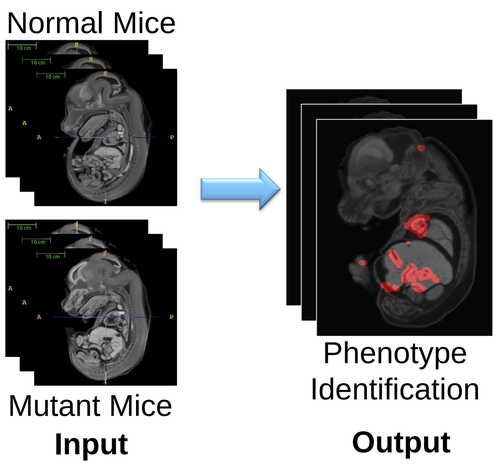
Phenotype Detection in Morphological Mutant Mouse using Deformation Features

Sharmili Roy, Xi Liang, Asanobu Kitamoto
Masaru Tamura, Toshihiko Shiroishi, Michael S. Brown

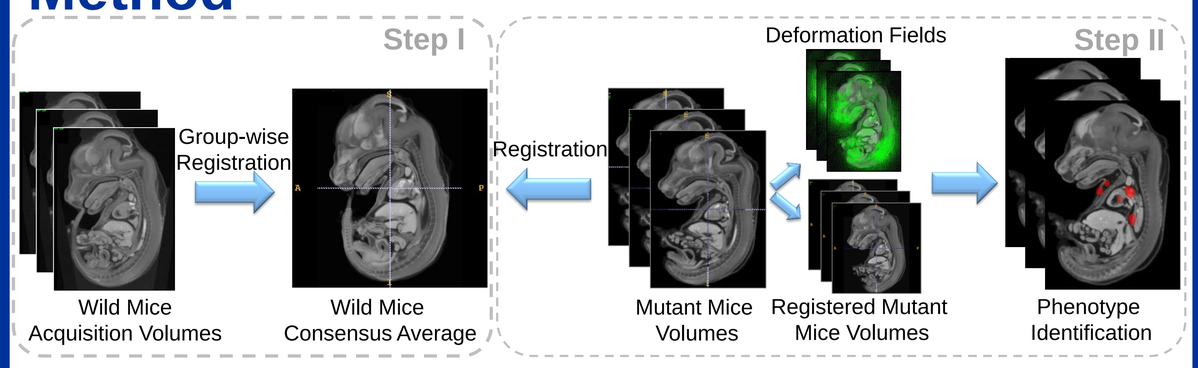
Introduction

Mouse phenotyping still largely relies microscopic evaluation of mouse sections which is not only extremely low throughput but is also highly inefficient.

We aim to enhance mouse phenotyping by proposing a generalized defect detection framework that automatically identifies phenotypic areas in micro-CT images of mutant mouse embryo using registration and deformation-based features.



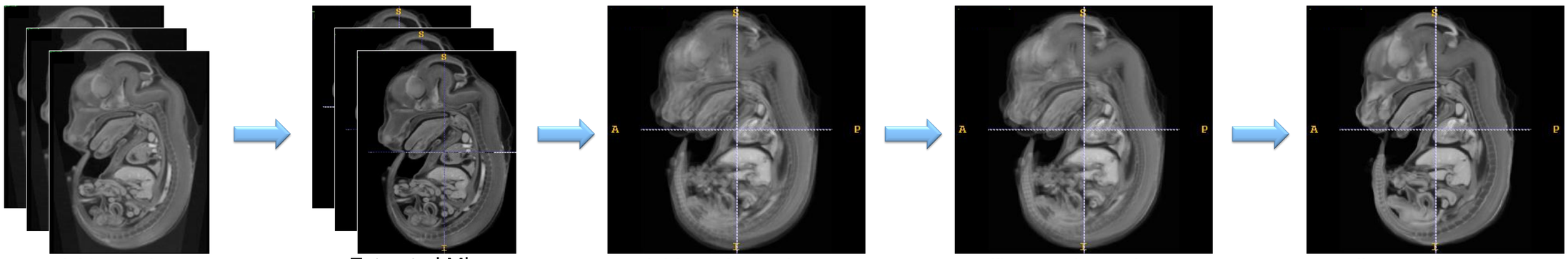
Method



Defect detection consists of two main steps; the first step is construction of a mean for the normal mouse population and the second step comprises of computing defects in mutants using deformation features obtained by registering them to the normal mean.

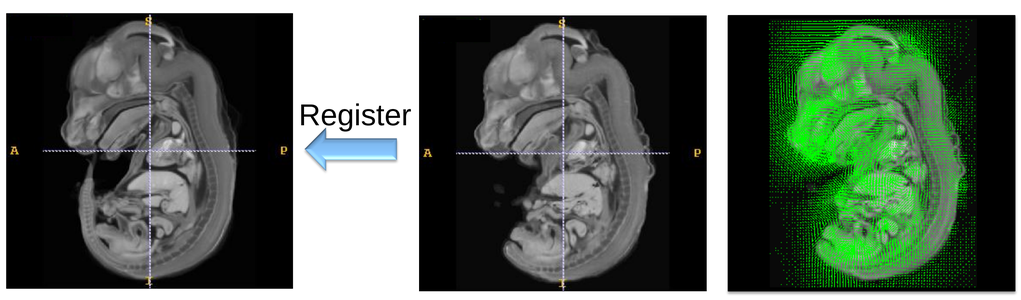
Step I: Construction of normal mean

This step consists of extracting mouse images from the acquisition volumes and group-wise registering them via rigid, affine and B-spline registration steps.



