The definitive version is available at `http://lcsr.jhu.edu/NeedleSteering/Workshop/Vidal.html`.

F. P. Vidal, A. E. Healey, N. W. John, and D. A. Gould: Force Penetration of Chiba Needles for Haptic Rendering in Ultrasound Guided Needle Puncture Training Simulator. In *MICCAI 2008 – Workshop on Needle Steering: Recent Results and Future Opportunities*. New York, September 2008.

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  author = {F. P. Vidal and A. E. Healey and N. W. John and D. A. Gould},
  title = {Force Penetration of Chiba Needles for Haptic Rendering in
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```

Force Penetration of Chiba Needles for Haptic Rendering in Ultrasound Guided Needle Puncture Training Simulator

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Abstract

Introduction and Motivations

We present a method for modelling the force penetration of needles into anatomic structures that are encountered during visceral punctures. Our aim is to provide a validated haptic model that can be used for the insertion of needles within our developing medical simulations of visceral interventional needle puncture procedures. This preliminary study is focused on Chiba needles. These are commonly used for gaining access to the kidney to perform Nephrostomy.

The force feedback delivered in current virtual environment (VE) medical simulator models is generally an approximation to a real procedure, as assessed by experts. Haptics based on real procedural forces will allow a more authentic simulation of the subtle cues perceived when carrying out an interventional procedure under real world conditions. In evaluating needle puncture procedures, *in vitro* studies are essential for detailed understanding of the physical components and effects of overall summated forces (soft tissue deformation force, clamping force, cutting force, *etc.*).

Material and Methods

We are collecting experimental data using a tensile tester used *in vitro* for pig and ox tissues obtained from a Butcher. However, due to the different physical properties of living tissues, *in vitro* data require verification by *in vivo* measurements. Until recently there were few devices available for measurement of instrument forces *in vivo* in humans, unobtrusively: flexible capacitance pads and other miniaturized sensors, however, present a novel opportunity to collect these data *in vivo*. Calibration *in vivo* has shown that the output of these devices is stable and reproducible.

Results

A Chiba needle was mounted and driven into the tissue at a fixed velocity, 500 mm per minute. This is an approximation of the speed of needle insertion during interventional radiological procedures. The needle orientation was orthogonal to the surface of the kidney. Ten punctures were repeated to obtain an average and the range of forces involved.

Finally, the force is modeled analytically using a radial-basis function (RBF) network:

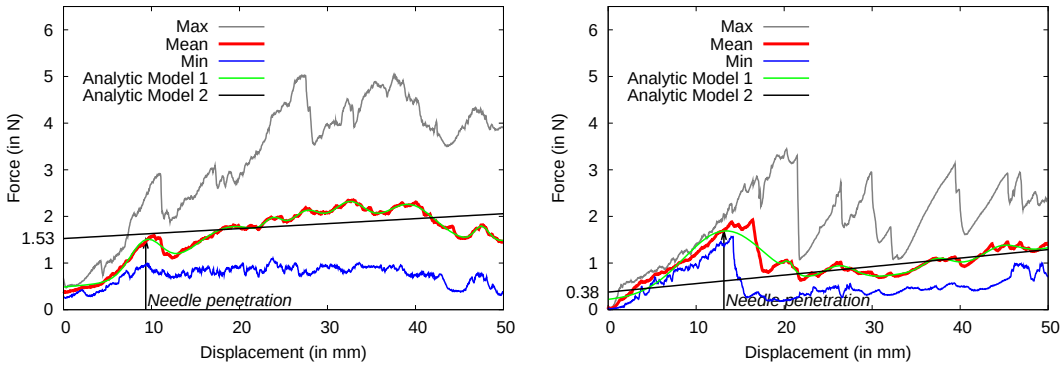
$$F(x) = \sum_{i=1}^{N} w_i \varphi_i(x - x_i)$$

$$\varphi_i(r) = -\exp^{\frac{r^2}{2\sigma_i^2}}$$

Each RBF corresponds to a Gaussian function, for which three parameters have been estimated: the centre x_i, the weight w_i, and the full width at half maximum σ_i.

Conclusion

This model closely matches the experimental data and accurately reproduces the same trend as shown by the experimental data. The resulting haptics model has been embedded into the needle insertion component of our ultrasound guided needle puncture simulator.



(a) In a pig kidney.

(b) In an ox liver.

Figure 1: Force penetration of a Chiba needle from a tensile tester used *in vitro* (needle velocity = 500 mm.min^{-1}).

Related Publications

F. P. Vidal, N. W. John, D. A. Gould, and A. E. Healey. Simulation of ultrasound guided needle puncture using patient specific data with 3D textures and volume haptics. *Computer Animation and Virtual Worlds*, 19(2):111–127, May 2008. doi:10.1002/cav.217

Links

- Virtual Environments for Training Intervention Radiology Procedures @ Bangor University – `http://www.hpv.cs.bangor.ac.uk/projects.php`
- CR*a*IVE - Collaborators in Radiological Interventional Virtual Environments – `http://www.craive.org.uk`
- Franck P. Vidal's webpage – `http://www.cs.bangor.ac.uk/Staff/fvidal.php`
- Nigel W. John's webpage – `http://www.cs.bangor.ac.uk/Staff/nigel_john.php`
- Derek A. Gould's webpage – `http://www.hpv.cs.bangor.ac.uk/CRaIVE/dag.php`

Force Penetration of Chiba Needles for Haptic Rendering in Ultrasound Guided Needle Puncture Training Simulator

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Abstract

This poster presents a method for modelling the force penetration of needles into anatomic structures that are encountered during visceral punctures. Our aim is to provide a validated haptic model that can be used for the insertion of needles within our developing medical training simulations of visceral interventional needle puncture procedures. This preliminary study is focused on Chiba needles.

