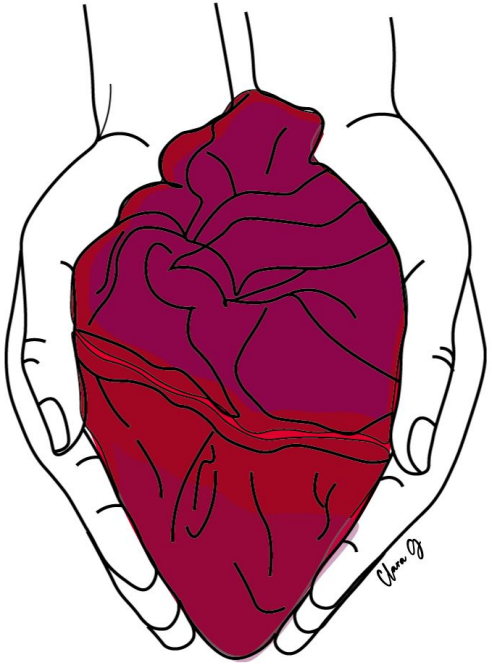
Visualizing Heart Development from 3D Volumetric Images

CENTURI Hackathon for Quantitative Biology



Project Presentation | 26 June 2022

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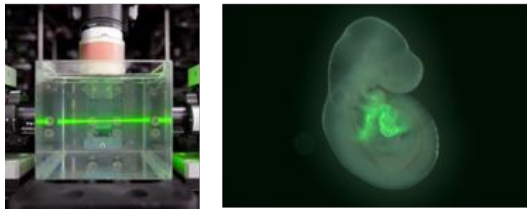
Motivation

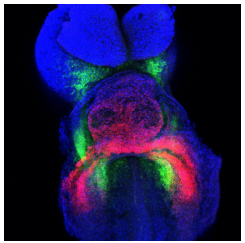
1. **It is not possible to perform live +3D imaging simultaneously . Only snapshots of the structures.**

Lightsheet microscopy

3D imaging



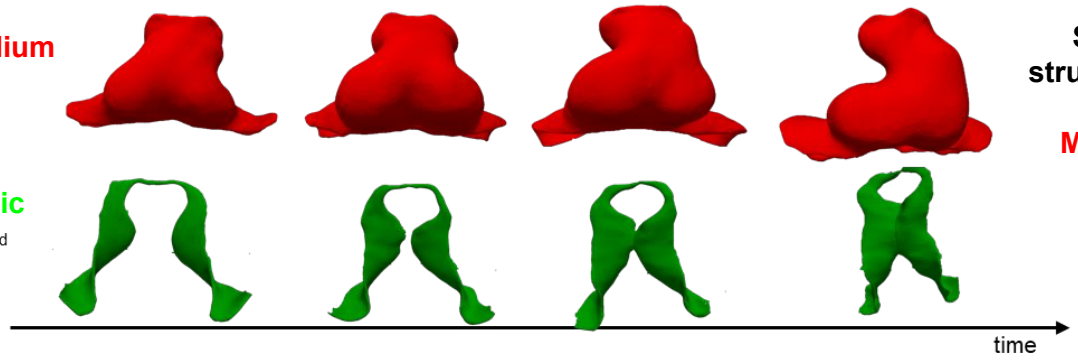
Embryo imaged in 3D



Raw data properties:
.lsm files
>300 slices
900MB aprox

Myocardium
Heart field
Tbx5+

Splanchnic
Progenitor field
Mef2c



Segmented and aligned structures from raw data from 4 different regions:
Myocardium, Splanchnic, Paraxial, Somatic

.ply files

(Esteban *et al.*, 2022)
Anatomical changes at tissue level

Objectives & Workflow

How to merge the 3D shots and create animation ?

