Stomach Motility: Effect of VNS

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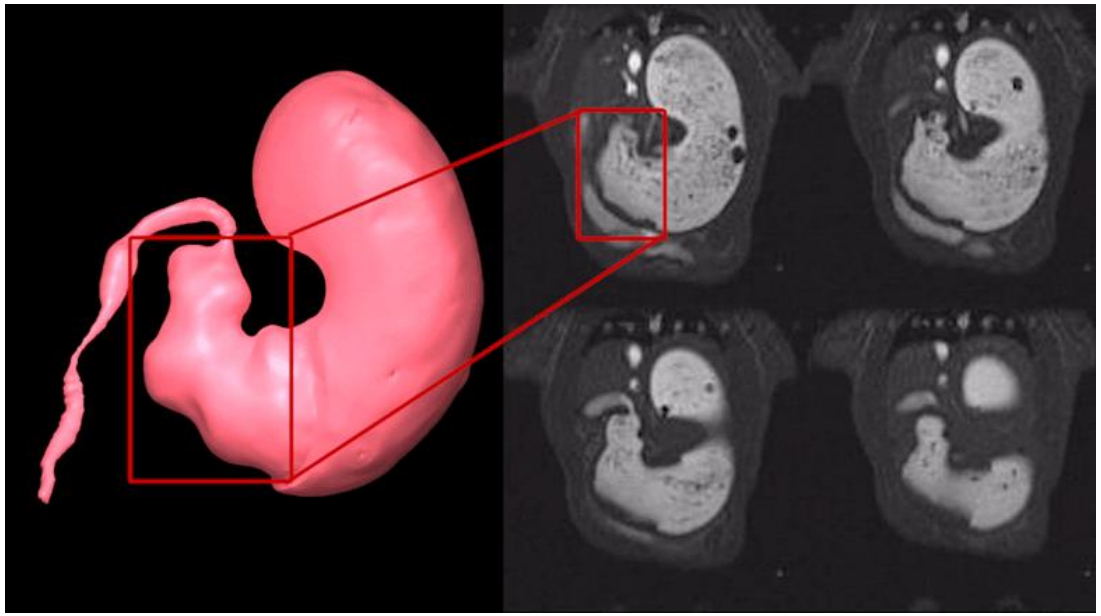
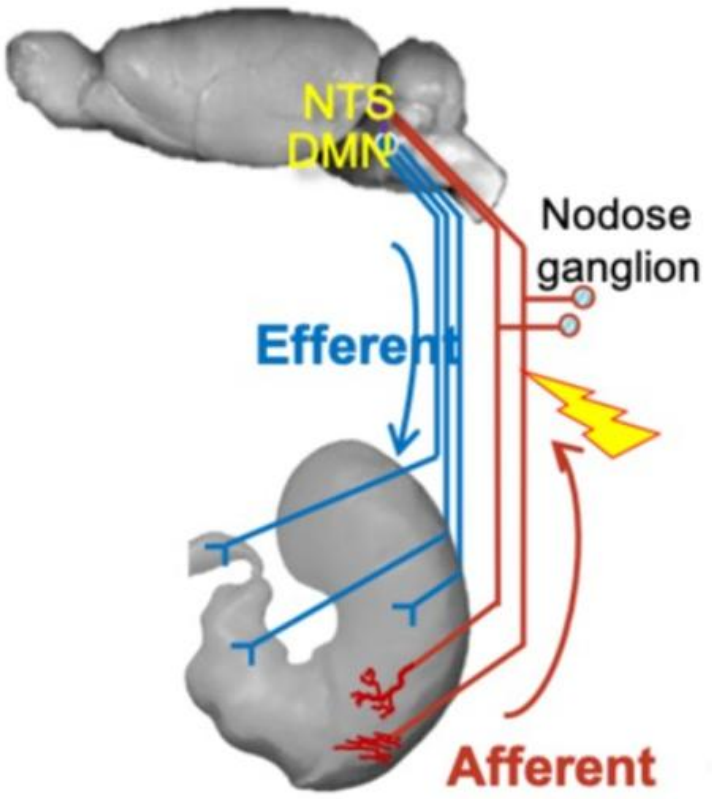
Introduction: Effects of Vagal Nerve Stimulation (VNS) on Stomach Motility



Stomach motility [1]



VNS pathway [1]

