IMAGE-GUIDED FLEXIBLE BEVEL-TIP NEEDLE CONTROL

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Abstract

Needle insertion procedures are a commonly used form of minimally invasive surgery. These procedures are used for diagnostic and therapeutic purposes. Image guidance is expected to improve targeting accuracy. In this study, an image-guided control algorithm is developed to robotically steer flexible needles with a bevel tip. The steering algorithm is based on assuming that needles with bevel tip will follow a circular path during insertion into a soft tissue phantom. A two-dimensional real-time needle tracking algorithm developed to determine the needle tip location and deflection during insertion.

Keyword(s): medical imaging

1 Introduction

In the current study, an image-guided control algorithm is developed to robotically steer flexible needles. The steering algorithm is based on rotating the needle 180° during insertion to change the direction of deflection [1].

2 Methods

Real time needle tracking was used to provide the control system with feedback about the current location and orientation of the needle. The position of the needle tip was determined using subtraction technique [2]. The control algorithm is based on the assumption that the needle follows a circular path with constant radius during insertion. The radius of the circular path is determined experimentally.

The effects of the needle system parameters on the needle deflection were investigated experimentally and this helped in selecting the needle system parameters used during insertion [3].

Three experimental cases are applied to validate the image-guided needle control system. In Case 1, the target is located along the circular curve that the needle is expected to follow during insertion, while in Case 2, the insertion point and the target are located on a horizontal line. Finally, in Case 3, the needle curves to avoid an obstacle and hit a target.

3 Results

The results of the needle system parameters experiments show that increasing the insertion velocity from 5.0 mm/s to 25 mm/s does not cause significant change in the deflection of the needles. The needle deflection decreases as the needle diameter increases from 0.8 mm to 1.5 mm. When the bevel angle increases from 30° to 60°, this leads to decrease in the maximum needle deflection. It can be concluded from the experimental results that the Nitinol needle of 0.8 mm with bevel angle of 30° provides the maximum deflection, and thus the highest steering ability among the needles used in the experiments.

The experimental results for control system validation of Case 1, Case 2 and Case 3 show that the needle tip could reach the target with mean accuracy of 0.36 mm, 0.21 mm and 0.21 mm, respectively. The targeting accuracy of the control algorithm is sufficient to reach the smallest size of breast and prostate lesions that can be detected using state-of-art imaging modalities.

4 Conclusions and Future Work

The control algorithm developed in this study is able to steer the needle to reach the target for the three experimental cases with maximum targeting error of 0.39 mm. The accuracy of the tracking algorithm is 0.4 mm. The targeting accuracy is influenced by the accuracy of the algorithm used for detecting the needle tip and deflection. The advantage of assuming that the needle follows a circular path with constant radius is that it allows us to predict the points that the needle tip can reach during insertion. In future work, the needle will move along a certain path. The path will be followed by the needle using sub-targets positioned on the planned path. The system will be extended to be three-dimensional. Ultrasound images will be used for image-guidance and position of the ultrasound probe will be controlled robotically.

References

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