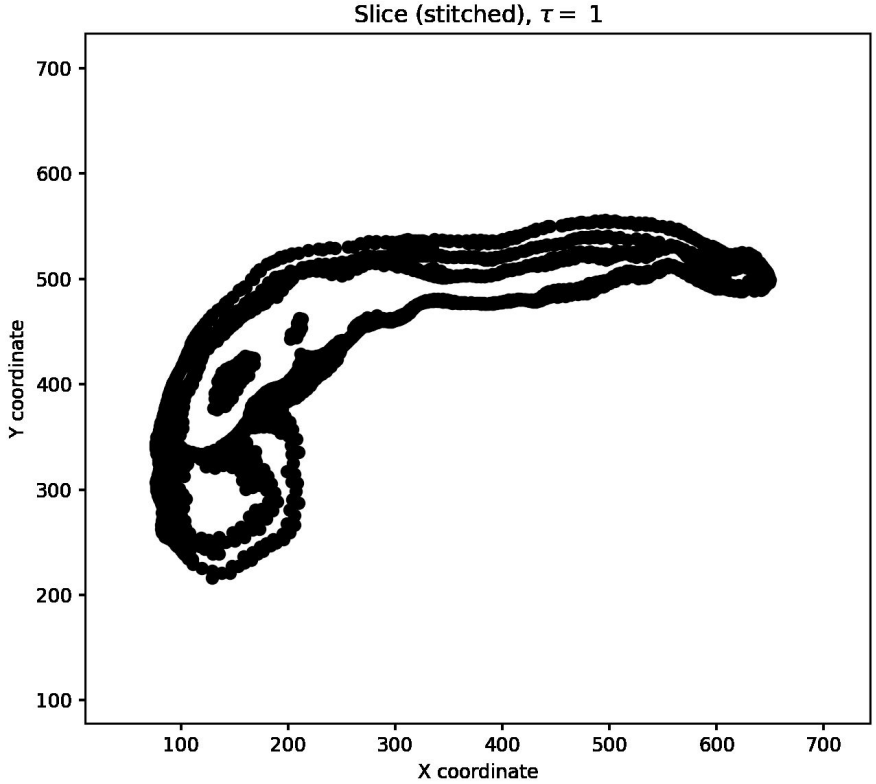
In case there's not enough time points acquired, How to interpolate new frames in between?

How to get quantitative data and information out of the growth? Ex. growth rate of each structure