M – Stomach motility

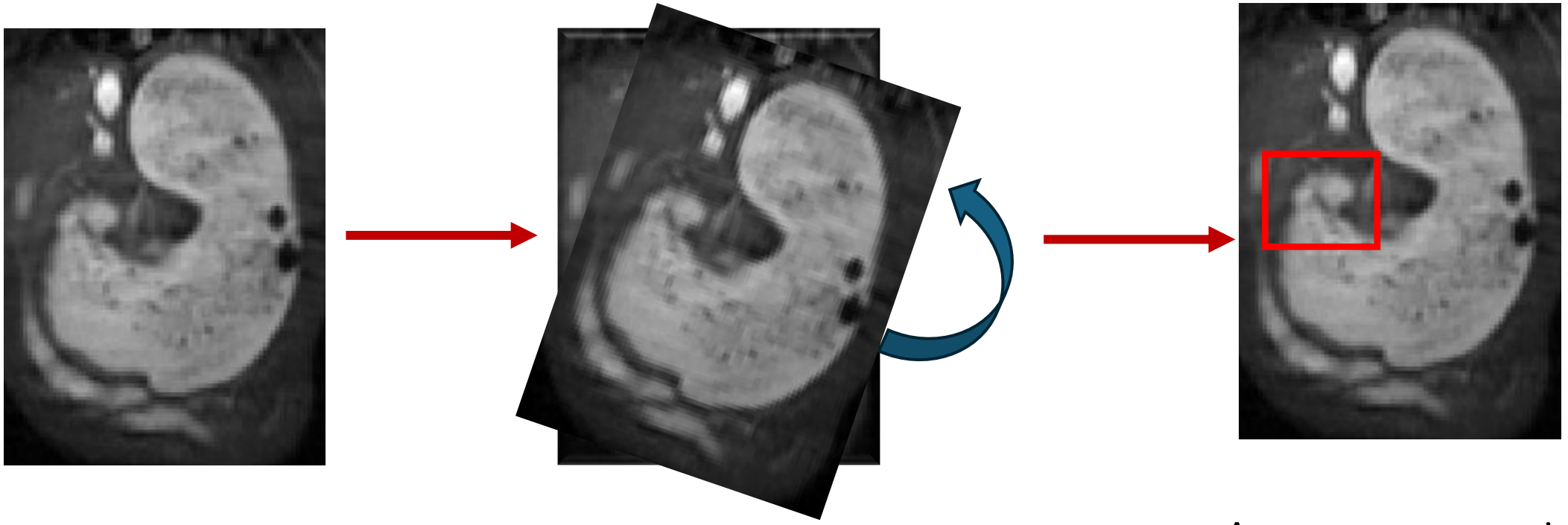
$$M = f(X1, X2, X3, X4)$$

X1 = Pyloric Sphincter opening
X2 = Antral contraction amplitude
X3 = Peristaltic velocity
X4 = Peristaltic frequency

Data science question

If we have values of X1/X2/X3/X4, can we predict using a model if the data belongs to VNS or not?

