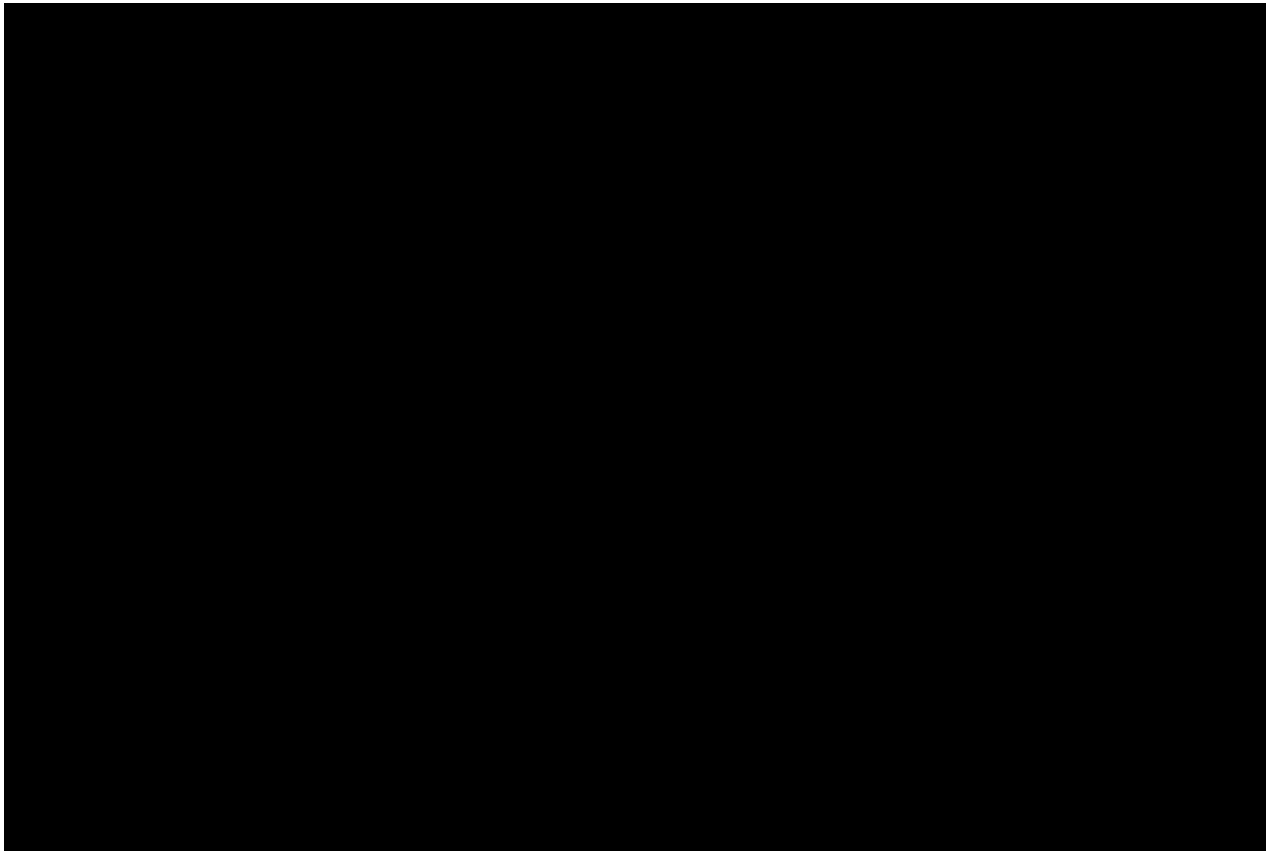


Ultrasound Specific Similarity Measures for Three-Dimensional Mosaicing

Christian Wachinger, Nassir Navab

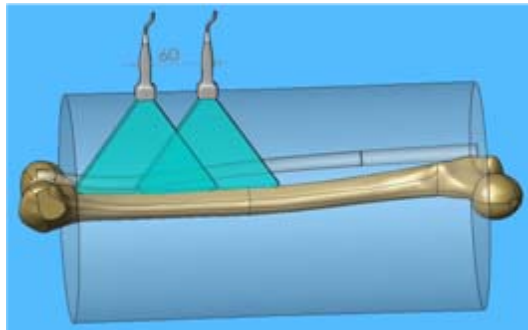
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Problem Statement