Make the data and visualization open-source

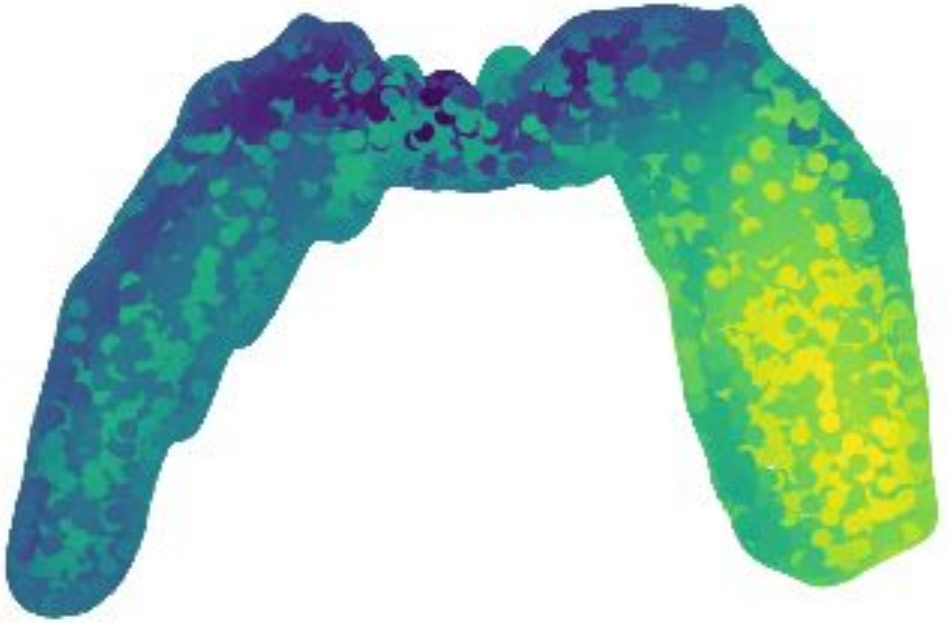
Exploring the data

x	y	z	region	time
483.896118	479.282166	250.736298	Myocardium	1
341.627777	479.173523	213.652100	Myocardium	1
497.380615	528.164246	199.392334	Myocardium	1
196.249435	408.848846	247.797150	Myocardium	1
381.311951	505.832550	195.637360	Myocardium	1
...	...	...	...	...
144.500214	305.350647	67.670044	Splanchnic	311
392.155609	455.405273	457.748535	Splanchnic	311
371.418091	534.623413	436.022980	Splanchnic	311
307.482758	482.779449	385.307312	Splanchnic	311
630.777344	383.874298	205.416473	Splanchnic	311



Exploring the data

- 2D scatter of the Myorcadium region of the heart colored by the z dimention over time

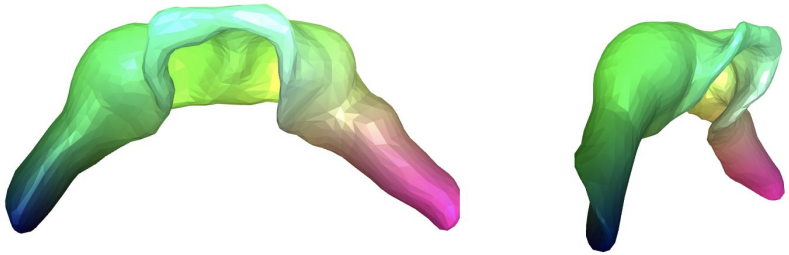


Testing Available Packages

- **µMatch: 3D shape correspondence for microscopy data**

  - *jaxlib* dependent, which doesn't support windows.
  - They did correspondence, but no morphing.

(Klatzow *et al.*, 2022)



(Dalmasso *et al.*, 2021)

- **Fearless Hearts :** Create continuous timecourse for the heart development from limited nb of samples acquired at different timepoints
  - They use .vti data, whereas our original data is in .ply, to convert them might be too time consuming → 2h to convert only 1 time point

Going back to the Data - Interpolation

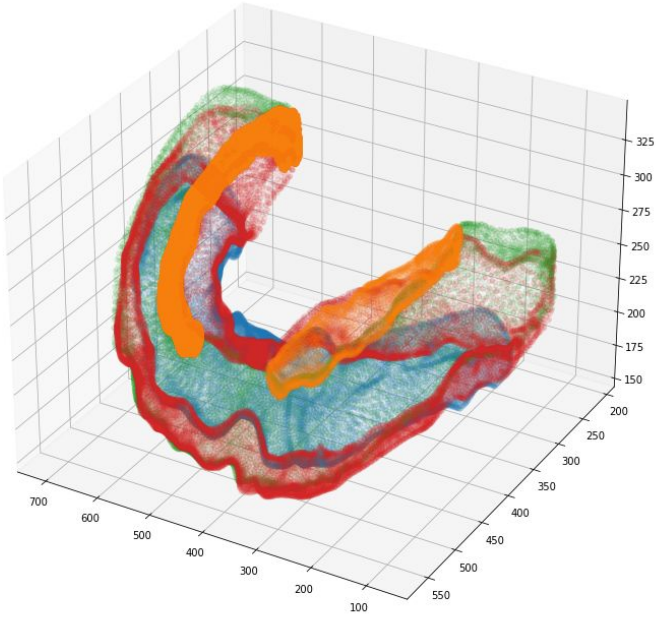
Geometric Loss functions between sampled measures, images and volumes

(Feydy *et al.*, 2022)

