VISION ASSIT FOR AUTONOMOUS SURGERY ROBOT

1 Madhu Mohan R, 2 Dr Grisha C, 3 Kunal M S, 4 Lokanatha Reddy V, 5 Mahendra M and 6 Pawan N

1 Professor, Mechanical-Engineering, A.M.C Engineering College, Karnataka, INDIA
2 HOD, Mechanical-Engineering, A.M.C Engineering College, Karnataka, INDIA
3,4,5,6 Student, Mechanical-Engineering, A.M.C Engineering College, Karnataka, INDIA

Abstract: The pedicle screw insertion has become the most exercised procedures in spine fusion surgery. It is performed to hold the vertebrae of the treated area in a fixed position. Each year there are about 1.3 million spinal surgeries performed in US alone. The miss-insertion rates in the lumbar spine region have been documented to be from 5% - 41%[1]. This paper provides a perspective on the development of vision assist system for an automated robot for fixation of pedicle-screw. Pedicle screw fixation devices are considered as class III medical devices. The technique of pedicle screw insertion in the spine has gone through significant development over the last two decades. Aim of this paper is to decrease the error rates by implementing an image-processing method which intends to eliminate the use of intra-operative fluoroscopy, MRI and CT.

1. Introduction

A medical protocol that uses operative instrumental and manual techniques on a patient to treat a pathological condition such as a disease or injury is known as Surgery. Every year there are about a million spinal surgeries performed in US, 53 percentage of which is classified as spinal-fusion surgeries. Pathological condition in the spine is one of the reasons why the patient requires medical
care. Hence there is increase in number of spinal surgeries performed. The surgeons or doctors diagnose and find out what the actual problem is and then if there are any major complications such as inflated intervertebral disc scoliosis, and kyphosis we resort to spinal fusion surgeries necessitating pedicle screw insertion which is a common solution to many of such complications. Most of these surgeries are performed by trained and experienced surgeons using conventional method where the surgeons operate in a blind spot. In conventional methods of operating miss-insertion of pedicle screws is quite often which is the main reason for the present error rates of about 18-20%[2]. But with the introduction of robotic technology to surgical field, the error rates can be minimized substantially and overall efficiency can be increased[3]. With this guidance system, the conventional approach of performing the surgery will be drastically improved as the whole process is automated. This system will be able to perform the operations by using a mere camera image which is then processed to find the exact point of insertion. This will be able to increase the overall efficiency and minimize the error rates and minimize or eliminate the usage of fluoroscopy, MRI and CT scans as too much of exposure to these radiations can cause cancers.

2. Objectives

Till date there have been many surgical robots for Pedicle screw insertion, which depend on intra-operative fluoroscopy, MRI, CT and CAS[4]. The use of these techniques increases the chances of bone cancers. This paper emphasizes on the vision assist system which excludes the use of such techniques and provides a cost-effective operation procedure. The main objective is to determine the exact point of insertion in the lumbar region of the spine with the help of a mere camera image. The average time taken required to insert the pedicle screw by conventional method is high which has error rates of approximately 18%, so with the help of this improved technique, the overall operating time will be substantially reduced along with increase in precision.

3. Methodology and Experimentation

The fixation of screw implants into the vertebrae is a complex procedure. Therefore, this system will be able to perform this complex procedure efficiently and without any error. The overall image processing is simplified into two steps:

1. Capturing the image of affected lumbar vertebrae: For this vision assist, a mere camera image of 720 pixels or 1080 pixels of the affected vertebrae is sufficient to obtain the point of insertion. Hence image can be captured using any device a camera or a Raspberry pi camera connected to a Raspberry Pi module can also be used to take pictures of the affected region. The operating region is illuminated by a light source which assists in capturing a better image.
Table 1. Angle of insertion of lumbar vertebrae.

| Vertebra | Gender | Transversal Pedicle angle | Inclination Pedicle angle |
|----------|--------|---------------------------|---------------------------|
| L1       | F      | 5                         | 6                         |
|          | M      | 7                         | 5                         |
| L2       | F      | 6                         | 5                         |
|          | M      | 7                         | 6                         |
| L3       | F      | 7                         | 6                         |
|          | M      | 8                         | 6                         |
| L4       | F      | 10                        | 7                         |
|          | M      | 11                        | 6                         |
| L5       | F      | 18                        | 8                         |
|          | M      | 17                        | 5                         |

Once the image is captured by the system, it will be compared with the predefined images to identify the exact lumbar vertebrae and its angle of insertion which are also predefined, refer table 1.

2. Image processing using MATLAB: The image captured is then processed in mat-lab where it undergoes gray scaling and edge detection. Image is imported using digital camera or medical Imaging devices. The imported image undergoes grey scale conversion process, which is an M*N array whose values have been scaled to indicate intensities. A new matrix with same number of columns & rows as RGB image is created. Each RGB pixel values at location (x, y) is converted to gray scale values which is assigned to a corresponding location (x, y) in new matrix. The image then undergoes edge detection method for finding object boundaries. It works by detecting discontinuities in brightness. A function f(x, y) is represented by the digital image. In this function ‘x’ and ‘y’ are structural coordinates. The amplitude of ‘f’ at any structural coordinate gives the magnitude of the image at that point. Each element in an array represents an image element.
4. Results for point of insertion

Using the captured image, by edge detection the articular facets and the transverse facets are distinctly identified. An algorithm is then used to determine the intersection of the tangential point of transverse and articular facet which gives the point of insertion of pedicle screw as shown in figure 6 and figure 7. The outcome of the vision system coincides with the actual point of insertion as shown in figure 8 and figure 9.
5. Conclusion

In previous years, the number of spinal surgeries carried out has increased due to which many surgical robots, whose operating cost is very high, came into existence[5]. The maintenance and cost of these robots are so expensive that only few hospitals have it, on the contrary the vision assist system provides an efficient and cost effective way of operation which is affordable with improved precision and dexterity.

6. References

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