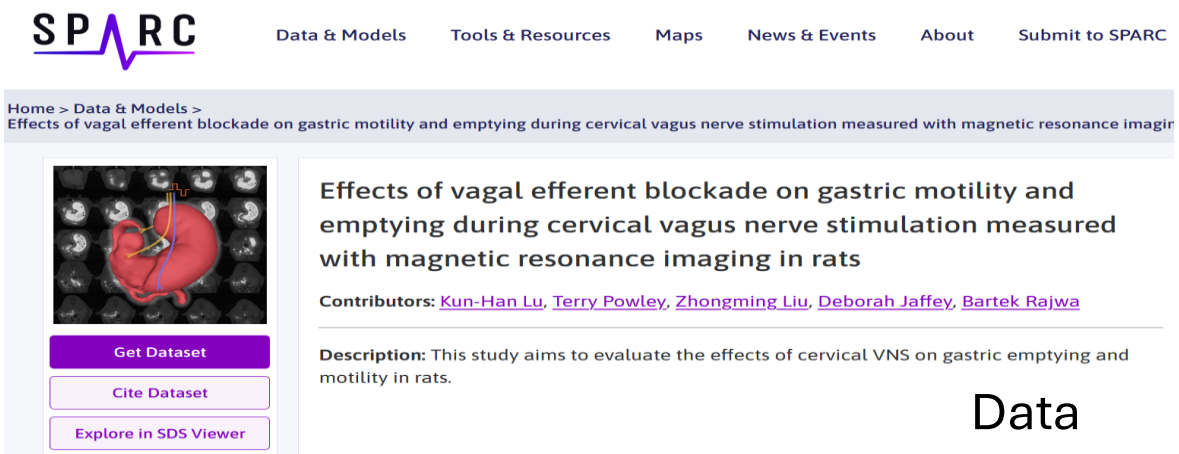
Procedure



Nifti file

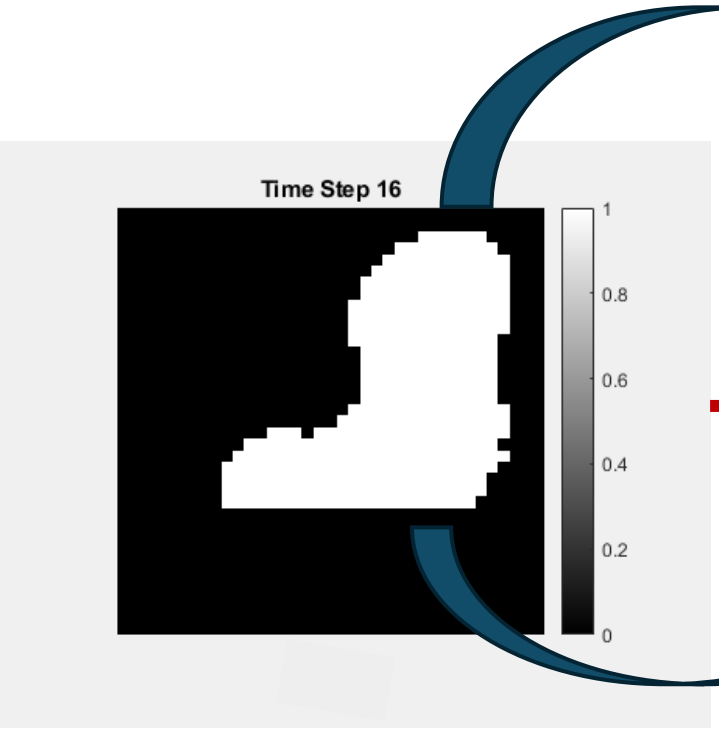
Motion correction

Antrum segmentation

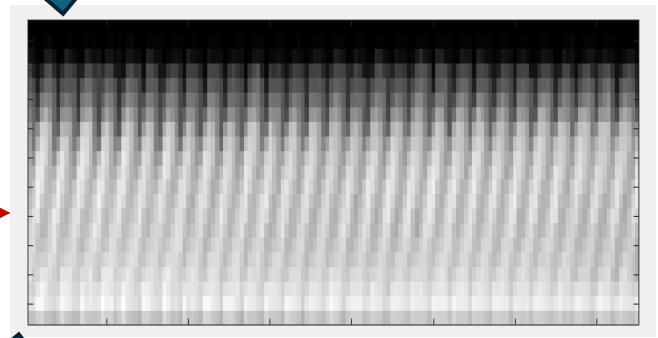


Data

Procedure



Otsu thresholding

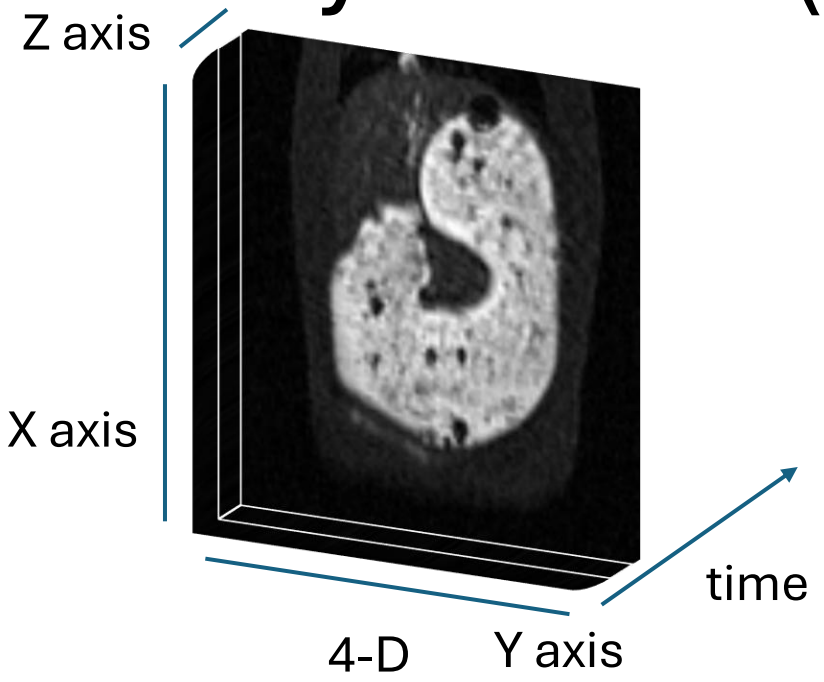


Spatial-temporal image

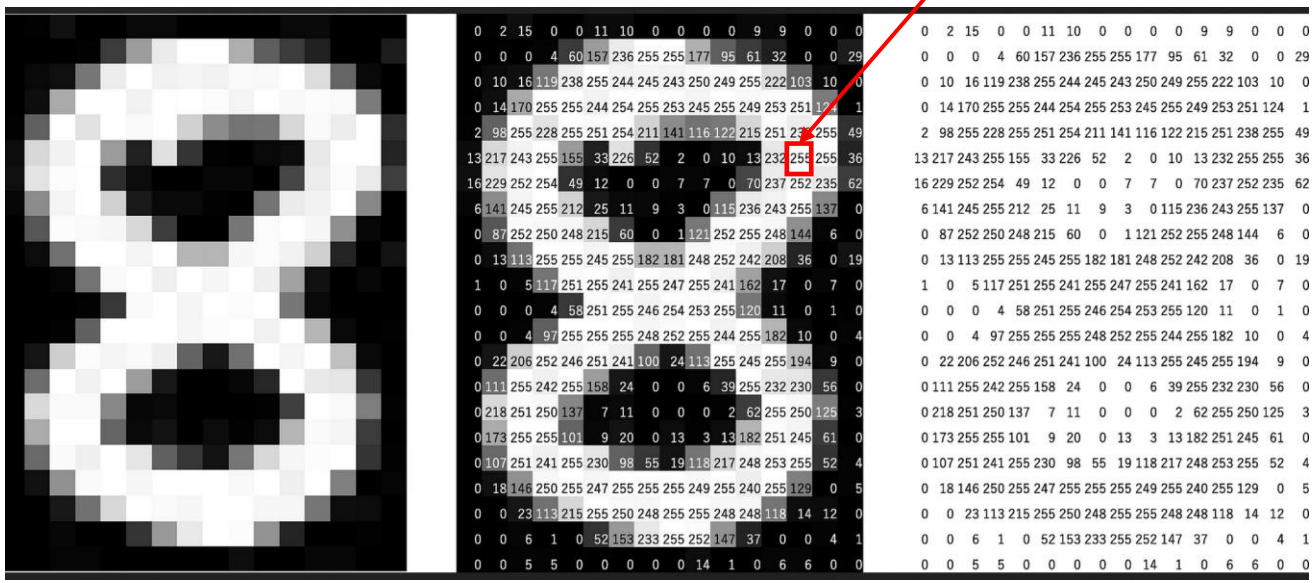
Data_Index	CPM	Average_occlusion	Stimulation
1	6	10.07480178	VNS
2	5.2	6.578330764	No VNS
3	6	8.708070145	VNS
4	5.5	8.191619705	No VNS
5	6.5	9.736769498	VNS
6	5.5	6.941190717	No VNS
7	6.8	9.70288256	VNS
8	5	8.370176901	No VNS
25	6.7	11.59166604	VNS
26	4.6	5.021489911	No VNS
27	6	10.90875863	VNS
28	4.9	5.773882165	No VNS
29	6	12.1073352	VNS
30	4.7	5.980506133	No VNS
31	6	9.605864178	VNS
32	4.6	9.528379173	No VNS
33	5.9	10.22848837	VNS
34	4.5	8.342551989	No VNS
35	5.7	10.18170793	VNS
36	4.4	6.960982225	No VNS
37	5.7	10.61640807	VNS
38	4.3	8.517416714	No VNS
39	5.6	10.84664797	VNS
40	4.7	11.03613591	No VNS

