Intermediate Deformable Image Registration (IDIR) via Windowed Cross-Correlation

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Global translation through cross-correlation of phase images: $\mathcal{O}(N \log N)$

$$u = \underset{x}{\operatorname{argmax}}\, I_1(x) \star I_2(x)$$

Local translations through windowed cross-correlation: $\mathcal{O}(N^2 \log N)$

$$u(\delta) = \underset{x}{\operatorname{argmax}}\big(w(x-\delta)I_1(x)\big) \star \big(w(x-\delta)I_2(x)\big)$$

Choosing a separable window function:

$$w(x) \coloneqq \cos x \;\rightarrow\; w(x-\delta) = \cos x \cos\delta + \sin x \sin\delta$$

Local translations: $\mathcal{O}(N^2)$

$$u(\delta) = \underset{x}{\operatorname{argmax}} \sum_i A_i(x) B_i(\delta)$$

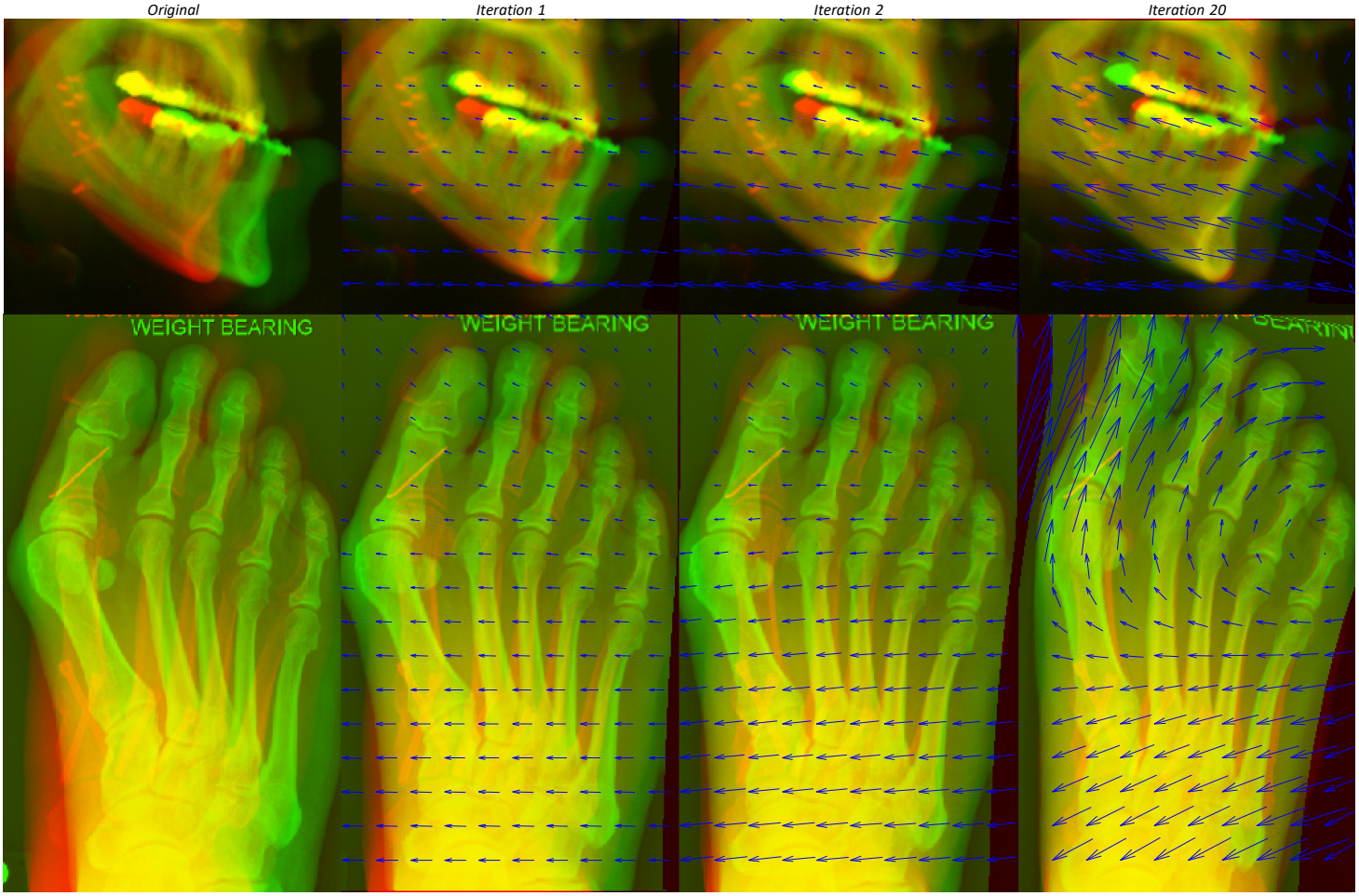
Approximating argmax:

