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Analytical approach for Intelligent Vision System Using Image Processing

Mr.Murugamani[1] Dr. S. Saravanakumar[2],
1. Research Scholar, St.Peters University
2. Professor, Department of IT, Panimalar Institute of Technology, Chennai,

***ABSTRACT*−*The vision-based automated needle wear monitoring systems are very important and efficient for unmanned surgical systems. This research is to use the needle vision inspection technique to automate the surgical monitoring of needles. A new method based on computer vision using image processing technique is proposed to estimate the wear and tear of surgical needles in order to identify the time for their replacement. This is possible by using a supervised approach, such that the replacement of needle is carried out before the wear reaches the highest level thereby causing harm. The perimeter of the wear region was described by means of a shape signature, which was normalized and resized to a set of values. These vectors have been classified using SNNalgorithm. This algorithm focuses on the appropriate estimation technique in order to replace the surgical needle based on its thickness and depth.*

Keywords: vision, image processing, surgical needles, replacement, SNN algorithm.

1, INTRODUCTION

Surgical suture is a medical device used to hold body tissues together after an injury or surgery. Application generally involves the use of a needle with an attached length of thread. A number of different shapes, sizes, and thread materials have been developed for this purpose. Suture selection is dependent on the anatomic site, surgeon's preferenceand the required suture characteristics. The length, diameter, and curvature of the needle influence the surgeon's ability to place a suture.No standardized sizing system or nomenclature is available for needles or needle holders; the main consideration in the selection of needle is to minimize trauma.

Recent advances in the field of image processing technology have led to this experimentation with needle vision as a potential means of directly evaluating needle condition.

Particularly with recent advances and applications in surgery, there is an increasing demand for high precision and accuracy; while the most serious problem is regarded to be pus formation, infections due to bacteria and viruses which may cause severe threat to life and when not treated properly may even cause death which is due to the breakage of needles or the wear of sutures. Needle condition monitoring is particularly required to detect suture wear and avoid needle breakage in order to protect the damage that would be caused later.

The common criteria used to determine the time for needle replacement will be greater than the lifetime of the needle, both in manual and unmanned operations. In manual processes, tool

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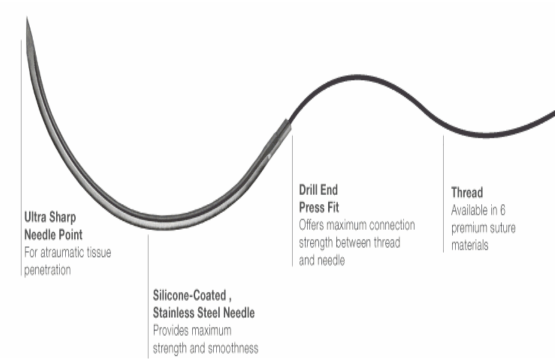
replacement depends mainly on the machinist subjective criterion which is based on experience. In unmanned systems, the time for replacement is defined on the basis of accumulated values for some production variables.



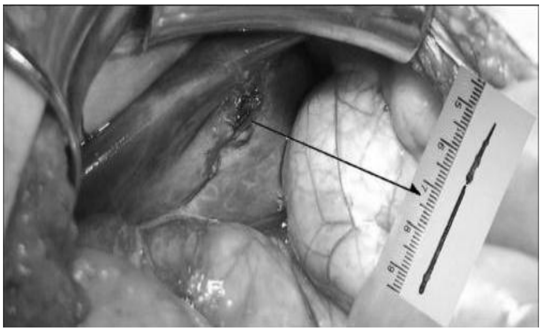
The most common cause of needle breakage is sudden unexpected movement of the patient. Smaller gauge needles (size 30) are more likely to break than larger ones (size 25). Some practitioners habitually bend the needle and the metal is weakened in this area. A needle that breaks with part of it visible can be easily removed with a hemostat but needles that break within the tissue may require removal by surgery.

The best way to avoid needle breakage is to routinely use a 25-gauge needle for any injection where there is a significant penetration of tissue. The hub is the weakest part of a needle, so unless the injection technique specifically requires it, the needle should not be inserted all the way to the hub. Rather, a longer needle must be used.

The patient has to keep his/her mouth open, and a bite block has to be placed if any problems are caused due to needle breakage.

If an end of the needle is visible, it should be retrieved with a hemostat or cotton pliers. If it is not visible, we cannot retrieve it in many cases. The patient must be sent by an oral surgeon for consultation. The broken fragments may be surgically removed or if the procedure may cause too much damage, they may leave it where it is.

Frequent usage of needles may lead to the weakening of muscles. Simply cutting the muscles frequently produces overcorrection that becomes difficult or impossible to reverse.



As the usage of suture causes problems, the technology has brought around strabismus surgeries which are done in the absence of sutures.