GPU support

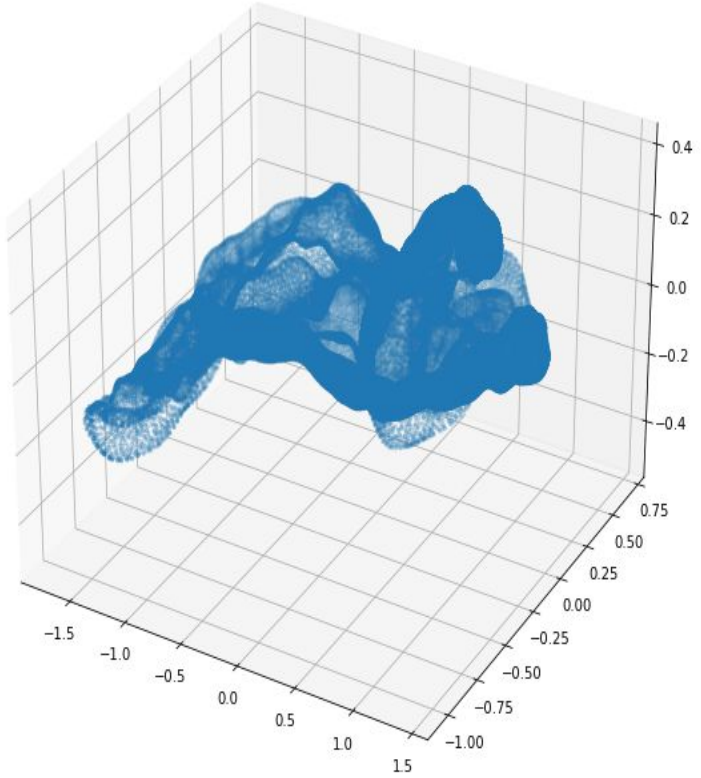
Geometric calculate loss functions with full support of Pytorch's autograd engine

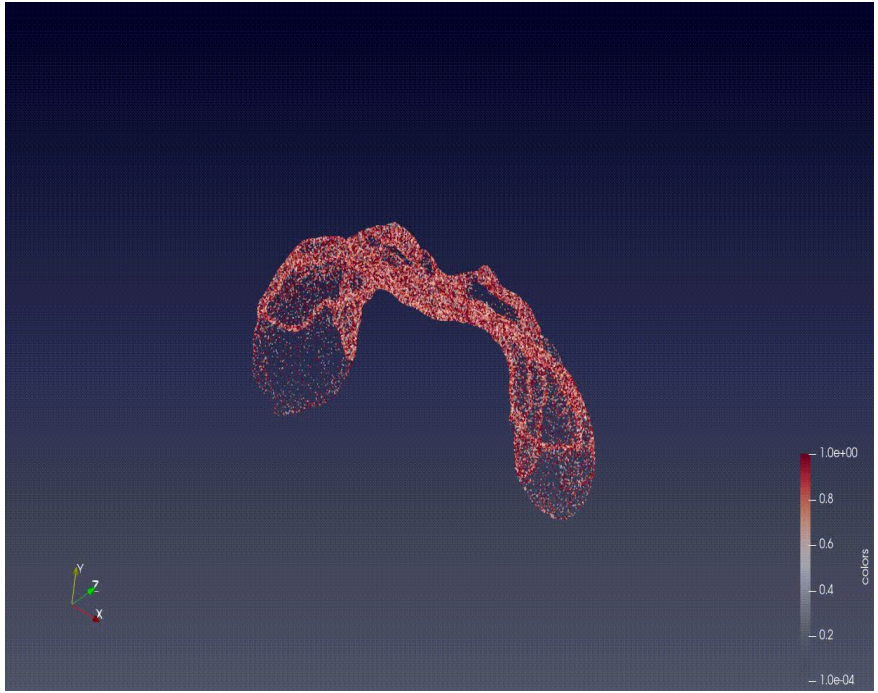
Interpolation



- Data loaded on GPU as tensors
- Combine 4 region time point corresponding heart data as one to show full heart
- Optimal Transport matchings
- Output VTKs, use *Paraview to view the animation*
- *Linear interpolation*