Dataset and data analysis

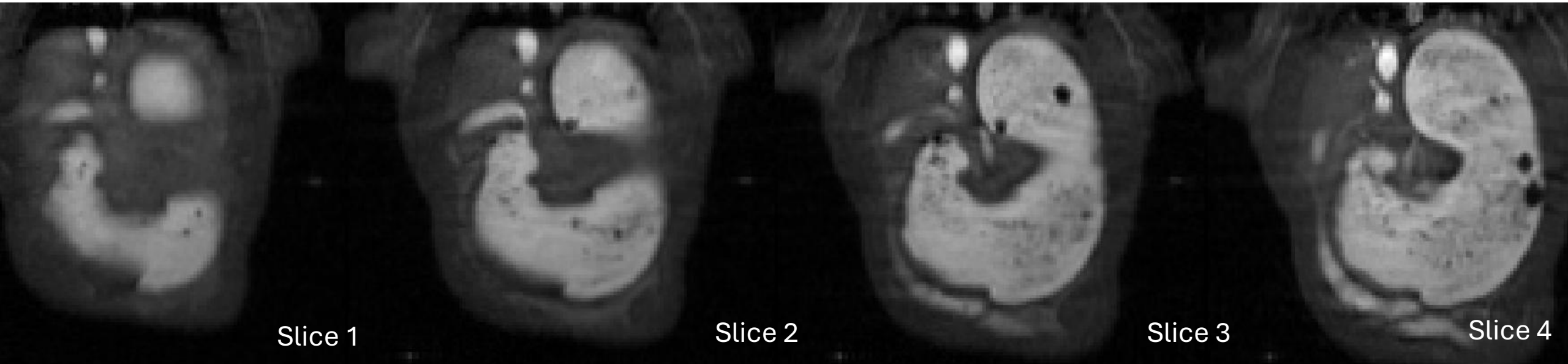
MRI Analysis-Data (Nifti files)



Greyscale images Pixel values (0-255)



[2]

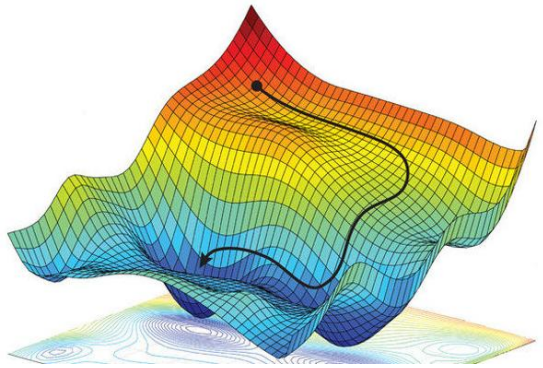


MRI Analysis-Image motion correction (Rigid registration)