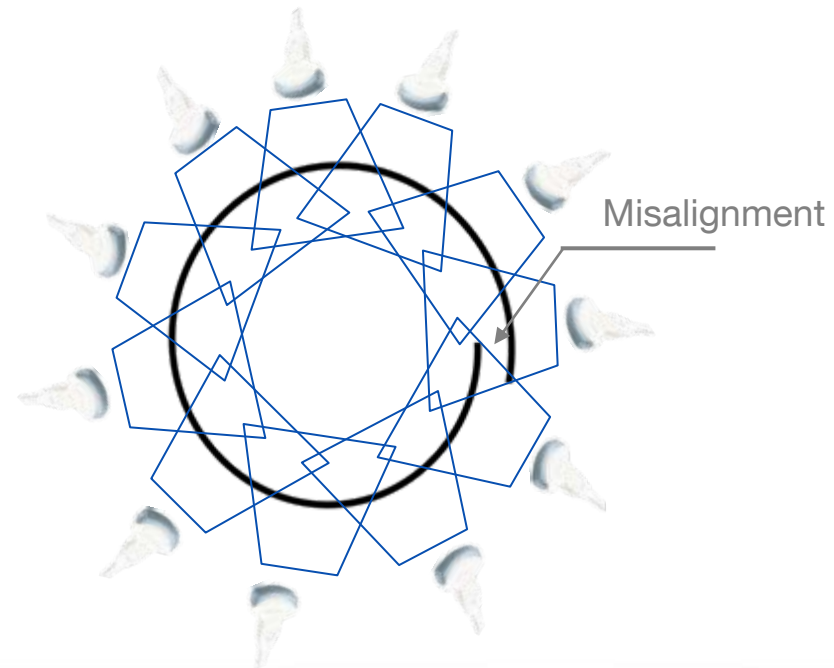
Proposed 3D mosaicing techniques by (*Gee, 2003*) and (*Poon, 2006*) use a **sequence of pairwise registrations**

Partial Overlap:



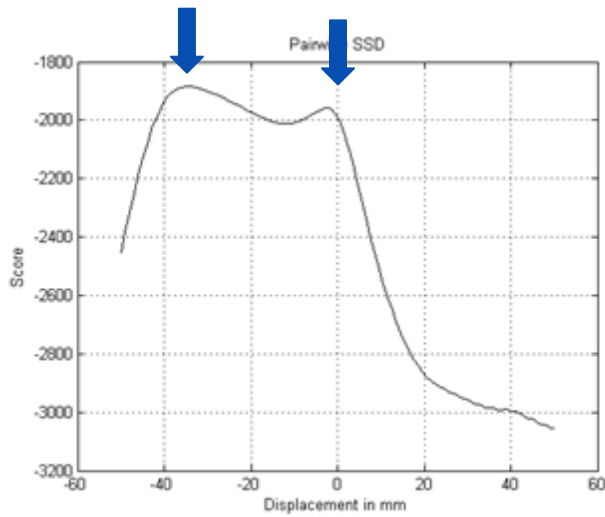
➔ High demands on the overlap invariance of similarity measures

Accumulation errors:

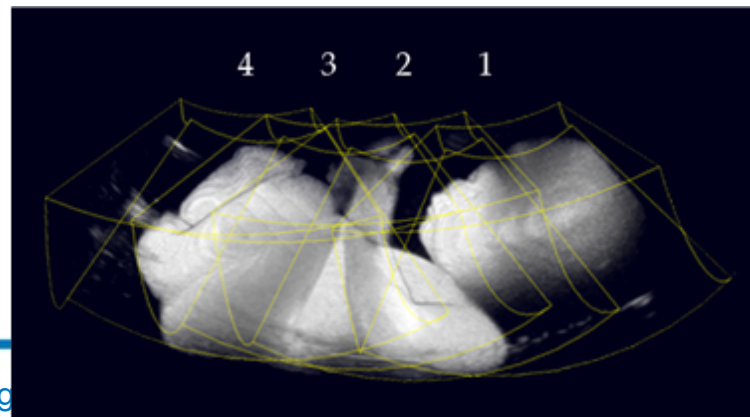
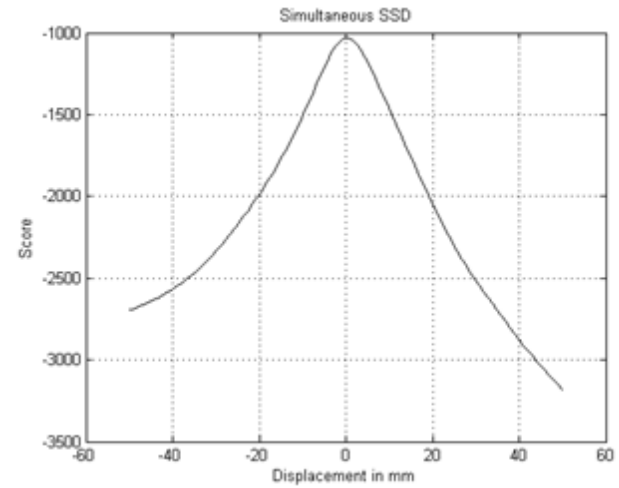


