ISSN:1991-8178

Australian Journal of Basic and Applied Sciences

Journal home page: www.ajbasweb.com

Avoid Tissue Fracture By Optimizing Needle Insertion Model Using Artificial Intelligence Technique With Reduced Needle Deflection

[1]C.Murugamani, [2]S.Saravanakumar, [3]S.Prabakaran and [4]S.A.Kalaiselvan

[1]*Research Scholar, Department of Information Technology, St.Peter's University, Avadi, Chennai, Tamil nadu, India.*
[2]*Professor, Department of Information Technology, Panimalar Institute of Technology, Chennai, Tamil nadu, India.*
[3]*Department of Computer Science and Engineering, University College of Engineering, Panruti, Anna University, Chennai, India.*
[4]*Research Scholar, Department of Computer Science and Engineering, St.Peter's University, Avadi, Chennai, India.*

ARTICLE INFO

Article history:
Received 23 June 2015
Accepted 25 August 2015
Available online 2 September 2015

Keywords:
Needle Insertion, Mechanical Behavior of Needle, Success Surgery.

ABSTRACT

It is essential to investigate the needle properties and the insertion location on the human body [tissue] should be more important to avoid deflection while surgery. Needle insertion is a surgery technique to be studied for percutaneous procedure, diagnosis, locating therapeutic drug delivery. To determine the success of every surgical procedure, a minimal attention should be given during the interaction of the needle and the tissue which helps to improve the design techniques and the development tools and surgical techniques. In this paper, it is addressed the interaction among the tissue and the needle while insertion into porcine back tissue and simulated flesh-like tissue. An optimized testing setup is developed to measure and quantify the interaction with the tissue. Various locations on the tissue, various types of tissues, needle insertion characteristics and the needle defection magnitude are measured and optimized by applying a fitness function to both tissues and the needle. The experimental setup and various test procedures are applied to understand about the mechanics of the needle insertion potentially aid the design improvement on surgical environment.

© 2015 AENSI Publisher All rights reserved.

To Cite This Article: C.Murugamani**,** S.Saravanakumar, S.Prabakaran and S.A.Kalaiselvan., Avoid Tissue Fracture by Optimizing Needle Insertion Model Using Artificial Intelligence Technique With Reduced Needle Deflection. ***Aust. J. Basic & Appl. Sci.,*** *9(27): 126-131, 2015*

INTRODUCTION

Guidance for needle insertion plays a vital role in medical procedures like brachytherapy and biopsy. It is well known that flexible needs are having more potential to simplify exact targeting and avoid crashes during medical interferences throughout decreasing strain to the patient and post-puncture issue. However, errors are presented while guiding damages the effectiveness of the planned therapy or diagnosis. Although direction-finding using flexible bevel-tip needles can deliver a great mobility and deftness, a major fence is the complexity of needle tissue communication that does not advance itself to spontaneous control. To daze this delinquent, an optimization system can be employed to achieve course organization and following by operation of the needle base. While inserting a bevel tip needle into a soft tissue, the tip asymmetry will result in the needle bending naturally. It may deviate from the intended path according to the in homogeneity of the tissue and anisotropy, deformation of the organ and patient's respiration etc. Also the medical experts and the surgeons and interventional radiologists aware that the tip asymmetry causes needle deflection, manual steering of highly flexible needles remains a challenge due to the limitations of human manual control.

Corresponding Author: C.Murugamani, Research Scholar, Department of Information Technology, St.Peter's University, Avadi, Chennai, Tamilnadu, India.
E-mail: murugamaniau@gmail.com

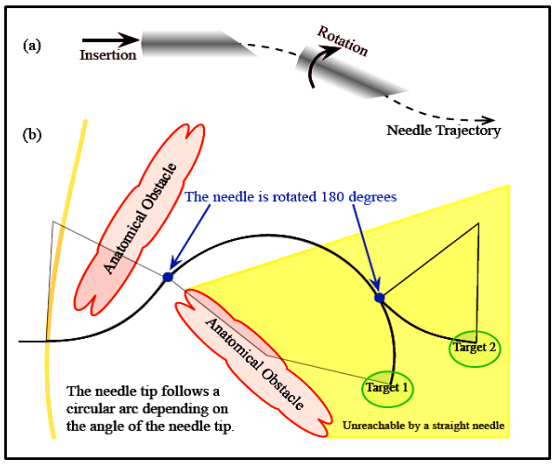

Fig. 1: Needle Analysis

A lack of access to quantitative tissue models, and complexity of the needle paths (Abolhassani, N., *et al*., 2007). Inaccurate needle placement creates malignancies not being detected during biopsy, radioactive seeds not being placed in the correct location to destroy cancerous lesions during brachytherapy, and traumatic or even fatal effects during administration of anesthesia.

