Hennawi[4], A. Geneid[4]

[1] Electrical Engineering Department, Faculty of Engineering, Alexandria University, Egypt,
[2] Arab Academy for Science and Technology & Maritime Transports, Alexandria, Egy
[3] Electrical Engineering Department, Faculty of Engineering, Alexandria University, Egypt.
[4] Faculty of Medicine, Suez Canal University, Egypt.
gamal_dr1430@yahoo.com

Abstract—In this paper a motion control system of a Head And Neck Swellings Resection (HANSR) Tool blade is described. In many cases, the task of accessing the location of the tumor in Head and Neck is very complicated. The abnormal tissues have to be removed without causing any injury in the adjacent structures during surgery. This paper introduces a method that uses the conventional way of ambiguous position to the blade, after which the intelligent HANSR Tool employs a program that allows the blade tool itself to autonomously determine the action required to move the blade into that position. Also, this blade is connected to three Stepper motors. A Stepper motor is chosen for the HANSR Tool blade and the author also presents how to choose this motor. The HANSR Tool blade is with single degree of freedom and motion control system for it is selected using MACH3 and ARTCAM algorithm. This paper mainly focuses on how to apply MACH3 and ARTCAM algorithm to Control system design. The system is designed to allow the motor to move the HNST blade to proper angular position according to the head and neck diagram. The method is applied to a set of real data of 20 MRI images with normal and abnormal tumors. The practice showed that the system has the characters of good performance and low cost, so it can be widely used in resection of most Head and Neck Swellings. In experiments, an intelligent HANSR Tool was successfully engineered to use MACH3 and ARTCAM algorithm to identify tumor location and autonomously move toward a target and the system has the characters of good performance and low cost using this technique, so it can be widely used in resection of most Head and Neck Swellings.

I. INTRODUCTION

Currently, *resection* operation of Head and Neck Swellings is manual using classic tools (1). Motion control is one of the main factors that prevent the Automatic Operation. These Swellings are located in complicated regions of the head and neck diagram. Motion control design to access the desired location of the tumor is to be removed without causing any injury of the adjacent structures (2).

 Head and neck tumor consists of heterogeneous groups of tumors with a multitude of histologies. It is the sixth most common sited neoplasm in the body today with 500,000 cases expected every year(3). Early diagnosis and treatment are important in improving survival in any form of malignancy (4). Any delay may lead to more advanced disease, decrease cure rate and effectiveness of treatment, leading to higher morbidity and mortality (5). Head and neck tumor usually originates in the lining of the mouth, nose, throat, or sinuses, or in glands in the neck. There are several types of head and neck tumor, including oral tumor (e.g., tongue tumor, lip tumor, mouth tumor) and throat tumor (e.g., laryngeal tumor) (2). The symptoms of Head and neck tumors depend on tumor size, type, and location. Symptoms may be caused when a tumor presses on a nerve or damages a certain area of the Head and neck. They also may be caused when the Head and neck swells or fluid builds up within the skull. Head and neck tumors are composed of cells that exhibit unrestrained growth in the brain (3).

This paper deals with a new motion control technique for head and neck tumors removal operation. In this paper, we use three Permanent Magnet Stepper Motors (PMSM) in order to make a robust controller because PMSMs have the capability to cover and minimize all uncertainties of the model.

A Stepper motor is an electromechanical nonlinear motor which has been designed to rotate in specific angular position. Stepper motors require simple and cheap controllers for position and speed control. Therefore, these motors are very popular in medical applications and are widely used in different industries(6). Permanent magnet stepper motors have become a popular alternative to the traditionally used brushed DC motors (BDCM) for many high performance motion control applications for several reasons: better reliability because of the elimination of mechanical brushes, better heat dissipation as there are no rotor windings, higher torque-to-inertia ratio, lower price and easy interfacing with digital systems(7). The shaft of a stepper motor rotates in discrete step increments when electrical command pulses are applied to it in the proper sequence (8). Rotation of the motors has several direct relationships to these applied input pulses. So, the changes in shaft position can generate oscillations or cause a long delay in the output (torque) which is related to selected

controller(9).Today, PMSMs are widely used in numerous motion control applications such as robotics, printers, and digital control circuits etc. Recently, various methods have been introduced for rotor positioning control and determination of proper control signals in PMSMs (10). It is important that a nonlinear controller will be required due to nonlinear structure of PM stepper motors while output tracking problem is represented(11). In recent decades, adaptive algorithms have been applied to PM stepper motors more than before. Also, motion control system of HANSR Tool blade is based on MACH3 and ARTCAM algorithms. These algorithms are deals with the 3D and 2D images. To be able to control a motion process, the precise position of objects needs to be direct access. Using a MACH3 and ARTCAM algorithms and processing the information contained in the acquired images allow controlling the position of a HANSR tool actuator or to guide a blade towards a target object. To improve the precision, the looking part, and the actual control of the position, the moving part, are included in a MACH3 and ARTCAM algorithms. Putting an object in the correct place with the right amount of force and torque at the right time is essential for efficient Head and Neck Swellings Resection operation.