Step II: Computation of deformation features

Mutant mice are registered to the normal mean and deformation features are extracted from the respective deformation fields



For each voxel we have:

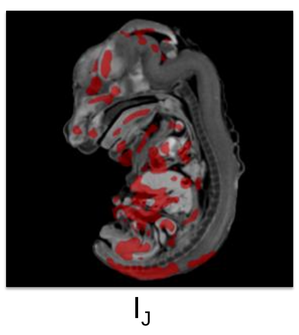
Transformation in x-direction – T_x , θ_x
Transformation in y-direction – T_y , θ_y
Transformation in z-direction – T_z , θ_z

1. Determinant of spatial Jacobian of transformation =

$$\begin{vmatrix} 1+\partial(T_x)/\partial(x) & \partial(T_x)/\partial(y) & \partial(T_x)/\partial(z) \\ \partial(T_y)/\partial(x) & 1+\partial(T_y)/\partial(y) & \partial(T_y)/\partial(z) \\ \partial(T_z)/\partial(x) & \partial(T_z)/\partial(y) & 1+\partial(T_z)/\partial(z) \end{vmatrix}$$

I_J = Volumetric regions with high determinant of spatial Jacobian of deformation

I_J measures local expansion and compression

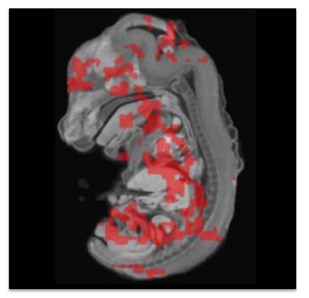


I_J

2. $\Theta = [\theta_x\ \theta_y\ \theta_z]^T$, divide the deformation field into small blocks and find blocks which have high entropy of Θ.

I_S = Volumetric regions with high entropy of deformation direction (Θ)

I_S captures the incoherency in deformation directions within small neighborhoods



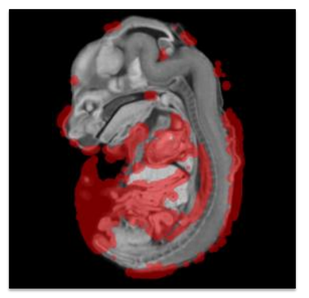
I_S

3. For a population of N_M mutant images registered to the normal mean N_{Avg}, compute voxel-wise intensity variance

$$V_{IV} = \frac{1}{N_M - 1}\sum_{i=1}^{N_M}(M_i - N_{Avg})^2$$

I_{IV} = Volumetric regions with high intensity variance

I_{IV} captures voxel-wise registration accuracy

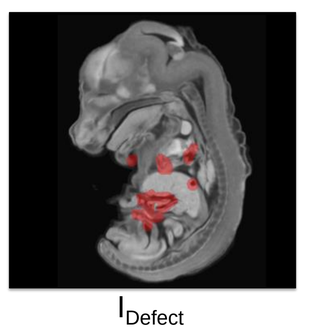


I_{IV}

4. Combine the three regions to detect defects as follows:

$$I_{Defect} = (I_{IV} \cap I_J) \cup (I_{IV} \cap I_S) \cup (I_J \cap I_S)$$

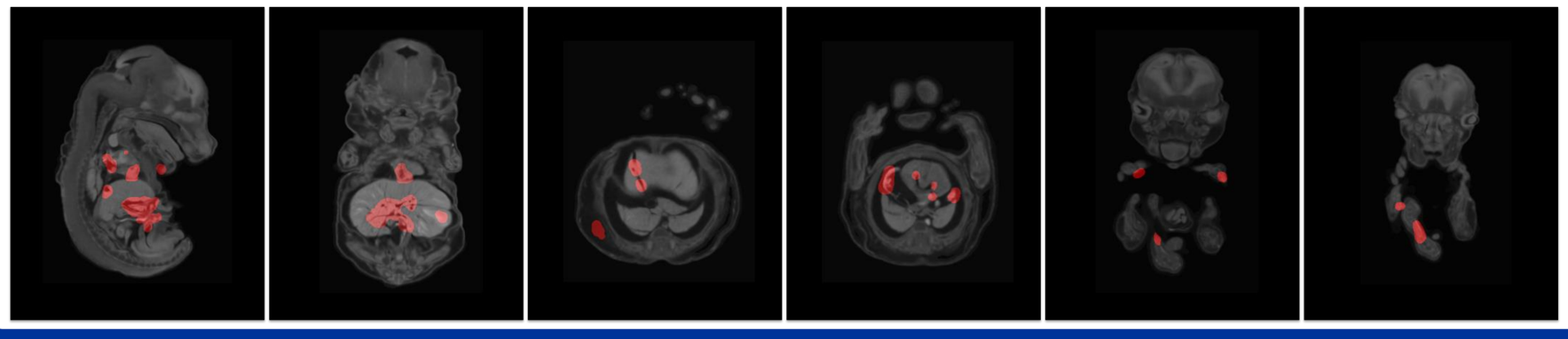
I_{Defect} represents the resulting defective regions



I_{Defect}

Results

Defective areas identified and laid over the mutant mouse images



Detection performance for known defects, such as polydactyly and ventricular septum defect (VSD). VSD is assumed detected if ventricular area is highlighted.

Performance Parameter	Value (%)
VSD Sensitivity	100.0
VSD Specificity	100.0
Polydactyly Sensitivity	92.3
Polydactyly Specificity	87.1

MICCAI 2013 NAGOYA JAPAN
The 16th International Conference on Medical Image Computing and Computer Assisted Intervention
MICCAI