Prediction of Insertion Force of Bioinspired Needles using Machine Learning Algorithm

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Introduction: Simulation of surgical procedures provides a safe and potentially effective method for surgical training and robot-assisted surgery for pre- and intra-operative planning. Accurate modeling of the mechanical behavior of the interface of surgical needles and organs has been well recognized as a major challenge in the development of reliable surgical simulators. Prediction of needle insertion forces especially has been recognized as a major challenge during needle-tissue interactions. In this study, a machine-learning algorithm is proposed to estimate the insertion forces of bioinspired needles [1].

Materials and Methods: Bioinspired needles with different bevel angles were developed and tested in gel phantom with varying stiffness. A machine-learning algorithm was explored to improve the prediction of the insertion forces. The algorithm was developed using measurement data from a specially-designed needle insertion test setup [1]. CAD software was used to develop the bioinspired needle design as shown in Fig. 1. The needle prototypes with different bevel tip angle were manufactured using Connex350 3D printer (Stratasys, Inc., Eden Prairie, MN). A force sensor (6 DOF F-T sensor Nano17® from ATI Industrial Automation, Apex, NC) was attached to the needle holder and used to record the force as the needle advancing in tissue gel phantom. Agarose gel was used as a tissue phantom and was prepared with concentration of 100 ml deionized water and 0.68 g of agarose powder. The needle insertion tests into agarose gel were performed. The recorded forces were then trained properly using machine-learning algorithm and verified with measurement data.

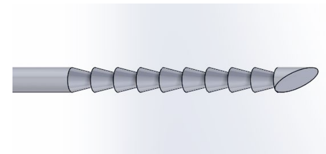

Figure 1: 3D CAD model of the bioinspired needle

Results and Discussion: The bioinspired needle insertion tests of bevel-tip bioinspired needles into agarose gels were performed. A typical insertion and extraction force profile is shown in Fig. 2(a). Using a machine-learning algorithm, a maximum insertion force of each test was collected and used to train the data to develop the predictive model. The preliminary result of the machine learning predictive model is shown in Fig. 2(b). It has been demonstrated that the model (dash) predicted the measurement data (solid) very well. The predicted results match very well with the measurement data with a root mean square error (RMSE) of 0.04 - 0.09.

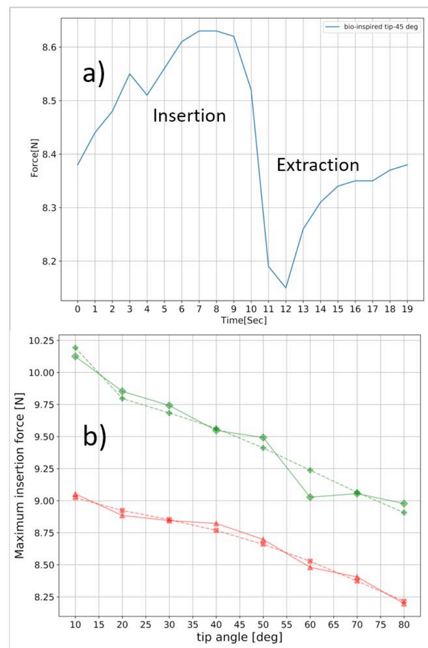

Figure 2: (a) A representative of insertion and extraction data, (b) comparison of prediction (dash) and measurement data (solid) for two gel phantom stiffness

Conclusions: It has been shown in this study that the machine learning algorithm can be used effectively to predict the needle insertion force. On going work is conducted to collect more data to improve the proposed model. Future work will focus on performing insertion tests in biological tissues, such as bovine liver and brain.

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References:

[1] M. Sahlabadi and P. Hutapea, "Novel design of honeybee-inspired needles for percutaneous procedure," *Bioinspiration and Biomimetics*, Vol. 13, No. 3, 2018.