Introduction

Interventional Radiology (IR) is a quite recent medical speciality, which consists of minimally invasive diagnostics or treatments guided by images (usually fluoroscopy, ultrasound, CT, or MRI). Training guided needle puncture, a core task in the radiology curriculum, is still an apprenticeship, and we are currently developing a training simulator for this [1].

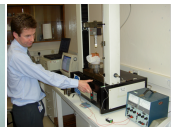
From apprenticeship to training medical simulators.

The force feedback delivered in current virtual environment (VE) medical simulator models is generally an approximation to a real procedure, as assessed by experts. Haptics based on real procedural forces will allow a more authentic simulation of the subtle cues perceived when carrying out an interventional procedure under real world conditions. In evaluating needle puncture procedures, *in vitro* studies are essential for detailed understanding of the physical components and effects of overall summated forces (soft tissue deformation force, clamping force, cutting force, etc.).

Implementation

We are collecting experimental data using a tensile tester used *in vitro* for fresh pig and ox tissues. However, due to the different physical properties of living tissues, *in vitro* data require verification by *in vivo* measurements. Until recently there were few devices available for measurement of instrument forces *in vivo* in humans. unobtrusively: flexible capacitance pads and other miniaturized sensors, however, present a novel opportunity to collect these data *in vivo* [2]. Calibration *in vitro* has shown that the output of these devices is stable and reproducible.

Capacitance pad.



Chiba needle mounted and driven in a tissue used in vitro (needle velocity = 500 mm/min).

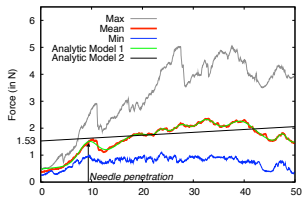
A Chiba needle was mounted and driven into the tissue at a fixed velocity, 500 mm per minute. This is an approximation of the speed of needle insertion during interventional radiological procedures. The needle orientation was orthogonal to the surface of the kidney. Ten punctures were repeated to obtain an average and the range of forces involved.

Finally, the force is modeled analytically using a radial-basis function (RBF) network:

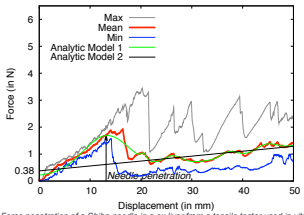
$$F(x) = \sum_{i=1}^{N} \omega_i \varphi_i (x - x_i)$$

$$\varphi_i(r) = \exp\left(-\frac{r^2}{2\sigma_i^2}\right)$$

Each RBF corresponds to a Gaussian function, for which three parameters have been estimated: the centre x_i, the weight w_i, and the full width at half maximum σ_i. This model is being incorporated within our medical simulator.



Force penetration of a Chiba needle in a pig kidney from a tensile tester used in vitro (needle velocity = 500 mm/min).



Force penetration of a Chiba needle in a ox liver from a tensile tester used in vitro (needle velocity = 500 mm/min).

Conclusion

This model closely matches the experimental data and accurately reproduces the same trend as shown by the experimental data. The resulting haptics model has been embedded into the needle insertion component of our ultrasound guided needle puncture simulator.

References

[1] F.P. Vidal, N.W. John, A.E. Healey, and D.A. Gould. Simulation of ultrasound guided needle puncture using patient specific data with 3D textures and volume haptics. *Computer Animation and Virtual Worlds*, 19(2):111–127, May 2008, DOI: 10.1002/cav.217
[2] A.E. Healey, J.C. Evans, M.G. Murphy, S. Powell, T.V. How, D. Groves, F. Hatfield, B.M. Diaz, and D.A. Gould. *In vivo* force during arterial interventional radiology needle puncture procedures. In proceedings of *Medicine Meets Virtual Reality 13 (MMVR 13)*, pages 178–184, Feb. 2005.
[3] VE for Training IR Procedures @ Bangor University -- http://www.vmg.cs.bangor.ac.uk/projects.php
[4] CRaIVE - Collaborators in Radiological Interventional Virtual Environments -- http://www.craive.org.uk
[5] Franck P. Vidal's webpage -- http://www.cs.bangor.ac.uk/Staff/fvidal.php
[6] Nigel W. John's webpage -- http://www.cs.bangor.ac.uk/Staff/nigel_john.php
[7] Derek A. Gould's webpage -- http://www.vmg.cs.bangor.ac.uk/CRaIVE/dag.php

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Figure 2: Poster presented at MICCAI 2008 – Workshop on Needle Steering: Recent Results and Future Opportunities. New York, Septe 6, 2008.