# A NOVEL NON-RIGID REGISTRATION ALGORITHM FOR ZEBRAFISH LARVAL IMAGES

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## OVERVIEW

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  - Minimum Weight Bipartite Graph Matching
  - Diffeomorphic Demons Method
- EXPERIMENTAL RESULTS
- CONCLUS|ON & FUTURE SCOPE

## BACKGROUND

- Precise mapping of gene expression profiles, neuronal types and connections during vertebrate brain development
- Zebrafish *(Danio rerio)* as evolved as an ideal model organism for bio-imaging approaches in vertebrates
- ViBE-Z fails to achieve accurate registration due to false landmark detection in low resolution image – and local under/over exposed image of the larvae

## PROPOSED METHODOLOGY

- Coarse affine registration using the LBFGS algorithm is applied first on the moving dataset
- The coarsely registered moving image and the reference image are divided into a union of overlapping patches
- Minimum weight bipartite graph matching algorithm is employed to find the correspondence between the two sets of patches
- The corresponding patches are then registered using the diffeomorphic demons method with proper intra-patch regularization
- Inter-patch regularization is imposed through a composite transformation obtained from the adjacent transformation fields

### Coarse Registration

- $M_p(x, y, z)$ denotes the pth voxel in the moving image M and $F_p(x, y, z)$ be the pth voxel in the fixed image F
- The affine transformation on $M_p(x, y, z)$ yields $M'_p(x', y', z')$ therefore, $M'_p(x', y', z') = T(M_p(x, y, z))$
- The L-BFGS algorithm is applied to optimize the cost function $\sum_p \left\| I(F_p) - I(M'_p) \right\|^2$ to obtain the affine transformation parameters

### Patch Correspondence using Minimum Weight Bipartite Matching

- The coarsely registered moving image M' and the fixed image F are divided into n overlapping volumetric patches
- A bipartite graph is represented by G = (V1 U V2, E) with two disjoint vertex sets V1 and V2 and the edge set E (edges exist only across the vertex sets)
- The centroids of the coarsely registered moving image patches $M'_{1c}$, $M'_{2c}$ … $M'_{nc}$ and that of the fixed image patches $F_{1c}$, $F_{2c}$, … $F_{nc}$ constitute the two disjoint vertex sets. For the present problem, |V1| = |V2| = n
- Mean of the differences in the intensity values of the constituent pixels in two patches is assigned as the weight of the edge between the respective patch centroids.
- The weight of the edges is given by $W(M'_i, F_j)$,

$$W(M'_i, F_j) = \frac{\sum_p |I(F_{jp}) - I(M'_{ip})|^2}{p}$$

- The Kuhn-Munkres algorithm is applied to solve the minimum weight bipartite matching problem. This algorithm yields an optimal match set $\Gamma(M'_i, F_{m(i)})$, i = 1, 2...n

### Patch Registration using Diffeomorghic Demons

- The corresponding patches are registered using diffeomorphic demons minimizing the following energy function.

$$E(T'_i) = \frac{Sim(I(F_{(mi)}), I(T'_i(M'_i)))}{\alpha_1^2} + \frac{Reg(T'_i)}{\alpha_2^2}$$

- The Similarity function is given by:

$$Sim(I(F_{(mi)}), I(T'_i(M'_i))) = \frac{\|I(F_{m(i)} - I(T'_i(M'_i))\|^2}{2}$$

- The Regularization term is given by:

$$Reg(T'_i) = \|\nabla(T'_i)\|^2$$

### Inter-Patch Regularization

- Inter-Patch Regularization ensures the smoothness and the continuity of the transformation field across the patch boundaries
- The inter-patch regularization is achieved by composite transformation which is a distance weighted average of the two transformation fields under consideration
- The composite transformation of two adjacent patches $M''_i$ (resulting from demons transformation on patch $M'_i$) and $M''_j$ (resulting from demons transformation on patch $M'_j$) for their corresponding nonrigid transformation $T'_i$ and $T'_j$ is given by:

$$T'_p = \frac{\frac{1}{d''_{ip}} * T'_{ip} + \frac{1}{d''_{jp}} * T'_{jp}}{\frac{1}{d''_{ip}} + \frac{1}{d''_{jp}}}$$

$$p \in (M''_i \cap M''_j)$$

$$d''_{ip} = \text{The distance of the pth pixel from the centroid of the patch } M''_i$$

$$d''_{jp} = \text{The distance of the pth pixel from the centroid of the patch } M''_j$$

## EXPERIMENTAL RESULTS

- Experimented with four multi-view confocal 3D datasets of 72 hpf zebrafish larvae generated using standard protocols for ViBE-Z sample preparation
- The reference image and the floating image are divided into 125 volumetric patches with dimensions 200 X 140 X 140 having an overlap of 50 pixels on each side
- Registration performance is measured using Structural SIMilarity index (SSIM) and Peak Signal to Noise Ratio (PSNR). SSIM can capture local variations between two images whereas PSNR can capture global differences
- We have compared our result with that of VibeZ and we have also done a internal comparison by replacing bipartite graph matching with a greedy approach and by removing inter patch regularization

## ACCURACY OF DIFFERENT ALGORITHMS

- *Comparison of performance with VibeZ*

| SSIM-Ours | SSIM-VibeZ | PSNR-Ours | PSNR-VibeZ |
|---|---|---|---|
| 0.7489 | 0.7418 | 20.0175 | 19.9382 |
| 0.7330 | 0.6315 | 22.7760 | 19.7279 |
| 0.7554 | 0.7388 | 21.7560 | 21.3490 |
| 0.7534 | 0.7427 | 19.0902 | 18.9961 |