MACH3 is a software package that runs on a PC and turns it into a very powerful and economical Machine Controller (12). It is a very flexible program designed to control machines such as milling machines, lathes, plasma cutters, and routers. Also, MACH3 can store the properties of up to 256 different tools. If, however, your machine has an automatic tool changer or magazine, you will have to control it yourself. Also, MACH3 provides program macro capability, but you must do the programming (12). MACH3 will control up to six axes simultaneously, coordinating their movement with linear interpolation or perform circular interpolation on two axes (out of X, Y or Z) while simultaneously linearly interpolating the other four with the angle being swept by the circular interpolation. The HANSR Tool can thus move in a tapering helical path if required. The feed rate during these moves is maintained at the value requested by your part program, subject to limitations of the acceleration and maximum speed of the axes. You can move the axes by hand with various jogging controls. MACH3 can switch the blade on, rotating in either direction, then switch it off. It can also control the rate at which it rotates (rpm) and monitor its angular position for resection of Head and Neck Swellings.

In this study, The ARTCAM algorithm is designed based on images for visual servo control of a HANSR tool is presented. ARTCAM Program is a unique software program which allows users to easily create impressive, high quality blade path. ARTCAM allows importing 3D models or files from other CAD packages, which can be added to make complex and intricate 3D points. This algorithm transforms images into G-code (G-code is sometimes called G programming language). In fundamental terms, G-code is a language in which people tell computerized machine tools what to make and how to make it. The "how" is defined by instructions on where to move to, how fast to move, and through what path to move far more quickly than is possible

using conventional methods. The problem with these images is that most of them are based on pixels (e.g. jpg, bmp, gif), rather than the vector type entities (lines, circles, arcs; e.g. dxf, dwg) that are needed for HANSR tool paths. Identify the tumor location with extensive CAD drawing tools on MRI images, then create blade path based on G-code related to tumor location. This allows surgeon to move the HANSR Tool blade to proper angular position according to the input images. Finally, the combination of MACH3 and ARTCAM algorithms identifies the target and actual positions. It is then a natural step in implementing a motion control system. This allows oncologists and Ear, Nose and Throat (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 resection of most Head and Neck Swellings. Finally the software including motor controlling program, communication program and human-machine interface program are designed.

We would advise the following points be considered before starting. The maximum and minimum speeds (rpm) that the blade will experience in normal operation, Pulley Ratio (an accurate ratio is required for MACH3 to be able to calculate the correct blade path to control the removal operation by motor), Motor Output Signal Setup for MACH3 Pins and Ports, blade path input required for MACH3 Ports and Pins, The correct blade path Setup under MACH3 Ports and Pins.

II.   SYSTEM DESCRIPTIONS

The overall structure of HANSR Tool is mainly composed of PC, MACH3 and ARTCAM algorithms, driving circuit, communication circuit and stepping motor. Its structure diagram is shown in Fig. 1.
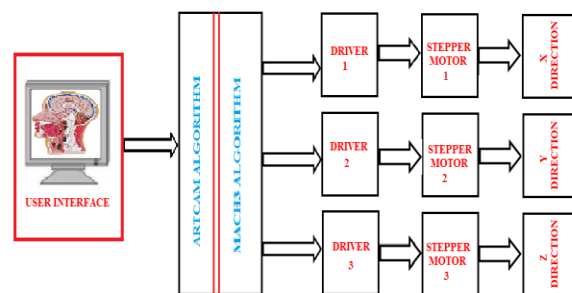

Figure 1. Block Diagram of the HANSR Tool System.

A.   ARTCAM ALGORITHM

ARTCAM algorithm can be generated by the G-code of HANSR Tool 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 controller of HANSR Tool blade. In this paper, ARTCAM algorithm moves the HANSR Tool blade to proper angular position according to the input blade path. This is because the determination of the direction and

the entry points of Head and Neck to target only the Swelling tissues region and to avoid other organs is a difficult job.