Mean square – Similarity Metric

$$\sum (I_A - I_B)^2 / N$$

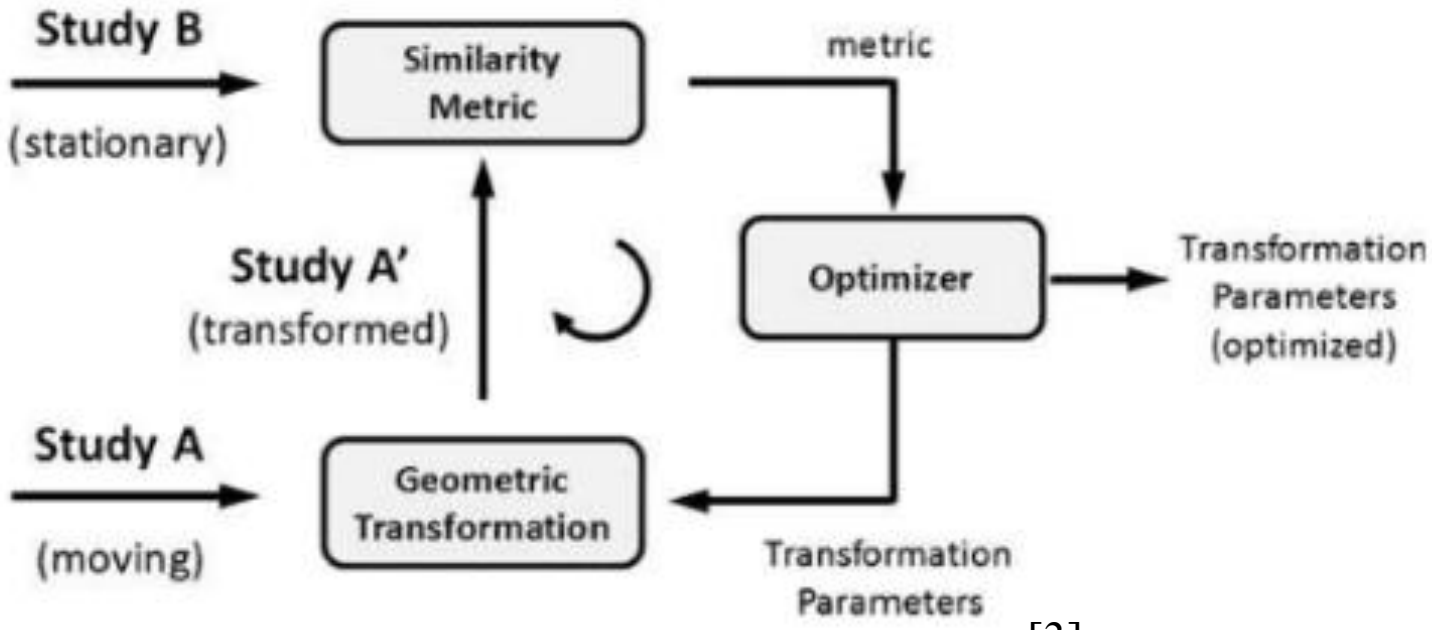
Optimizer: gradient descent



[4]

1	4	0
3	8	0
0	0	0
0	0	0
0	0	0

0	0	0
1	4	0
3	8	0
0	0	0
0	0	0



[3]

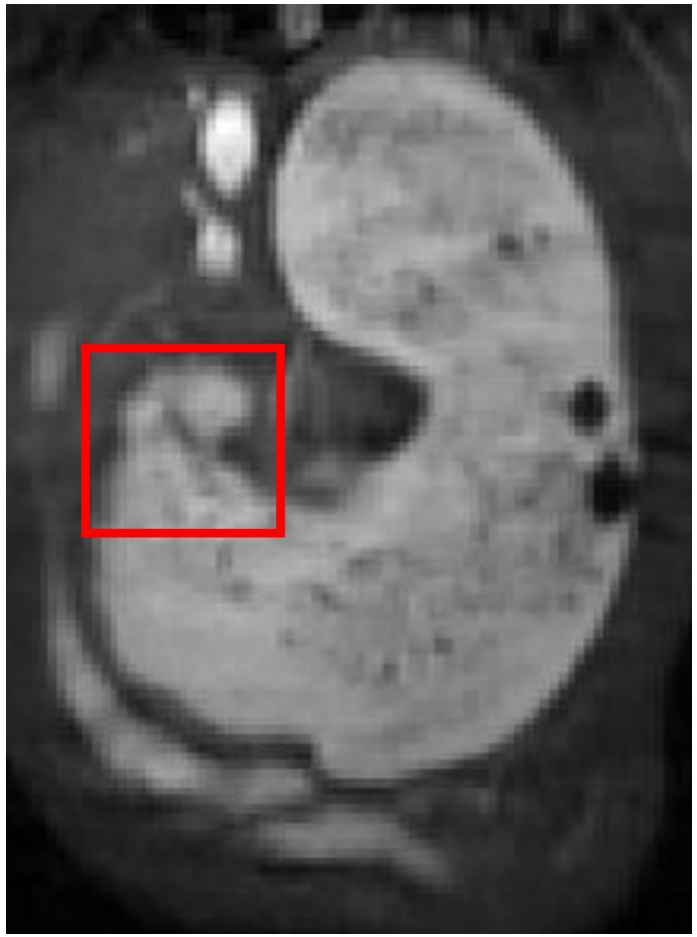
MATLAB command

Img_mc(:,:,islice,itime) = imregister(Img(:,:,islice,1), 'rigid', optimizer, metric);

Geometric transformation

- 6 degrees of freedom
- 3 associated with the translation vector: $t = (t_x, t_y, t_z)$
- 3 associated with the rotation parameters: $\theta = (\alpha, \beta, \gamma)$.