Registration Strategies – Similarity Plots

Pairwise



Simultaneous



moving image 2 along the cranio-caudal axis

Similarity Measures

- Maximum likelihood estimation to model registration mathematically

- Bivariate log-likelihood function

$$\log \mathcal{L}(T, \varepsilon, f) = \log P(u|v, T, \varepsilon, f)$$

u, v : images

ε : noise

f : intensity mapping

- Multivariate log-likelihood function

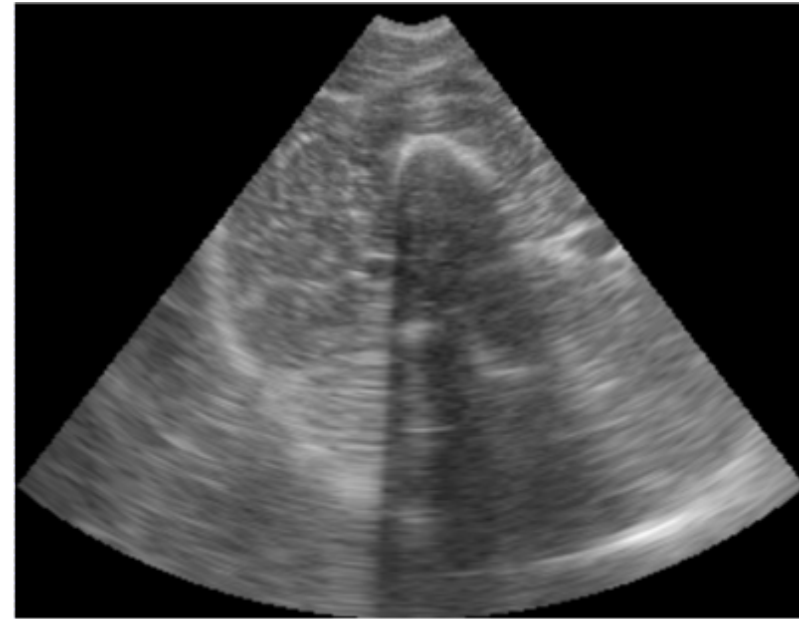
$$\log \mathcal{L}(\mathcal{T}, \varepsilon, \mathbf{f}) = \sum_{i \neq j} \log P(u_j | u_i, T_i, f_i, \varepsilon_i)$$

$$\mathcal{T} = \{T_1, \dots, T_n\}$$

- Assuming **additive Gaussian noise** and variation of intensity mapping leads to SSD, NCC, CR, and MI (*Viola 1995, Roche 2000*)

Speckle

- Ultrasound images are degraded by artifacts caused by coherent wave interference



Ultrasound Specific Similarity Measures

- Ultrasound specific likelihood terms

$$P(u|v, T, \varepsilon, f)$$

- Strintzis and Kokkinidis '97 - US motion estimation

- SK₁: multiplicative Rayleigh noise

$$u(x) = v(T(x)) \cdot \varepsilon$$

$$P(y) = \frac{\pi \cdot y}{2} \cdot \exp\left(-\frac{\pi \cdot y^2}{4}\right)$$

- SK₂: signal dependent Gaussian noise

$$u(x) = v(T(x)) + \sqrt{v(T(x))} \cdot \varepsilon$$

$$P(y) = \frac{1}{\sqrt{2\pi\sigma}} \exp\left(-\frac{y^2}{2 \cdot \sigma^2}\right)$$