The ARTCAM algorithm is used as an identifier to identify the tumor location from the brain MRI images as shown in fig.2. In addition, the Calculation technique for the tool path motion direction in computed tomography images is based on oncologists' and ENT surgeons' experience. After that, testing of this path should be performed using a test image set to verify the efficiency of the constructed path and reach the optimum path allowing identification to take place. This allows oncologists and ENT surgeons to access the location of the tumor in Head and Neck during eradication operation and 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 as shown in fig. 2.
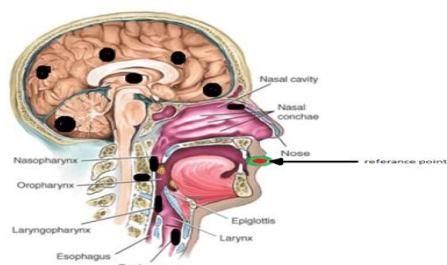

Figure 2. Head and neck tumors location diagram

B. MACH3 ALGORITHM

In this study, MACH3 2.0 is used to control the motors and interface between the user input and the driver circuit. MACH3 is low cost software available it implements motor control from manual input or programmed blade control. There are some requirements for proposed system design. The first fact of MACH3 is to provide inexpensive, programmable logic control and interfacing to external devices. The second option is that there are about 32 I/O pins required for interfacing various input and output devices. MACH3 is used in this study because it is compatible with all these requirements. 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. When MACH3 receives a command from the ARTCAM , it will be calculated into the control pulse signal by the algorithm and outputted through I/O port to driving the stepper motor. Its control is totally by computer and has vision capability which leads its blade to certain places. After finding the target coordinates, the control orders are given to blade by computer through parallel port to the interface circuit. These commands can turn off/on stepper motor through drive circuit in order to move blade to correct direction. The G-Code window and blade path displays provide information from MACH3 to oncologists

and ENT surgeons. The software provides functions including system configuration, combination code generator, program editor, terminal emulator, and program tester. With communication to the PC card and the indexer, the program can be used to control the system upon selection of the type of motor controller as shown in fig.3. The MACH3 algorithm 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.
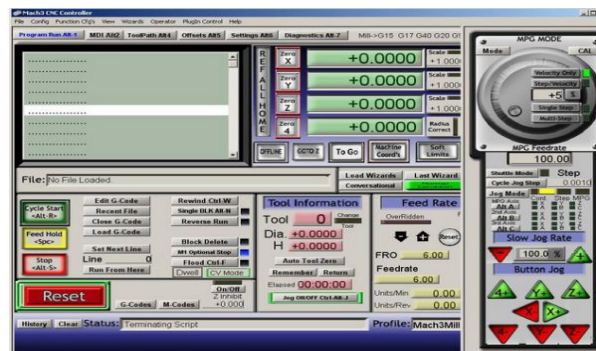

Figure 3. MACH3 software control panel

C. 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 indiscrete step increments when electrical command pulses are applied to it in the proper sequence. Rotation of the motors has several direct relationships to these applied input pulses (11, 13). The stepper used in this study has 200 steps per revolution. The relationship between steps per revolution and step angle is given by the following formula;

$$\text{Step angle} = \frac{360°}{\text{Number of steps per revolution}} \qquad (1)$$

$$\text{Step angle} = \frac{360°}{200 \text{ steps}} = 1.8°$$

It is found that the step angle is 1.8 degrees in a step. In this study, The stepping motors are used to drive the positioning tool blade in X and Y directions and the cutter in Z direction. The motors used are two phase bipolar stepping motors with 1.8 degrees per step. The rated voltage for one of them is 5 V DC and 3.2 V DC for the other.

In this study, we have a standard step motor with 200 steps per revolution. This motor is driven by a driver set to 5 micro steps per full step. The motor is directly coupled to the lead blade which has a pitch of 5mm per revolution. That means the axis will move 5mm for each revolution of the blade. So we'll take the motors 200 steps multiply that

by the drives 5 micro step. (200 X 5 = 1000). The drive needs 1000 pulses (or steps) to turn the blade one revolution thus making the axis move 5mm. So now we take those 1000 steps and divide by the pitch of the blade, which is 5. (1000 / 5 = 200). In other words we need 200 steps to move one unit or mm.

D. Stepper Motor Driver Circuit

The drive circuits are used to drive the two phase bipolar X,Y and Z stepper motors. The drive circuit to drive the X and Y axes is given in Fig. 4. while the circuit for driving the Z axis is given in Fig. 5.The principal function of the driver circuits is to generate motor phase sequences.