MRI Analysis-Antrum segmentation



Antrum segmentation

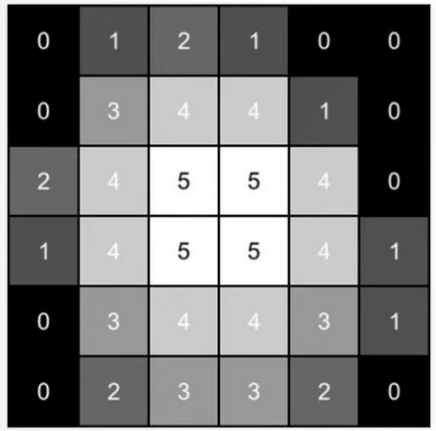
MRI Analysis-Otsu thresholding

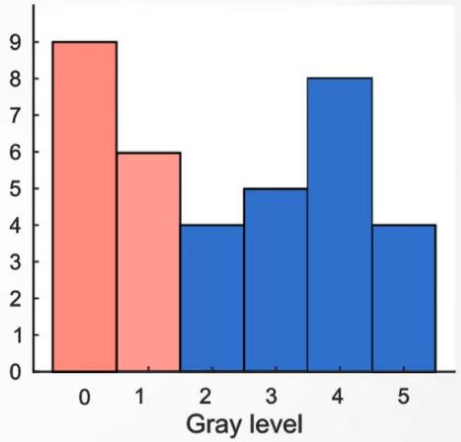
- Searches for the threshold intensity I_t which maximizes the *between class variance* σ_B^2

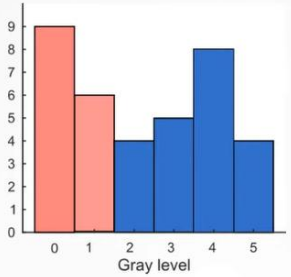
$$\sigma_B^2 = W_b W_f (\mu_b - \mu_f)^2$$

$W_{b,f}$ = Number of pixels in background (foreground)/Total number of pixels

$\mu_{b,f}$ = Mean intensity of background (foreground)







Background

$$W_b = \frac{9+6}{36} = 0.42$$

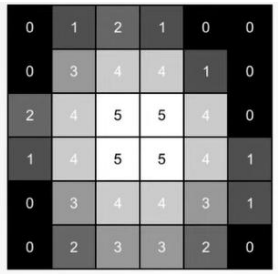
$$\mu_b = \frac{(9\times 0)+(6\times 1)}{9+6} = 0.4$$

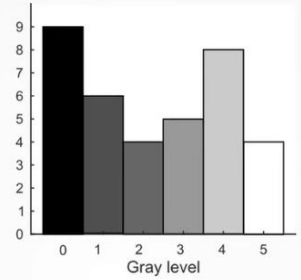
Foreground

$$W_f = \frac{4+5+8+4}{36} = 0.58$$

$$\mu_f = \frac{(4\times 2)+(5\times 3)+(8\times 4)+(4\times 4)}{4+5+8+4} = 3.57$$

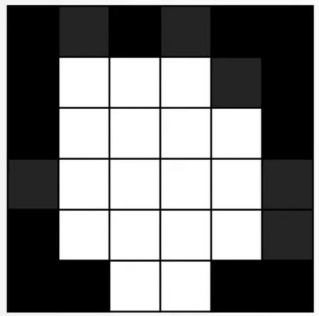
$$\sigma_B^2 = W_b W_f (\mu_b - \mu_f)^2 = 2.44$$

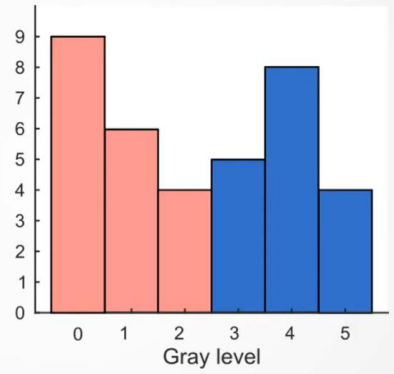




I_t	0	1	2	3	4	5
W_b	0	0.25	0.42	0.53	0.67	0.89
μ_b	0	0	0.40	0.74	1.21	1.91
W_f	1	0.75	0.58	0.47	0.33	0.11
μ_f	2.25	3.00	3.57	3.94	4.33	5.00
σ_b^2	0	1.69	2.44	2.56	2.17	0.95