From figure-1, it is easy to understand the steering mechanism, bevel tip of the needle, deflection of the needle during insertion. Also while needle rotation how the input is controlled along with the needle shaft and steered inside the tissue. (a) Shows the steering, (b) shows the needle reached the surface target. When needle reach the sub-surface target with a small amount of rotation on the needle including a force, multiple targets can be reached without fully retracting the needle. Bones, vessels, nerves and the other structures on the human body are include in the anatomical obstacles that a needle might get damage or not be able to penetrate.

Needle deflection distresses the exactness and ultimately the while surgery (Podder, T.K., *et al*., 2006). An appropriate and a constant measurement procedure on the needle deflection profile provide an accurate feasibility study on the usability of a needle guidance medical device. In this paper, it is described for experiment the AIS procedure and tests the samples. Second the results and discussion of the experiment is characterized the needle deflection while needle insertion into the Goat breast tissue. Thirdly the results and discussion on the needle deflection against the composition of the goat tissue are experimented to simulate the invasive surgery. Fourthly, it is tested and compared with the mechanical properties of the goat tissue with the gelatin (Ka Wei Ng, *et al*., 2013). Finally a conclusion is provided and recommendation for future works.

Background Study:

In point of earlier researches, a very good survey report is provided by Abolhassani *et al*. (2007). Misra *et al*. (2008) also provided a good survey report about the tool-tissue interactions with more surgical applications. Gerwen *et al*. (2012) has reported the empirical aspects of needle-tissue interactions in terms of force. Force is also one of the main attribute which affects the needle-tissue interactions. When analyzing about the force, Okamura *et al*. (2004) calculated force by finding the summation of capsule stiffness force, friction and cutting forces. Podder *et al*. derived a numerical prototype to assessment the extreme force that the needle practiced throughout insertion into the prostate and the perineum. By applying FEM mathematical model the needle –tissue interaction forces are calculated. A FEM based model to reproduce the non-linear and viscoelastic response and velocity dependency of the needle displacement is calculated while a puncture occur.

Problem Statement:

From the related works, it is essential to develop an optimum solution and procedure to avoid surgical problems like injured death due to inaccurate needle types [width, height, precision], needle insertion based friction, modulation, target location and so on. In this paper, an optimum solution based measurements are taken to avoid these problems during surgery. Nowadays various methods are discussed and proposed for controlling a needle insert into a tissue. Which includes tip-based needle steering, base-manipulation, and tissue manipulation? All the methods also advantages and disadvantages, related to the relationship among the needle and the tissue while needle insertion. Whereas, according to Figure-2, all the methods are combined to enable high steer ability at multiple insertion depths while reducing tissue damages.

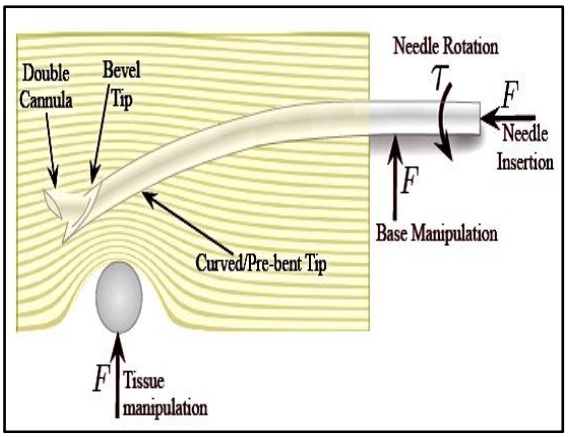

Fig. 2: Needle Operation

Various methods of needle steering has been proposed in the literature survey. Here Asymmetry based steering is utilized the forces generated at the tip of the needle during insertion to bend the needle. The curvature of the tip can be assigned as a constant or variable using multiple concentric cannula. The needle is bended as the base manipulation according to the force applied on the needle while insertion. Also the target is reached according to the path chosen for needle insertion. Each of these methods are conceptually independent but it is combined with one another which increases the controlling capability over the needle trajectory.

The main aim of this paper is to optimize the needles in terms of various effects according to the mechanical behavior of the needle. The fitness function applied on the needle insertion, retraction and compared with the best constant value as the velocity. The optimized values of the needle are provided to the LAB for manufacturing the needle for specific types of surgery and the tissue. To do optimization an Artificial Immune System is taken and the values with the fitness function are applied. Artificial Immune system is a biological optimization method, which can do optimization for large size problems. AIS are adapted from parallel and distributed problems. It is enthused by imagination on immunology and practical immune function. It selects a best value by applying a best fit solution finding method. By using a special function called "Matching" and using four measurements as choice, pattern, likelihood measurement and changing the pattern retrieves the best optimum result. The step followed in AIS is:

Proposed Approach:

Artificial Immune System Steps:

1. Making an input pattern
2. Creating a fitness function called as objective function
3. compute the objective[fitness value] in the input pattern
4. compare the calculated objective value with the previous objective value and choose the best objective value as the optimum value
5. Change the pattern and repeat step3 to 5 until reach the final optimum objective value as the best objective value as the solution to the problem.