In these circuits L298 dual full-bridge driver and L297 stepper motor controller IC are used as motor drive circuit components. There are three control signals, which are used to control each of the motor axes, as "clock" to give the stepping command, "direction" to determine the sense of rotation of the motor and "half/full" to decide whether to operate in full or in half step mode(14). Although it is possible to choose full or half step mode, only the full step mode is used as indicated before. Normal drive mode is practiced to the full step mode and it is selected by a low logic level on Half/Full input (Full step mode)(8,13). The cable connection used between the stepper motor controller circuit inputs to the proper outputs in order to drive the step motors are given in Table 1, Table 2 and Table 3.

TABLE 1. Cable connection of X-Y axis card

X-Y Axis Card	Parallel Port Connector	Stepper Motor
KN1-1	-	GND pin of Y axis motor
KN1-2	-	Phase line 1 of Y axis motor
KN1-3	-	Phase line 2 of Y axis motor
KN1-4	-	Phase line 3 of Y axis motor
KN1-5	-	Phase line 4 of Y axis motor
KN3-1	-	GND pin of X axis motor
KN3-2	-	Phase line 1 of X axis motor
KN3-3	-	Phase line 2 of X axis motor
KN3-4	-	Phase line 3 of X axis motor
KN3-5	-	Phase line 4 of X axis motor
KN2-1	Pin 1 (Half/Full*)	-
KN2-2	Pin 6 (Clock X)	-
KN2-3	Pin 7 (Cw/CCw X)	-
KN2-5	Pin 1 (Half/Full*)	-
KN2-6	Pin 4 (Clock Y)	-
KN2-7	Pin 5 (Cw/CCw Y)	-

TABLE 2. Cable connection of Z axis card

Z Axis Card	Parallel Port Connector	Stepper Motor
KN1-1	-	GND pin of Z axis motor
KN1-2	-	Phase line 1 of Z axis motor
KN1-3	-	Phase line 2 of Z axis motor
KN1-4	-	Phase line 3 of Z axis motor
KN1-5	-	Phase line 4 of Z axis motor
KN2-1	Pin 1 (Half/Full*)	-
KN2-2	Pin 2 (Clock Z)	-
KN2-3	Pin 3 (Cw/CCw Z)	-

TABLE 3. Cable connection of cards and supply

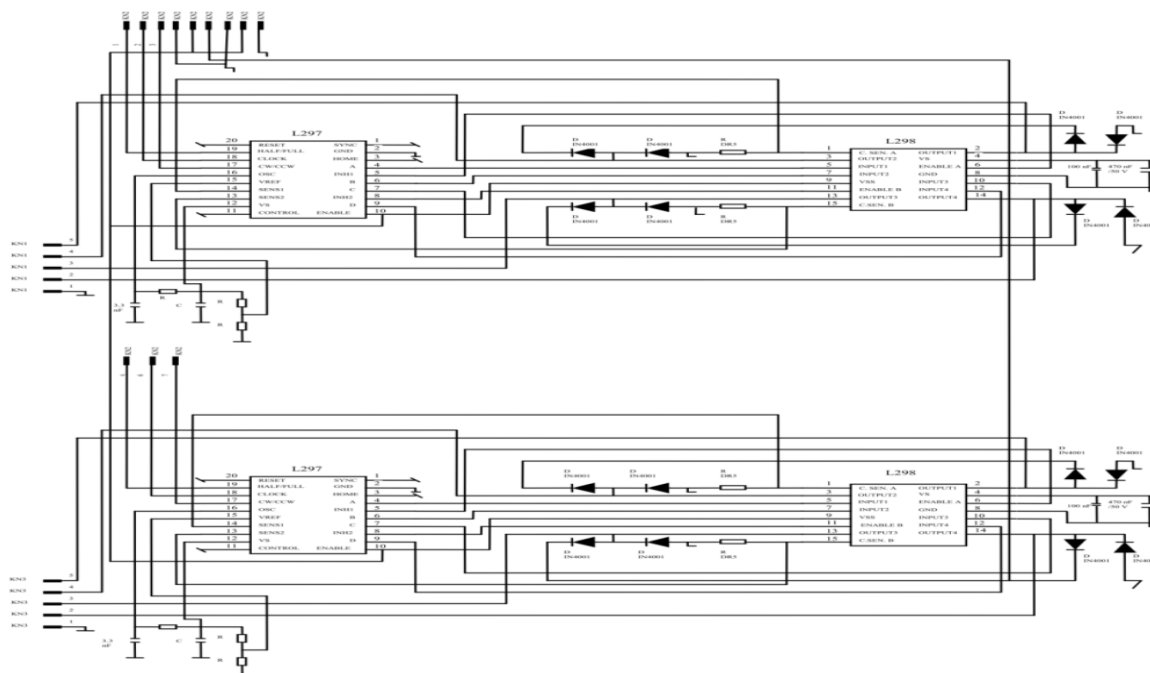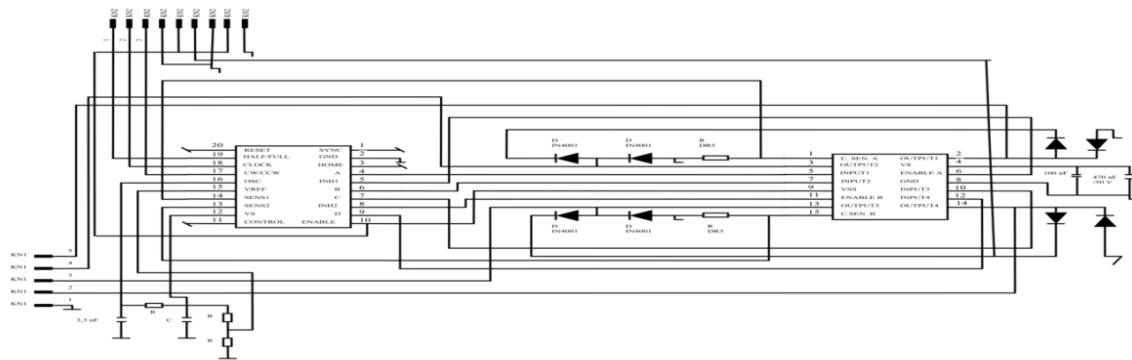| X-Y Axis Card	Z Axis Card	Power Supply	Cable Connector
KN2-8	KN2-8	+5V	-
KN2-4	KN2-4	GND	GND pin1
KN2-9	KN2-9	+24V	-