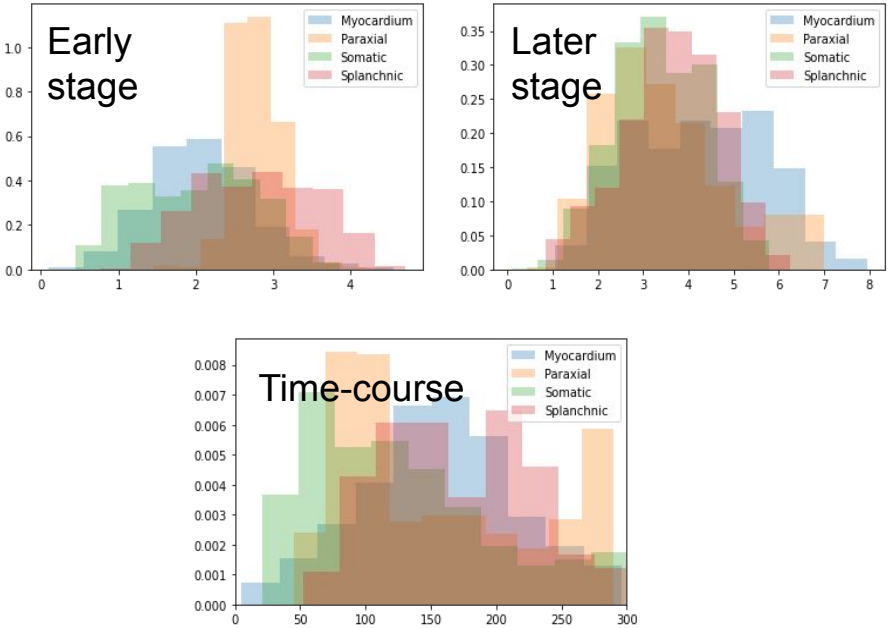
Pick time points 1, 5, 11 and reconstruct a interpolation video of heart development from beginning to end. 32 interpolations in between two points.