In addition to the standard consent form with the usual disclaimers used for any type of surgery, it is necessary to advise patients undergoing strabismus surgery of the following complications unique to strabismus surgeryDiplopia, Loss of vision and Need for reoperation. A separate consent obtained by the anesthesiologist can include information about the chance of breathing difficulties, vomiting, sore throat, or even of heart attack or death!

2, Existing Architecture

By the second half of the 19th century, heavy Silk sutures about the size of current 4-0 or 5-0 caliber were employed to control weakening and for muscle shortening or strengthening. These silk sutures were often waxed at the time of surgery to help ease the passage through tissue. The reusable needles for introducing this suture were large, made of round wire and had an eye to thread the suture. Because of the bulk of these needles compared to the thickness of the sclera, sutures secured the muscle to overlying tendon's capsule and conjunctiva with the knots tied externally.

Muscles were not anchored to the sclera as they are done today. These silk sutures had to be removed to avoid infection and excess reaction.Strabismus surgery made use of the catgut suture which was actually made from the sheep intestine.Catgut suture offered a definite advantage over the silk suture as they were absorbable. The drawback of catgut suture is that it lacks strength and uniformity.These sutures also produce significant inflammatory reaction.

In an attempt to provide remedy to some of these problems, Collagen suture was introduced in the 1960's. Though still an animal product absorbable suture and no stronger than catgut, collagen promised some improvement over catgut. Collagen suture is formed by an extrusion of homogenized, pooled beef fascia and is 100% collagen, making it smooth, conformable and easy to handle. Collagen suture also is easy to tie, producing a secure knot. Theoretically, thepooled fascia making up collagen suture should result in reduced antigenicity and therefore reduced inflammatory reaction making it superior to catgut. On the contrary, reaction with collagen is similar to that seen with catgut. Mild to moderate inflammatory reaction occurs in about one case

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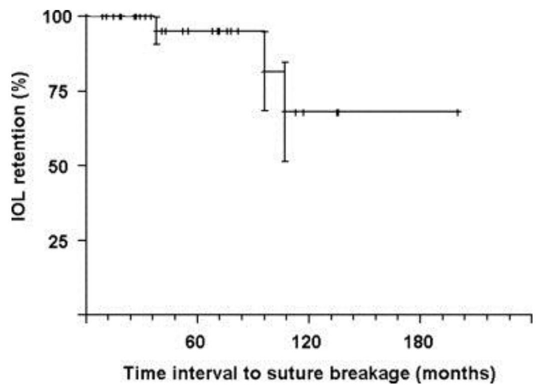
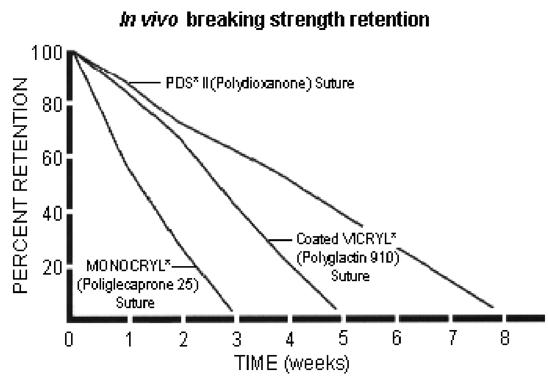
in five and severe suture granuloma occurs in about one percent. An additional drawback is that while using either catgut or collagen suture, anyone but the most expert surgeon can expect to break at least one suture per strabismus surgical procedure.



The Surgeons' knot slippage or breakage can pass unrecognized as a cause of wound dehiscence, and it has been suggested that the Aberdeen knot and the Half-blood knot are easier and safer than the Surgeons' knot for tying these materials. The effect of different knots upon the breaking strain of common monofilament sutures was assessed using an InstronTensiometer.



The tapered suture needle is a penetrating needle that has an extremely sharp tapered point and easily cuts through tissues. The conventional suture needle has three sharp sides and is mostly used to repair torn tissue; it is also a penetrating needle. The reverse cutting suture needle and the tapered cutting suture needles are designed to penetrate deep wounds located in thick fleshy areas, while the blunt needle is used to remove and dissect tissue.

3, Proposed Architecture

A surgical needle is a needle which is used in surgery. Such needles are usually made fromstainless steel, because this metal is strong and resists corrosion, and will also bend before

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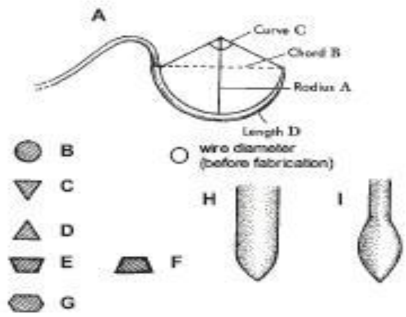
breaking, which can be critical when it is being used in a location where breakage might be at risk.Preventing needle breakage is important, as it can be a traumatic experience for the patient when it affects other parts of the body.