Ultrasound Specific Similarity Measures

- Cohen and Dinstein '02
 - CD₁: division of Rayleigh noises

$$u(x) \cdot \varepsilon_1 = v(T(x)) \cdot \varepsilon_2$$

$$\Leftrightarrow u(x) = v(T(x)) \cdot \varepsilon, \quad \varepsilon = \frac{\varepsilon_1}{\varepsilon_2}$$

$$P(y) = \frac{2 \cdot y}{(y^2 + 1)^2}$$

- CD₂: logarithm of division of Rayleigh noises

$$\log u(x) = \log v(T(x)) + \log \varepsilon$$

Multivariate Ultrasound Specific Similarity Measures

SK₁:

$$\sum_{i \neq j} \mathbb{E}_k \left[\frac{\pi}{4} \frac{i_k^2}{j_k^2} - \log \left(\frac{i_k}{j_k} \right) \right]$$

CD₁:

$$\sum_{i \neq j} \mathbb{E}_k \left[\log \frac{j_k^2}{i_k} \left(\left(\frac{i_k}{j_k} \right)^2 + 1 \right)^2 \right]$$

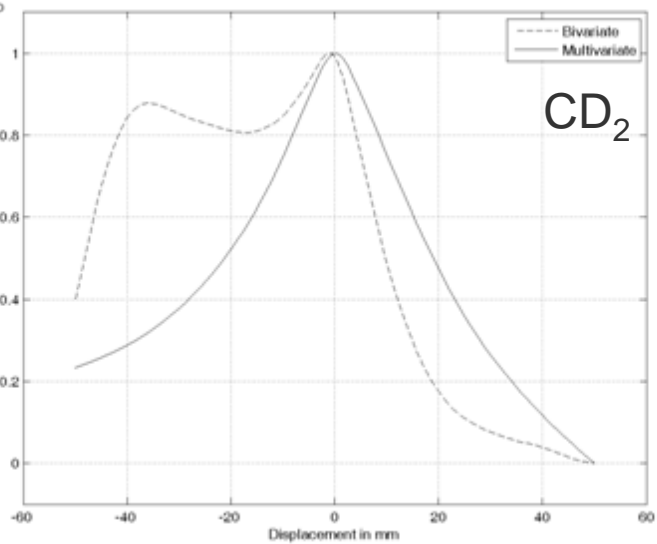
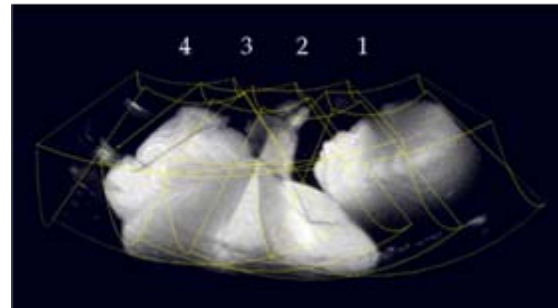
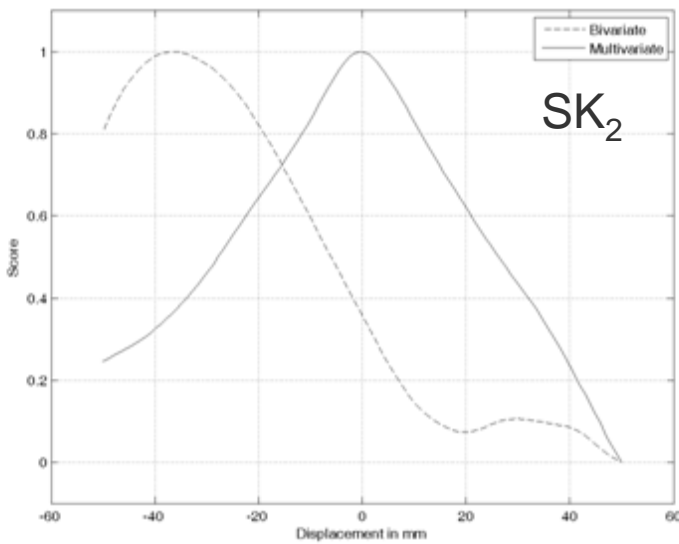
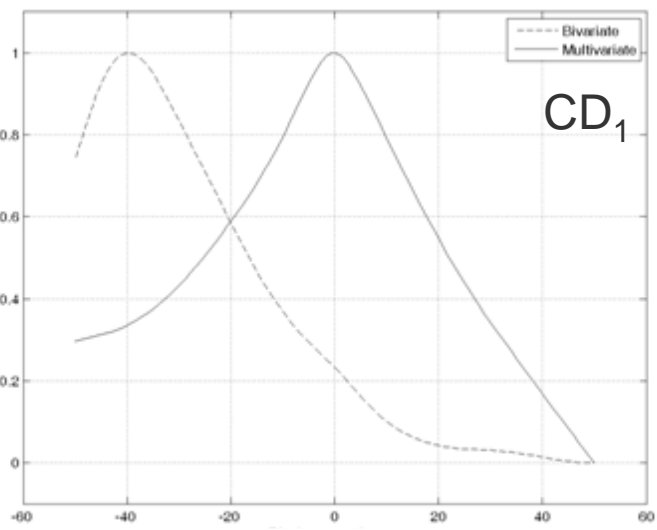