Force displacement occur while needle insertion and removal from the human tissue. To make successful surgery the following parameters are optimized such as LD-[Loading Deformation], R-[Rupture], C-[Cutting] and ULD-[Unloading Deformation] using AIS.

Initialization:

LD = {0.. 1}, R = {1 .. 2}, C = { 2 .. 3} and ULD = {3..4};

Objective Value [OFV] = δ // initial value

Input patter is: *S1 = { LD, R, C, ULD}.*

Population $P = \{S_1, S_2, S_3, \ldots, S_n\}$ every S_i is an input pattern.

Objective Function:

OFV = min (Si) $\forall$ *i reduce the fracture*

label: 10

For I = 1 to n
Compute OFV (Si)
If OFV(Si) < OFV then
OFV = OFV(Si)
end if
end I
Change Pattern
Mutate (pattern (Si))
GOTO 10:
Return OFV
End

The above algorithm says that the needle properties are assigned from an initial value to a final value the objective function is tested. According to the objective function, a pattern [S_i] is selected as a best pattern assigned with values. After so many mutations and the clonal process, the best pattern is obtained and it is taken as the final pattern represents

the loading deformation, rupture, cutting and unloading deformation of the needle during interaction with the soft tissue. Following the above procedure, the tissue pressure, cutting force while needle insertion are eliminated which is has lowest or highest OFV values. Therefore it is safe to assume that the resulting interaction force is maintained for needle tissue interaction.

Experimental Setup:

N number of needles and their insertion procedure are experimented on fresh Goat breast pieces. During this insertion various set of frequencies of vibration and the velocities, force, cutting and rupture values are assigned and the AIS procedure is applied. Also various types of needle with various kinds of tips, gauge, diameter and length are mounted to the digital force measurement gauge. In this paper, the bevel cut is a cylinder cut through various angle for optimization and it is stressed down to touch the surface of the tissues. Both the tissues are taken in the size of 100 cm X 100 cm are utilized for experiment. Tissues are frozen for 2 weeks until the experiment. After 3 days defrosting, it was utilized for the experiment. The temperature of the tissues at the time of testing is 23.4C. For experimenting permanent the Si [best sequence] values are taken.

In this situation, the needle insertion procedure is experimented in various locations of the tissue with various forces at various angles. This process is repeated for N number of times with a short interval among the needle insertion on the tissue. According to the force and the location the deformation, needle behavior, puncture and fractures with rupture are calculated and the experimented results are shown in the following figures.

Figure-2 shows the insertion force measurement according to the velocity applied on the needle. The forces of the needle insertion directly affect the frequency of the needle and it makes fracture or puncture on the tissue. So it is essential to concentrate on the force applied on the needle for insertion into the soft tissue. Figure-3 shows the experimental result and the measurements are taken as needle deflection in the goat and gelatin samples. All this process is monitored by a camera and the deflection in terms of magnitude is measured. The needle defection in terms of the depth of the needle insertion is calculated and shown in Figure.3. Unlike the gelatin samples the goat sample based deflection is very less.

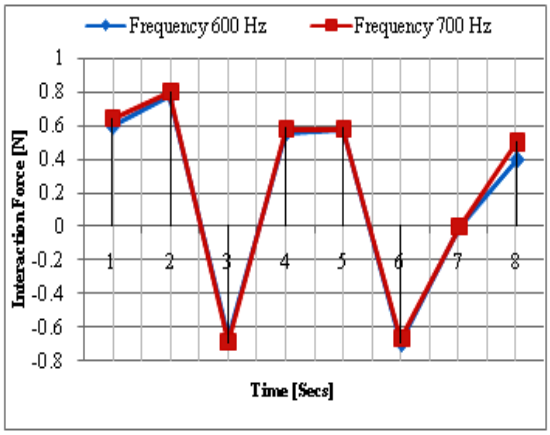

Fig. 2: Force Measurement at 5mm velocity

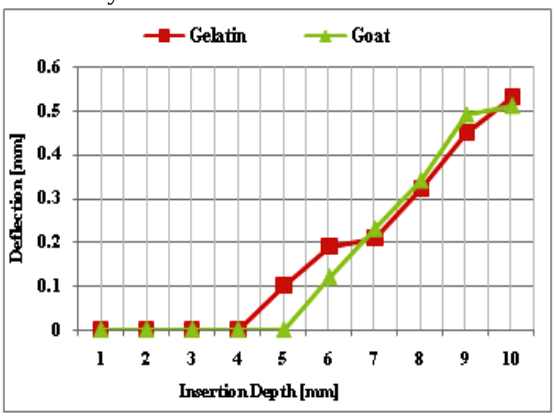

Fig. 3: Deflection vs. Insertion Depth

In common, the tissue modeling is a complex work due to the in homogeneity, non-linear, anisotropic elastic and viscous behavior. By utilizing similar material, parameters and tests the in homogeneity is determined and it applied to manufacture the testing equipment. The compression force of the goat and gelatin sample is tested repeatedly 10 to 20 times and the bio-mechanical behavior is measured and applied to AIS. Where, it helps to fetch the optimum measurements for determining needle insertion behavior with the soft tissue.