We have proposed a system which will detect the breakage of needles or its wear during the surgical process. There are various shapes and sizes of needles which have varied tips.



A - Various dimensions
B - Round
C - Cutting
D - Reverse cutting
E - Keystone - up cutting tip
F - Keystone - down cutting tip
G - Hexagon - neutral tip
H - Parallel
I - Cobra head

The camera tracks the needle movement along the path of the needle. All these are captured and a set of images are taken and stored in the system. When the actual surgery takes place, the needle's position and its movement is captured and compared with the stored block of images. Digital signatures are also used for this process. If the needle's lifetime expires, or if it begins to wear off, then there might be a slight change in the physical structureof the needle tip. This picture when captured by the camera produces a minute change which may not be visible to the human eye. Usingimage processing, we have proposed an algorithm called as SNN algorithm. When a light source is passed through the needle which is currently being used in the process of surgery, the images of the original needle and that of the needle being used is compared based on their thickness and depth as well as their determined angles. By this method, we can find the changes in the part of the needle where the wear has occurred or any crack in the metal body of the needle which may cause the needle to break when inserted into thicker muscles during surgery.

SNN Algorithm:

By projecting stripes of light having uniform slope and spacing onto the surface of the needle at a first determined angle, we can illuminate a worn portion as well as an unworn planar portion. But, the stripes of light on the unworn planar portion that can be viewed from a second angle are straight and uniform.
Sensing an image of the stripes of light projected on the surface of the needle from the second angle, we can identify the unconnected line segments which are mainly caused due to noise.
Constructing from the unconnected line segments, complete lines extending across the worn and unworn portions can be derived. This is done based on the offset value of the image which acts as a function of the depth of wear and the said angles. It is done by calculating straight reference lines in the worn portion that are extensions of the completed lines on the unworn portion, and measuring anoffset distance of the completed lines in the worn portion from the calculated straight reference lines to extract depth of wear information.
The digital display system or a monitor has to be attached to the camera or the system, which informs the surgeon that it is time to replace the needle. This information is displayed in the screen and a beep sound is heard for every second to alert the surgeon if any complications might occur when the same needle is being used continuously. The beeping may stop when the needle is replaced. This is done by continuous monitoring of the system and the camera taking pictures of the needle for every second. Each image is compared with the previously stored images using the algorithm which may only take a fraction of a second. This is done using signatures.
Signature is a method that represents a contour using one-dimensional function. A signature consists of a vector where each element contains the distance from the centroid of the region to the pixels in the boundary. A signature will be a good descriptor if it is invariant with respect to the location, size and orientation of the object in the image.
The size invariant is achieved via signature normalization. With respect to location, our problem is not affected by location changes and treatment of this invariant was not required. However, an invariant to orientation signature is important since the starting point affects the signature shape. In order to obtain always the same starting point the one nearest to the right-up corner of the image was chosen. This point is also a wear region characteristic point.

4, Extensions

Over the past 20 years, robotics has revolutionized surgery, and new innovations are continuing to push the boundaries of medicine. This can be extended so that in future surgeries may be done by machines or robots on human supervision. Human error is minimized as the systemeliminates false-positive (mistakenly complete count) andreduces false-negatives (the mistaken belief that a spongeis missing). Also, we cut down the time and effort thatis otherwise needed for manual counting during for eachintervention.

5, Conclusions

A new method to estimate the wear level in surgical needle is proposed. Identification of the adequate time for replacement of needle is possible using a computer vision system and a neural network classifier. It is remarkable that description of the wear region by means of a signature vector was also used. Sources of error have to be identified, and the system has to be evaluated under realistic surgical conditions. This method further more enhances the effectiveness of the needle and also the process by which surgery is safely done for the patients without any side effects and harm. Appropriate method of computing the thickness and depth of a needle used for surgery is used.

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BIOGRAPHY

Dr S.SARAVANAKUMAR has more than 12 years of teaching and research experience. He did his Postgraduate in Master of Engineering in Computer Science and Engineering at Bharath

Engineering College, Anna University, Chennai, and Ph.D. in Computer Science and Engineering at Bharath University, Chennai. He occupied various positions as Lecturer, Senior Lecturer, Assistant Professor and Professor. He has published more than 25 research papers in High Impact factor International Journal, National and International conferences and visited many countries like Taiwan, Thailand, Malaysia, Srilanka and Singapore. He is guiding a number of research scholars in the area ANN, Image processing, Data Mining, Cloud computing and Adhoc Network.