Figure 4. (X-Y) Axis Drive Circuit

Figure 5. Z Axis Drive Circuit

E. Digital I/O

1) *Requirements for Digital I/O :*Base drive circuit is designed such that the control signals are at TTL logic level which is 0 or 5 Volts. In order to have maximum efficiency in the system, these control signals must be as fast as possible (14). This speed depends on the torque requirement from the motor, simply the physical characteristics of the material are drilled, and the control scheme of the motors. Closed-loop control scheme will require faster signals than the open-loop case. Experimental results show that with the open-loop control scheme, motor types and material given, 5msec, as the step motor pulse duration is adequate. These signals may be generated by specially designed, commercially available professional devices that are sold by various vendors with respectively higher prices. Another solution for digital I/O is utilizing the parallel port which is available on every personal computer (8,15).

2) *Parallel Port of PC :*Parallel port 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 4, the base hardware addresses of the parallel ports are given.

TABLE 4. 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 dataports.
- 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 parallel port applications, for not to damage the mainboard the driver circuits should fulfill the requirements given above.

In Fig. 6, the block diagram of the parallel interface is given while in Fig. 7. the illustration of a parallel port is shown.
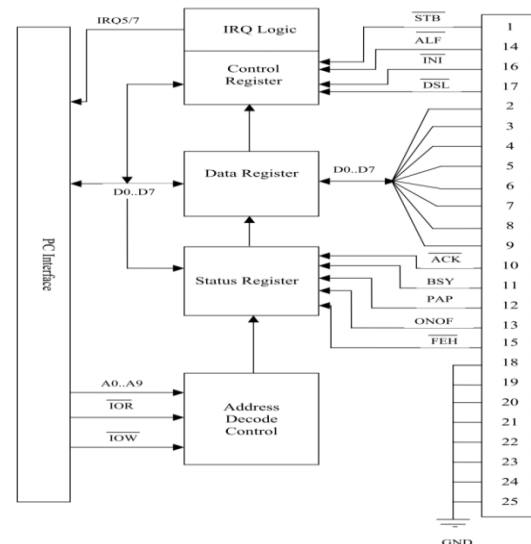

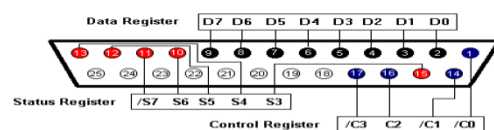Figure 6. Block diagram of the parallel interface

Figure 7. Parallel Port I/O Scheme

III.   SYSTEM OPERATION

This study is designed to control the blade movement system of the HANSR Tool path. Therefore a three Stepper motors is used. These motors are used to control the direction of the blade for X, Y and Z-axis. A MACH3 is also used to drive the three motors. Motors convert current into torque which produces motion. Motor's torque properly to move the blade at the required speed and acceleration must be determined for each motion.

