Optimized Tissue Modeling

Computer Integrated Surgery II

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Team 10

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Introduction

- Accurately reconstruct a tissue/surface from finite number of force sensor palpation readings
- Functional Geometry remodeling
  - : MSE ~1.17
- Functional Stiffness remodeling
- Combined geometry/stiffness remodeling
- Optimal Palpation trajectory on unknown surface
- Potential application: guiding exploratory surgery
- Accurate real time localization of tumors

The Problem

- How can we accurately reconstruct a surface without any assumptions on the underlying structure?
- How do we select the fewest number of points to perform this reconstruction?

The Solution

1. Create Gaussian Process (GP) algorithm to independently model both geometry and stiffness:
   - Use force sensor palpations to measure tissue height and stiffness
   - After each palpation, the two independent GP’s will be updated in light of the new data
   - A GP modeling is achieved by sampling from a multivariate Gaussian distribution such that:
     \[
     k(x,x^*) = \sigma^2 \exp\left(-\frac{(x-x^*)^2}{2l^2}\right) + \sigma_f^2\delta(x,x^*)
     \]
   - \( y \) Values from training points
   - \( y^* \) Values at test set inputs
   - \( K \) Training set covariances
   - \( K^* \) Training-test set covariances
   - \( K^*^* \) Test set covariances
   - \( k(x,x^*) \) Covariance element
   - \( f \) Query Candidate

2. Approaches taken to selecting the next point:
   - Randomly select nearby points to choose from based on these criteria:
     a) Dynamic Sampling Area
     b) Predicted Change in Variance:
     c) Quadsense

   - Optimization of Tissue Modeling

   - b) Predicted Change in Variance:
     \[
     \Delta y^2(l(l)) = (K_\text{var} - \text{Cov}(l,l)) \cdot \text{Cov}(l,l) - \text{var}(l)
     \]

   - c) \[ a \cdot \text{Max(predicted mean)} + b \cdot \text{Max(predicted variance)} \]

Future Work

- Grid Initialization and Adaptive Grid Search
- Test on other stiffness distributions.
- Assume stiffness to be a non-linear model.
- GP with co-dependent outputs

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Lessons Learned

- While GPs are versatile, they do have their limits
- Adaptive searching is no small feat
- Algorithms that work well on simulated data may not perform perfectly in practice
- Reports are good for thinking.
- Procrastination is not good

Measurement

Meaning

Optimal Palpation trajectory on unknown surface

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