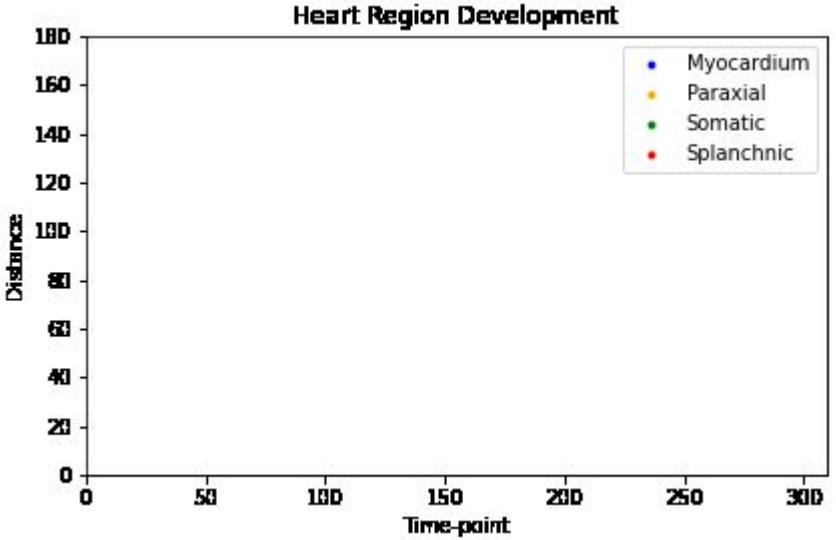




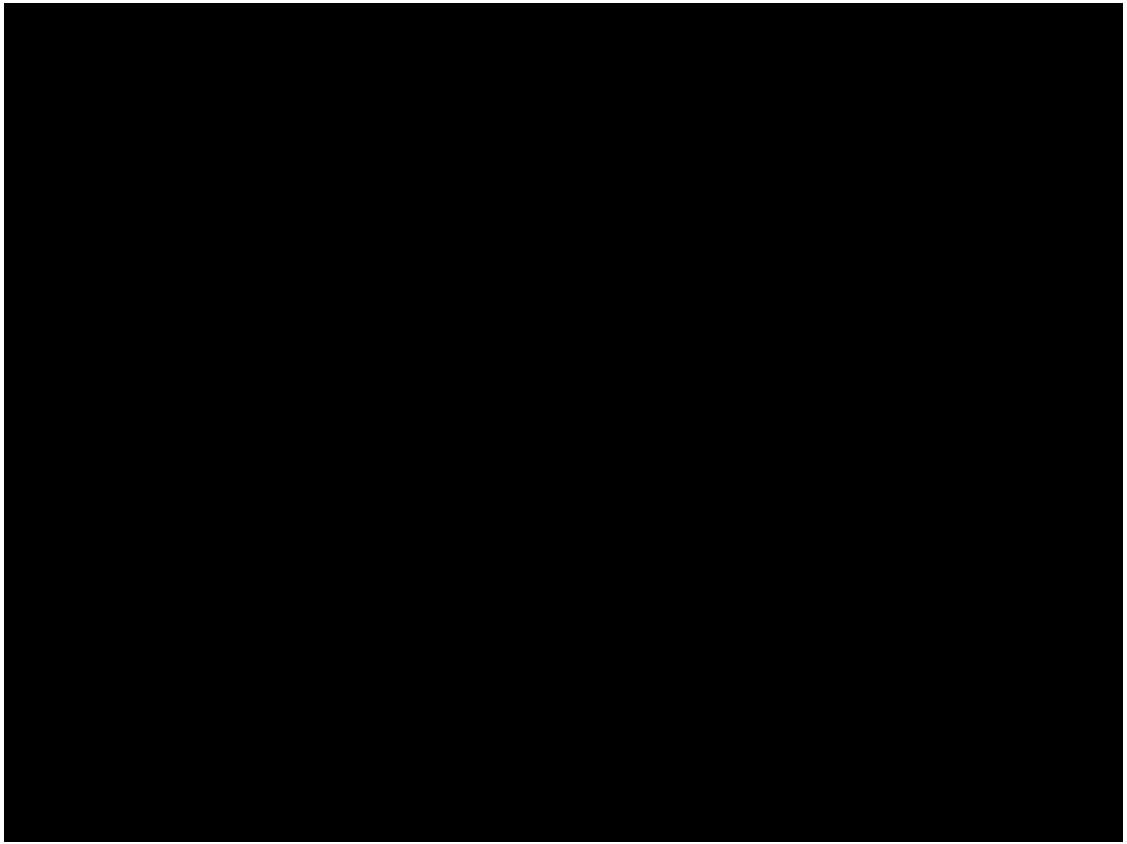
Going back to the Data - Quantification

Distribution of Distance Moved



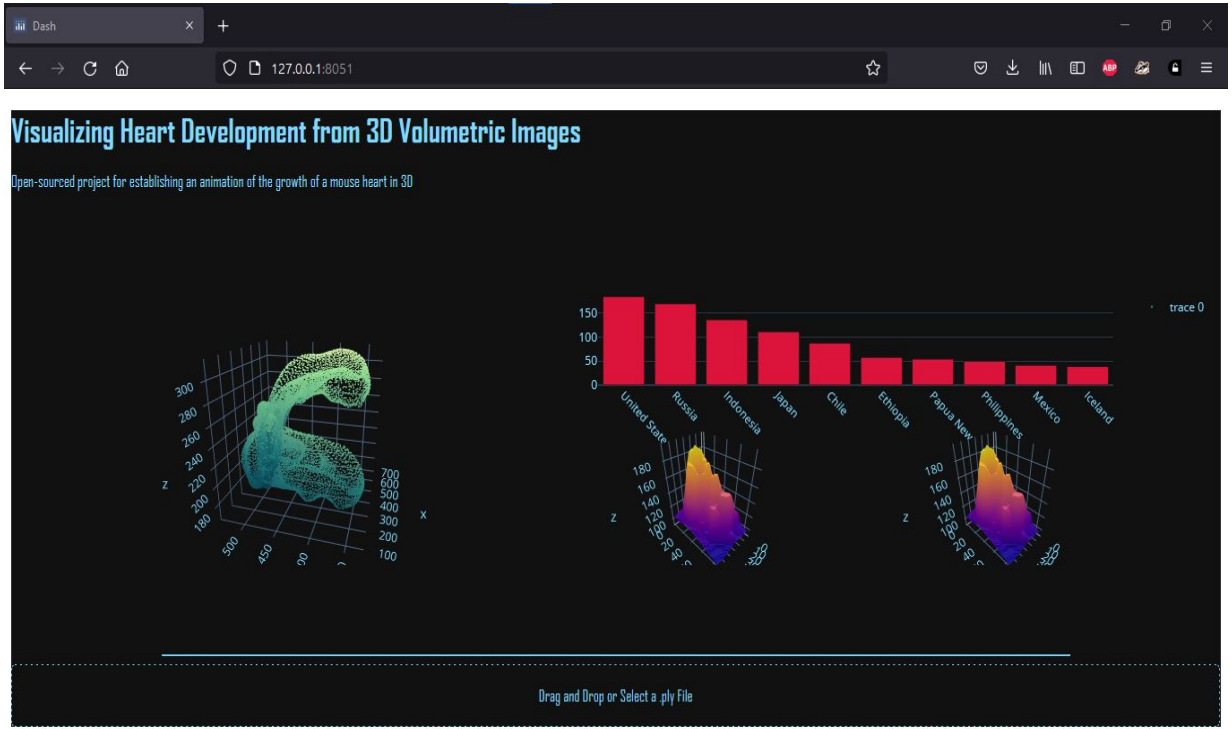


3D representation of the heart growth



User Interface

- Open-sourced
- User-friendly



Moving Forward

- Deployable and versatile user interface
- Suggestion for optimal sampling and interpolation