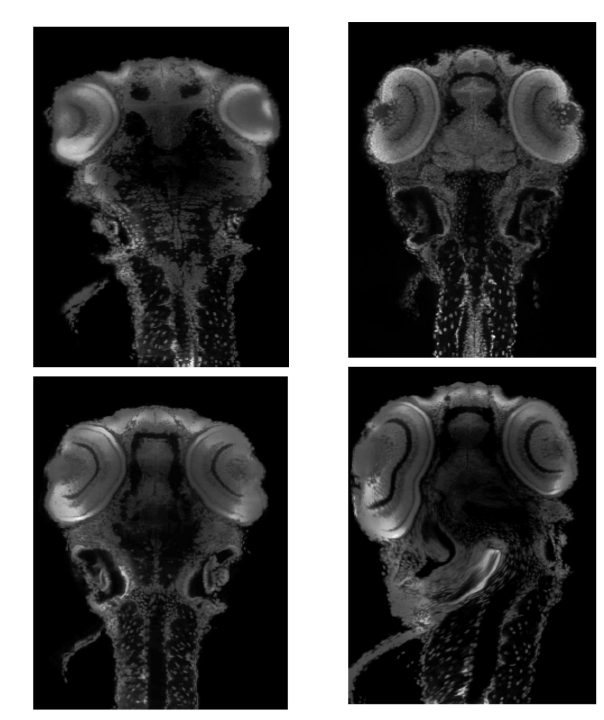

Fig. 1. Top Left: Moving Image, Top Right: Fixed Image, Bottom Left: Registration using our method, Bottom Right: Registration using VibeZ. All implementations are done in 3D and all results are shown for the same 2D slice of dataset 2.

- *Internal Comparisons:*
  - *Greedy Correspondence(GC):*

| SSIM-Ours | SSIM-GC | PSNR-Ours | PSNR-GC |
|---|---|---|---|
| 0.7489 | 0.6894 | 20.0175 | 19.1551 |
| 0.7330 | 0.6894 | 22.7760 | 21.6930 |
| 0.7554 | 0.71 | 21.7560 | 21.037 |
| 0.7534 | 0.6897 | 19.0902 | 18.883 |

  - *No Inter Patch Regularization(NIPR):*

| SSIM-Ours | SSIM-NIPR | PSNR-Ours | PSNR-NIPR |
|---|---|---|---|
| 0.7489 | 0.6894 | 20.0175 | 19.6899 |
| 0.7330 | 0.7277 | 22.7760 | 22.446 |
| 0.7554 | 0.7531 | 21.7560 | 21.6386 |
| 0.7534 | 0.7473 | 19.0902 | 19.0206 |

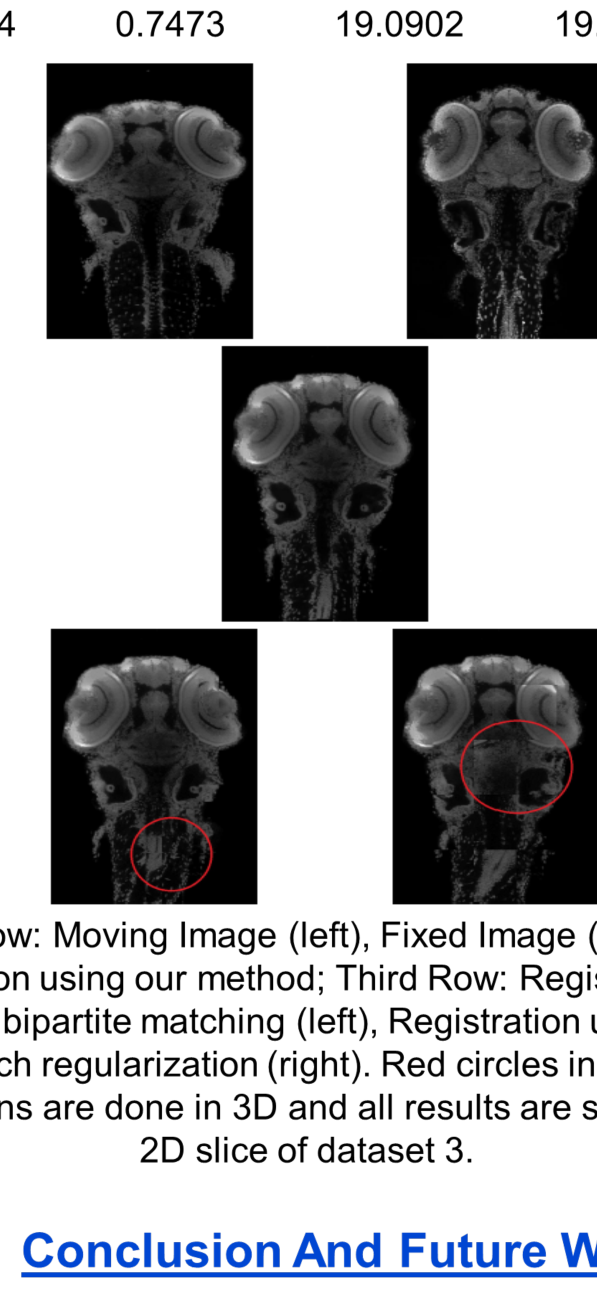

Fig2: First Row: Moving Image (left), Fixed Image (right); Second Row: Registration using our method; Third Row: Registration using our method without bipartite matching (left), Registration using our method without inter-patch regularization (right). Red circles indicate distortions. All implementations are done in 3D and all results are shown for the same 2D slice of dataset 3.

## Conclusion And Future Work

- A novel non-rigid registration algorithm for zebrafish larval images yielding better accuracy
- In future, we plan to embed geometric information in the solution pipeline