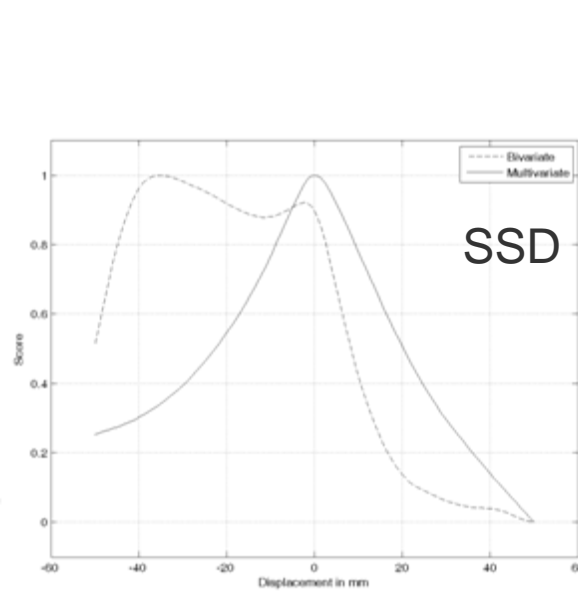
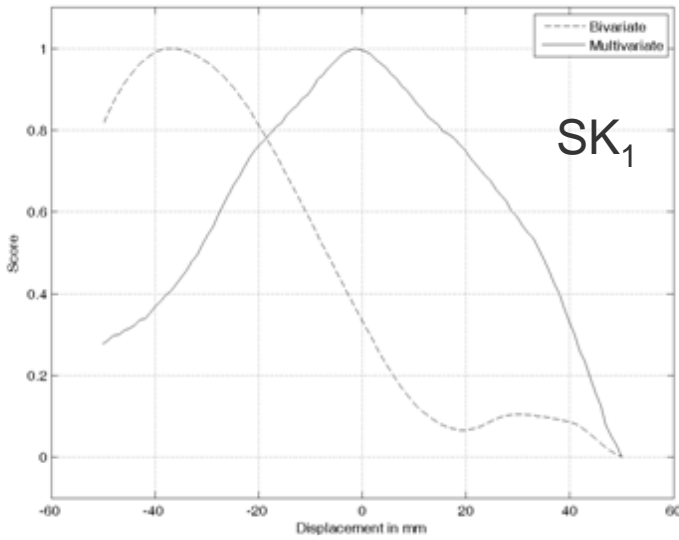
SK₂:

$$\sum_{i \neq j} \mathbb{E}_k \left[\log j_k + \frac{(i_k - j_k)^2}{j_k} \right]$$

CD₂:

$$\sum_{i \neq j} \mathbb{E}_k \left[\tilde{i}_k - \tilde{j}_k - \log(e^{2(\tilde{i}_k - \tilde{j}_k)} + 1) \right]$$

$i_k = u_i(T_i(x_k))$	$\tilde{i}_k = \log u_i(T_i(x_k))$
$j_k = u_j(T_j(x_k))$	$\tilde{j}_k = \log u_j(T_j(x_k))$



Conclusion

- Good results for CD_2 are conform with those from Boukerroui *et al.* and Revell *et al.*
 - Need to adapt the mosaicing framework to ultrasound images
 - First step are ultrasound specific similarity measures
 - Not much difference between using high- and low-resolution images
 - Conduct further experiments to evaluate the performance of multivariate similarity measures
-
- We thank Siemens Corporate Research for generously providing ultrasound images.

Thank you for your attention!