  - Loss of information quantification
- Correlative and more quantitative integration of data
  - Cellular level inference on growth and morphology
- Determine the minimum real data we need that we can use interpolation to reconstruct good enough simulate data to mimic reality

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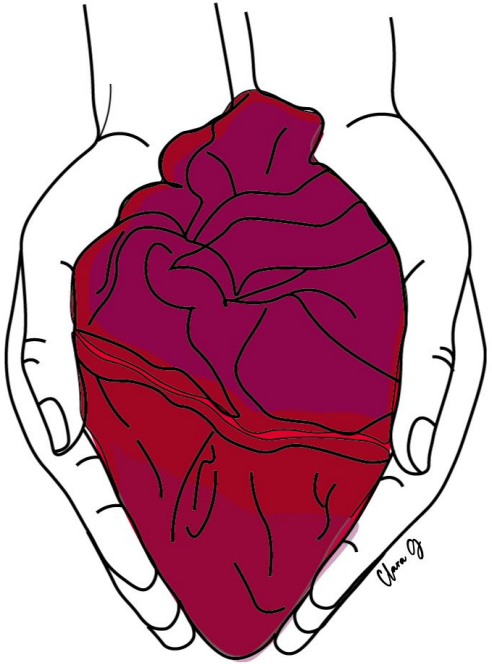