When the operation is started, 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.

A.   Stepper Motor Control

One of the critical points in the software is to send the data to the driver circuit properly i.e. to the right axis with the right timing. To determine the movement axes that should in fact determine which bits of the parallel port to change
. According to the axes and movement determined, the signals are generated and sent to the driver circuit.

The first thing in the tuning process is to calculate how many steps per unit of travel we have. This depends on a few things:

- The amount of steps per revolution.
- The step resolution of the motor drive, full step, half step, 5, 10, 100 micro steps etc.
- The reduction ratio between the motor shaft and lead blade.

In this design, a minimum step of 0.0005" was chosen. A stepper motor (ten micro-steps) gives 2000 steps per revolution so a 5:1 reduction (belt or gear box) is needed between the motor shaft and lead blade to make one step equal to 0.0005" of travel [0.0005" = 5"/(2000 x 5)], and because of the 5:1 gear reduction one revolution of the stepper motor will result in 1" of travel. With this design, if we get 500 rpm from the stepper, travel will be 500 inches per minute, or 8.33 inches per second. The rapid feed of 60" would, neglecting acceleration and deceleration time, take a reasonable 7.2 seconds. [60" / 8.33 = 7.2].

B.   Drive Circuit Operation of MACH3 Motor setup

The drive needs 2000 pulses, or steps, to turn the motor one revolution. But since we have the 3 to 1 belt reduction between the motor and the blade we need to multiply the 2000 by 3 to make the screw turn one revolution. 6000 steps will make the blade turn one revolution, making the axis move 1/5 of an inch. To make the axis move one inch we need the blade to make five revolutions so 6000 X 5 = 30.000 steps per unit or

inch. In reality a step per unit value as high as 30.000 will greatly reduce the speed at which the HANSR Tool blade can move. This is for X Axis as shown in fig.8. Then do the same for the Y and Z axis.

Now that we know the required motor revolution per unit of travel, we can finally calculate:

$$\text{MACH3(s/u)} = \text{MACH3 (s/r)} \times \text{Motor (r/ u)} \qquad (2)$$

Where   s: step, u : unit and r: revolution

Fig. 9.   Shows the dialog for Configuration Motor Tuning. Select the axis that you are configuring, and enter the calculated value of MACH3 steps per unit in the box labeled Steps per unit. This value does not have to be an integer. Whatever the number, it is a specific, calculated number determined by the drive configuration.
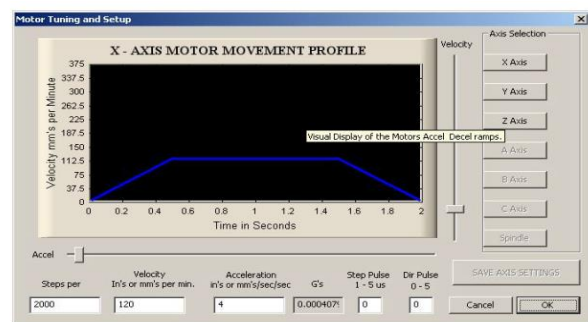

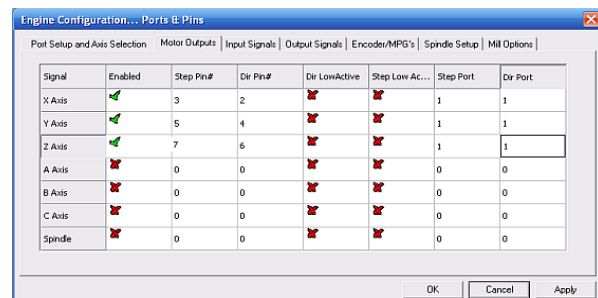Figure 8: Motor Tuning and Setup by MACH3 software.