$$\underset{x}{\operatorname{argmax}}\, f(x) \approx \frac{\int x f^P(x)\mathrm{d}x}{\int f^P(x)\mathrm{d}x}$$

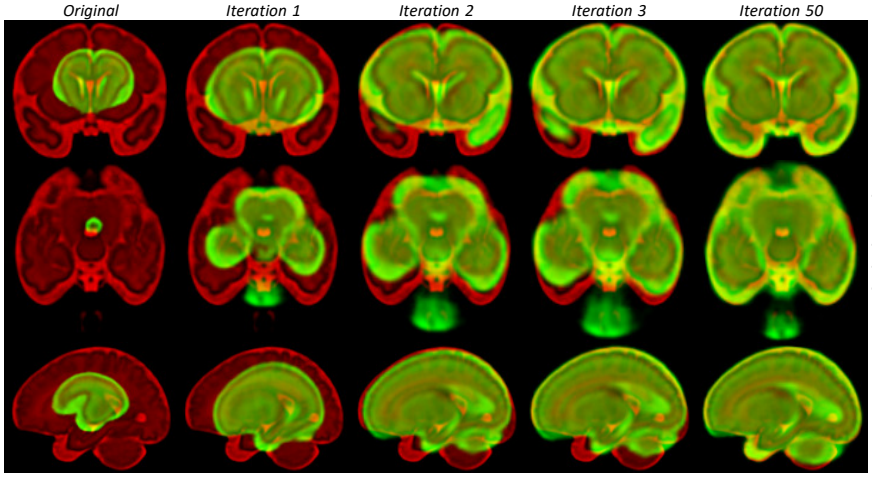
Local translations for IDIR: $\mathcal{O}\big(N(DM + (2^{D+1}+3^D)\log N)\big)$ $\ll \mathcal{O}(N^2 \log N)$

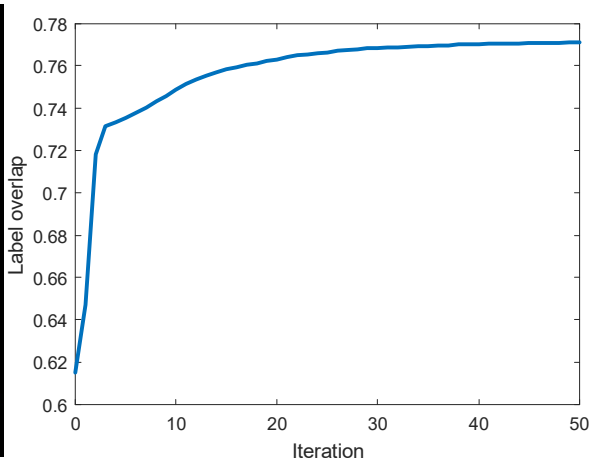
$$u(\delta) \approx \frac{\sum_{j=1}^{M} \hat{B}_j(\delta) \int x \hat{A}_j(x)\mathrm{d}x}{\sum_{j=1}^{M} \hat{B}_j(\delta) \int \hat{A}_j(x)\mathrm{d}x}$$

Intermediate Deformable Image Registration (IDIR) is more flexible than affine registration and less flexible than standard deformable registration, making it suitable to initialize the latter. It is computationally efficient, given its moderately low complexity and the few iterations that it requires to align the bulk of large deformations.



2D X-ray image registration: IDIR results on pre- to post-surgery images. Data sources: Chong Ai Dental Clinic and Chelsea and Westminster Hospital NHS Foundation Trust.





3D fetal brain MRI registration: The first time-point (week 21) in the longitudinal atlas is registered to the last time-point (week 38) using IDIR. In comparison, by using coarse-to-fine diffeomorphic demons, label overlap was 0.76, which increased to 0.80 when initialized with IDIR. Data source: Gholipour *et al*, *Scientific Reports*, 2017.

NIH National Institute on Aging

Code: www.nitrc.org/projects/msi-register