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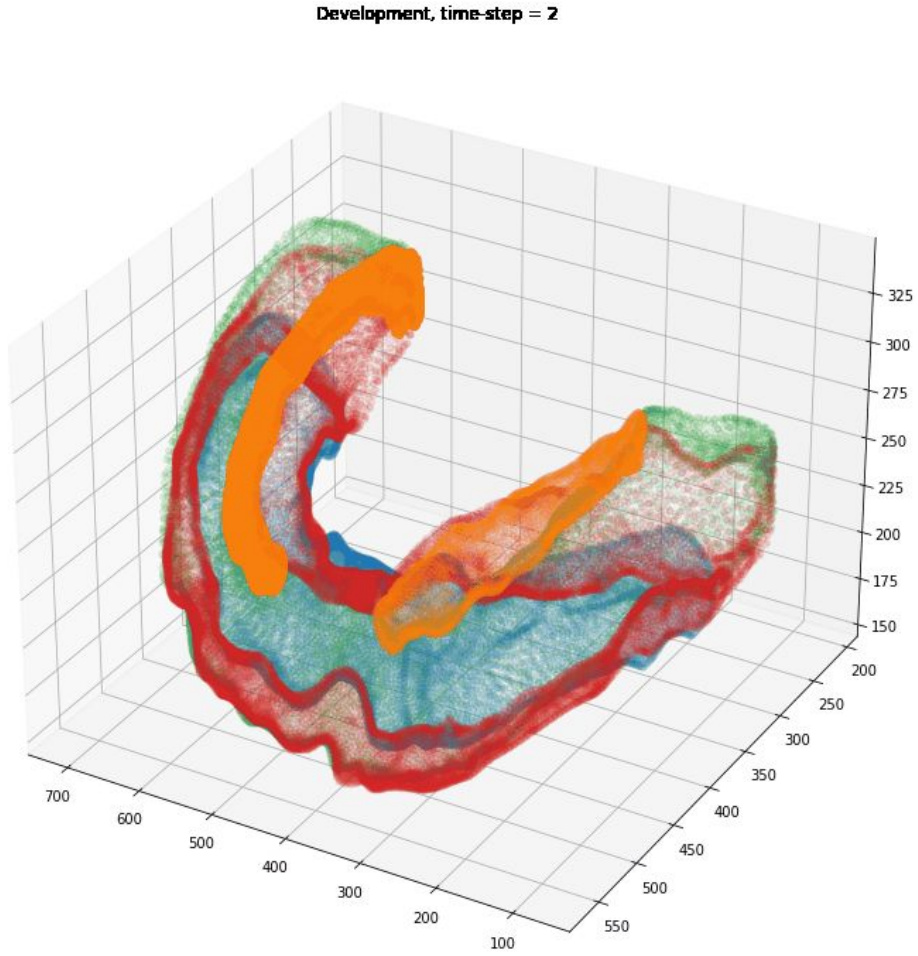
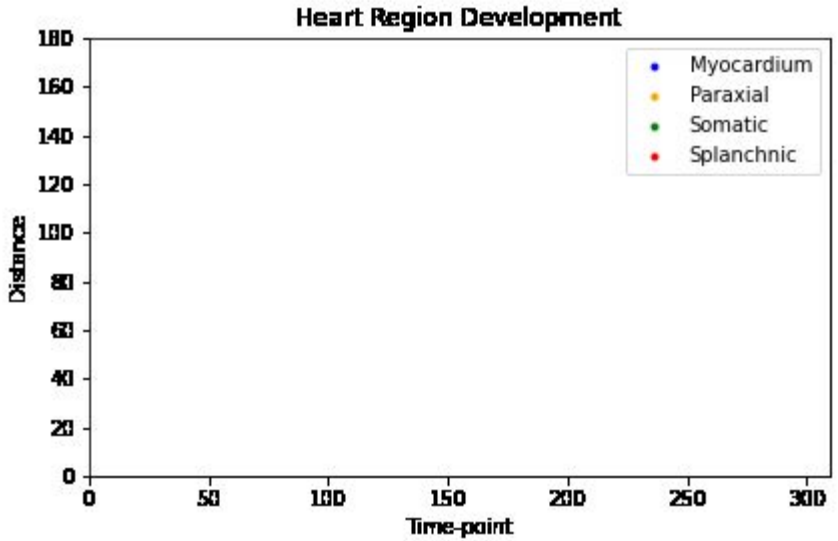

Development, time-step = 2
325
300
275
250
225
200
175
150
200
250
300
350
400
450
500
550
700
600
500
400
300
200
100


Heart Region Development
Myocardium
Paraxial
Somatic
Splanchnic
Distance
Time-point
0
20
40
60
80
100
120
140
160
180
0
50
100
150
200
250
300