Figure 9. MACH3 Motor Tuning Configuration setup

C.   The blade speed and Pulley Ratio calculations

The maximum speed is the speed at which the blade will rotate when the motor is at full speed. Full speed is achieved by 100% pulse width modulation (PWM) and at the set value on Motor Tuning "blade Axis" for Step and Direction. If a speed greater than the Maximum Speed is requested, MACH3 will display a warning and use the Max Speed value. If the Minimum Speed feature is used, its value for each pulley should be calculated as a percentage of the maximum speed, with the percentage determined by the minimum speed rating of the motor or controller. It is, also the minimum percentage PWM signal ratio. For this system, we choose a PWM of less than 20% gives unacceptable

motor performance, then the minimum speed should be calculated as 20% of the maximum speed. If a speed lower than the minimum is requested, then MACH3 will display a warning and use the minimum acceptable speed. In this study, there is a maximum speed of 1600 rpm on pulley 4 and a minimum speed of 320 (20% of 1600), an S200 command would display a warning and the minimum speed of 320 would be used. This feature is to avoid operating the motor or its motion controller at a speed below its minimum rating. MACH3 uses the pulley ratio information as follows:

- When the part program executes an S-word or a value is entered into the Set Speed DRO, then the value is compared with the maximum speed for the currently selected pulley ratio. If the requested speed is greater than the maximum, then an error occurs.

- Otherwise, the percentage of the maximum for the pulley that has been requested is used to set the PWM pulse width, or Step pulses are generated to produce that percentage of the maximum motor speed as set in Motor Tuning for the "blade Axis." In this study, suppose the maximum blade speed for Pulley 1 is 1500 rpm. S1600 would be an error.

An S200 command would give a PWM pulse width of 40% (600/1500). If the maximum Step and Direction speed is 3600 rpm, then the motor would be "stepped" at 1440 rpm (3600 x 0.4).The Ratio value can be set if the actual speed of the blade is for any reason different than the measured speed being seen by the tachometer. This may occur if, because of physical constraints, the speed sensor must be mounted at a point in the spindle drive train that has additional gearing between its location and the blade movement. Check reversed if, because of gearing, blade rotation of a pulley setting is opposite to the rotation of other pulley settings.

Figure 10. Pulley Ratio and blade speed calculations.

IV.   TEST AND RESULT

The motion control system of a HANSR Tool blade is operated by the ARTCAM and MACH3 2.0 software. The algorithm is applied to 20 sets of real data in the form of images for the adenoid and head and neck tumor tissue before and after removal operation. These images are classified to 12 sets of classifications (A to L) depending on the tumor location identification. Enter these images to the ARTCAM algorithm then start tool path simulation. Since this software consists of many separate path way programs which pulse a large number of additional G-code files, it is the fact that oncologists and ENT surgeons decide to use this

software. As already mentioned, ARTCAM algorithm is used to move the HANSR Tool blade to proper angular position and check the end position of the blade path as shown in fig.11. Drive Circuit is used to control each of the motor axes, to give the stepping command, "direction" to determine the tumor location to pick up the desired target. To make Automatic Setting of Steps per Unit, calculate the steps per unit by measuring the gearing of motor axis drive. Then MACH3 can calculate the steps per unit that should be configured, as shown in Fig.12.

The operation of the system is supervised by the MACH3 algorithm related to blade path resulting from ARTCAM algorithm. The three Stepper motors are used to move the blade to X, Y and Z-axis according to G-Code of blade path as shown in fig.13.

The HANSR Tool Stepper motors are controlled by the operator the blade path to get desired tumor location. In this system, oncologists and ENT surgeons must select the type of image class firstly, and then open this image in an ARTCAM algorithm. After that, start the MACH3 algorithm to start the automatic eradication operation. When the MACH3 algorithm is started, the stepper motors will rotate according to the predefined data of MACH3 algorithm.
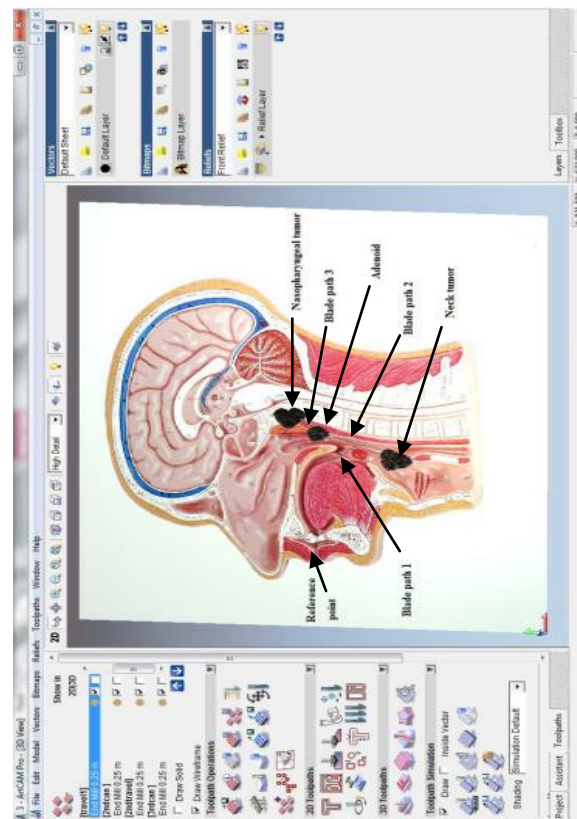

