**Orientation-Driven Ultrasound Compounding**

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### Methods

**Complex Ultrasound Image Formation**

- Dependent on angle, probe pressure, patient positioning, ...
- Same anatomy may yield different information if scanned from different perspective or at different time

**Traditional US Compounding Techniques:**

- Assume undistorted input data
- Correlation between US frames depends on
- Important step towards “real” 3D Freehand Ultrasound

**The above compounding scheme can be rewritten**

\[ \text{Uncertainty} = \frac{\sum_{c \in C} (1 - U_c(x)) ||U_c(x)||}{\sum_{c \in C} 1 - U_c(x)} \]

### Introduction

**Our Vision: Free Clinicians from Restrictive Scanning Protocols!**

- Allow arbitrary trajectories
- Support incremental acquisition with interactive feedback on reconstruction

**Our Contributions:**

- Orientation-driven pressure compensation and frame clustering
- Uncertainty-based incremental information fusion

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### Orientation-Driven Inter-Frame Registration

- Correlation between US frames depends on proximity and orientation to each other [1]
- Windowed SSD with orientation-driven correlation term:

\[ \sum_{p \in P} \sum_{n = -N}^{N} C(i, i + n) \cdot (I_i(p) - I_{i+n}(p'))^2, \]

\[ C(i, j) = \exp \left( -\frac{n^2}{2\sigma^2} \right) \cdot \left( 1 - \frac{2}{\pi} \acos \left( \frac{n_i \cdot n_j}{||n_i|| ||n_j||} \right) \right) \]

#### Pressure Compensation

- Apply deformable inter-frame registration to a grid of independent 1cm x 1cm patches

### Orientation-Driven Frame Clustering

- Hierarchical clustering by frame orientation
- Compounding of clusters into independent volumes
- Uncertainty-based (e.g. Confidence Maps [2]) fusion of the compounded clusters

\[ I(x) = \sum_{c \in C} (1 - U_c(x)) ||U_c(x)|| \]

**Incremental Compounding**

- The above compounding scheme can be rewritten into an incremental in-place algorithm

\[ I_i = \frac{U_{i-1}I_{i-1} + (1 - U_c)I_c}{U_{i-1} + (1 - U_c)}, \]

\[ U_i = U_{i-1} + (1 - U_c) \]

### Accuracy

Comparing average target diameter in liver phantom

- Compounded US: 14.63 ± 0.48 mm
- CT: 14.5 ± 0.84 mm

### Registration Quality

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<th>Baseline NCC</th>
<th>SNR [dB]</th>
<th>Our Technique NCC</th>
<th>SNR [dB]</th>
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</table>

### Results

- No pressure compensation
- No clustering
- With pressure compensation
- Frame clustering and uncertainty fusion

### Conclusion

- Orientation-driven compounding approach superior to traditional techniques
- Important step towards “real” 3D Freehand Ultrasound

### References