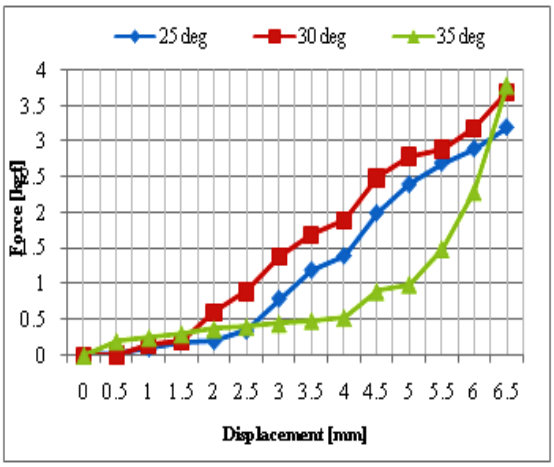

Fig. 4: Needle Defection In Terms Of The Depth

Conclusion:

The deflection of the needle while interacting with soft tissue was independently measured by a newly designed test setup. For each deflection it is related with the bio-mechanical behavior of the human soft tissues. In this paper instead of human tissue an equivalent tissue is taken from goat. Various times the insertion methodology is handled with various force and various velocity the overall performance is optimized using AIS algorithm and the best values are taken for the needle to interact with the tissue without any facture on the tissue. In this paper the experiment result is obtained for goat tissue and it is compared with the gelatin tissue sample proposed earlier.

REFERENCES

Abolhassani, N., R. Patel and M. Moallem, 2007. “Needle Insertion into SoftTissue", A Survey of Medical Engineering Physics, 29: 413-431.

Abolhassani, N., R. Patel and M. Moallem, 2007. "Needle Insertion into Soft Tissue", A Survey of Medical Engineering Physics., 29: 413-431.

Misra, S., K.T. Ramesh and A.M. Okamura, 2008. "Modeling of Tool-Tissue Interactions for Computer-based Surgical Simulation: A Literature Review," Presence-Teleop. Virt., 17(5): 463-491.

Van Gerwen, D.J., J. Dankelman and J.J. van den Dobbelsteen, 2012. "Needle-Tissue InteractionForces: A Survey of Experimental Data," A Survey of Medical Engineering Physics., 34(6): 665-680.

Okamura, A.M., C. Simone and M.D. O’Leary, 2004. "Force Modeling for Needle Insertion into Soft Tissue," IEEE Transaction on Biomedical Engineering, 51(10): 1707-1716.

Podder, T.K., J. Sherman, E.M. Messing, D.J. Rubens, D. Fuller, J.G. Strang, R.A. Brasacchio and Y. Yu, 2006. "Needle Insertion Force Estimation Model Using Procedure-Specific and Patient-Specific Criteria," In Proceeding of 28th IEEE EMBS Annual International Conference, pp: 555-558.

Dehghan, E., X. Wen, R. Zahiri-Azar, M. Marchal and S.E. Salcudean, 2007. "ParameterIdentification for a Needle-Tissue Interaction Model," In Proceeding of 29th IEEE EMBS Annual International Conference, pp: 190-193.

Crouch, J.R., C.M. Schneider, J. Wainer and A.M. Okamura, 2005. "A Velocity-Dependent Model for Needle Insertion in Soft Tissue," In Proceeding of Medical Image Computing and Computer Assisted Intervention (MICCAI), pp: 624-632.

Kobayashi, Y., A. Onishi, H. Watanabe, T. Hoshi, K. Kawamura and M.G. Fujie, 2008. "In Vitro Validation of Viscoelastic and Nonlinear Physical Model of Liver for Needle Insertion Simulation," In Proceeding of 2nd Biennial IEEE/RAS-EMBS International Conference on Biomedical Robotics and Bio-mechatronics, pp: 469-476.

Reed, K.B., A.M. Okamura and N.J. Cowan, 2009. "Modeling and Control of Needles withTorsional Friction," IEEE Transaction on Biomedical Engineering, 56(12): 2905-2916.

Ka Wei Ng, Jin QuanGoh, Soo Leong Foo, 2013. "Needle Deflection Studies for Optimal Insertion Modeling", International Journal of Bioscience, Biochemistry and Bioinformatics, 3(6).