figure .11. ARTCAM algorithm moves the HANSR TOOL blade to proper angular position according to the input MRI head and neck images.
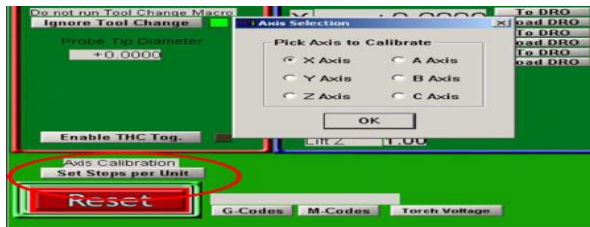
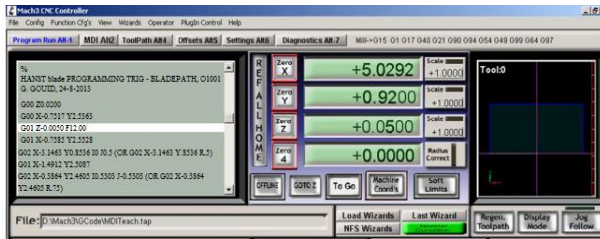figure 12. Automatic Setting of Steps per Unit

figure 13. The Program Run screen, with G-Code window of blade path out.

V.   CONCLUSION

This paper presented an HANSR Tool blade motion control system using a MACH3 and ARTCAM algorithm. The design sequence of the current system is described and parameters of three stepper motors driving are calculated at optimal values. In this design, the MACH3 and ARTCAM algorithm are used to build a high performance of swellings automatic removal operation. 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. The experimental results verify the performance of the blade motion control.

REFERENCES

[1]   Kowalski LP, Carvalho AL. Influence of time delay and clinical upstaging in the prognosis of head and neck cancer. Oral Oncol. 2011; 37(1): 94-8.
[2]   http://www.emory.edu/ANATOMY/AnatomyManual/pharynx.htm.
[3]   Prasad U, Pua KC. Nasopharyngeal carcinoma: a delay in diagnosis. Med J Malaysia 2005; 55(2): 230-5.
[4]   Fanucchi M, Khuri FR, Shin D, Johnstone PAS, Chen A. Update in the management of head and neck cancer. Update Cancer Ther 2006; 1: 211-9
[5]   Huang HM, Chao MC, Chen YL, Hsiao HR. A combined Method of conventional and endoscopic adenoidectomy. Laryngoscope 1998; 108:1104-6.
[6]   R.C. Speagle and D.M. Dawson, "Adaptive Tracking Control of Permanent Magnet Stepper Motor Driving a Mechanical Load", IEEE Conference, 1993.
[7]   F. Nollet, T. Floquet and W. Perruquetti, "Observer based Second Order Sliding Mode Control Laws for Stepper Motors", Control Engineering Practice, Vol. 16, pp. 429-443, 2008.
[8]   AN1495, Application Note, "Microstepping Stepper Motor Drive Using Peak Detecting Current Control", Thomas Hopkins,(2010),pp 4-9.
[9]   M. Zribi, H.S. Ramirez and A. Ngai, "Static and Dynamic Sliding Mode Control Schemes for a Permanent Magnet Stepper Motor", International Journal of Control, Vol. 74, pp. 103-117, 2001.
[10]   S.S. Ge, C.C. Hang and T. Zhang, "A Direct Method for Robust Adaptive Nonlinear Control with Guaranteed Transient Performance", Systems and Control Letters, Vol. 37, pp. 275-284, 2002.
[11]   Perriard, Y., Scaglione, O. and Markovic, M. "Self-Sensing Methods for PM Motors in Mechatronics Applications". Proceedings of the IEEE/ASME International Conference on Advanced Intelligent Mechatronics (AIM 2010).
[12]   ArtSoft USA. software incorported; MACH3 Controller Software Installation and ConfigurationVersion 3; 2010.
[13]   SGS Thompson Microelectronics, "Stepper Motor Controllers", August 2010.
[14]   Semih Mümin Ateş, "A PC Controlled Three Dimensional Machine Tool Control System", METU MS Thesis, Dec. 2008.
[15]   Oliver Faugeras, "Three Dimensional Computer Vision: A Geometric Viewpoint", MIT Press, 1998.

11/21/2013