Highest value chosen

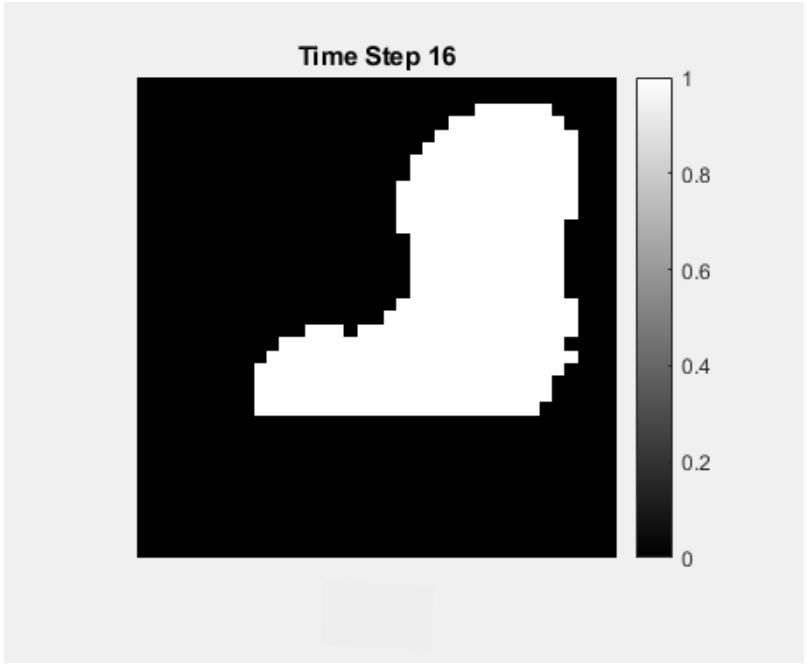




[5]

MRI Analysis-Otsu thresholding

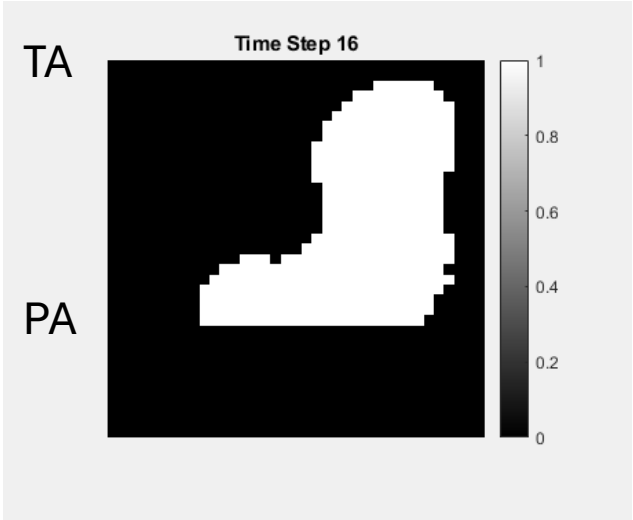
MATLAB command
T = otsuthresh(counts)

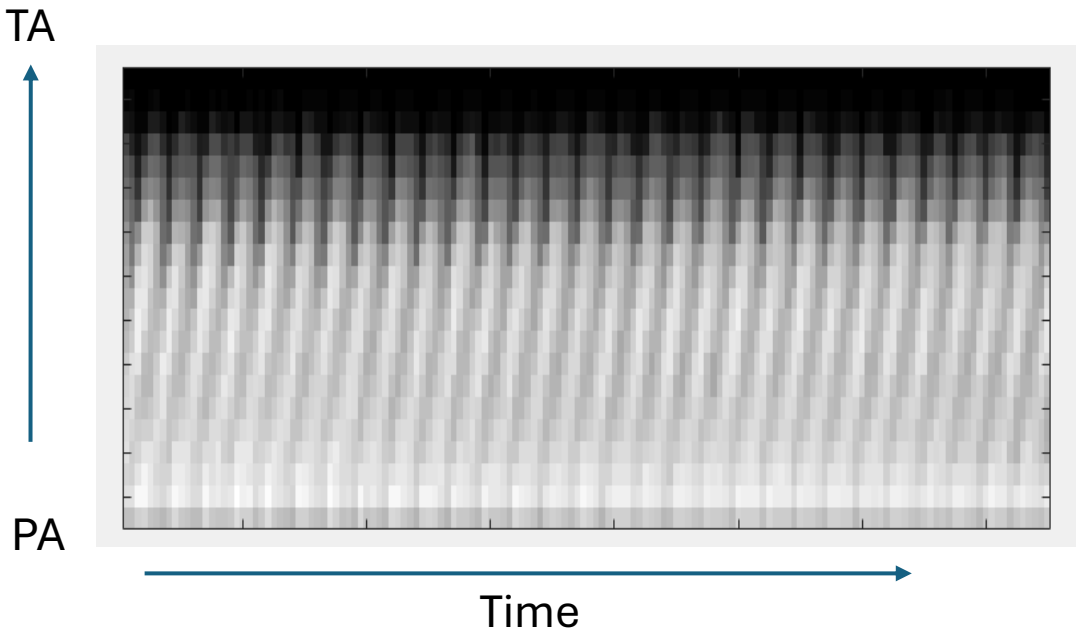


Otsu thresholding

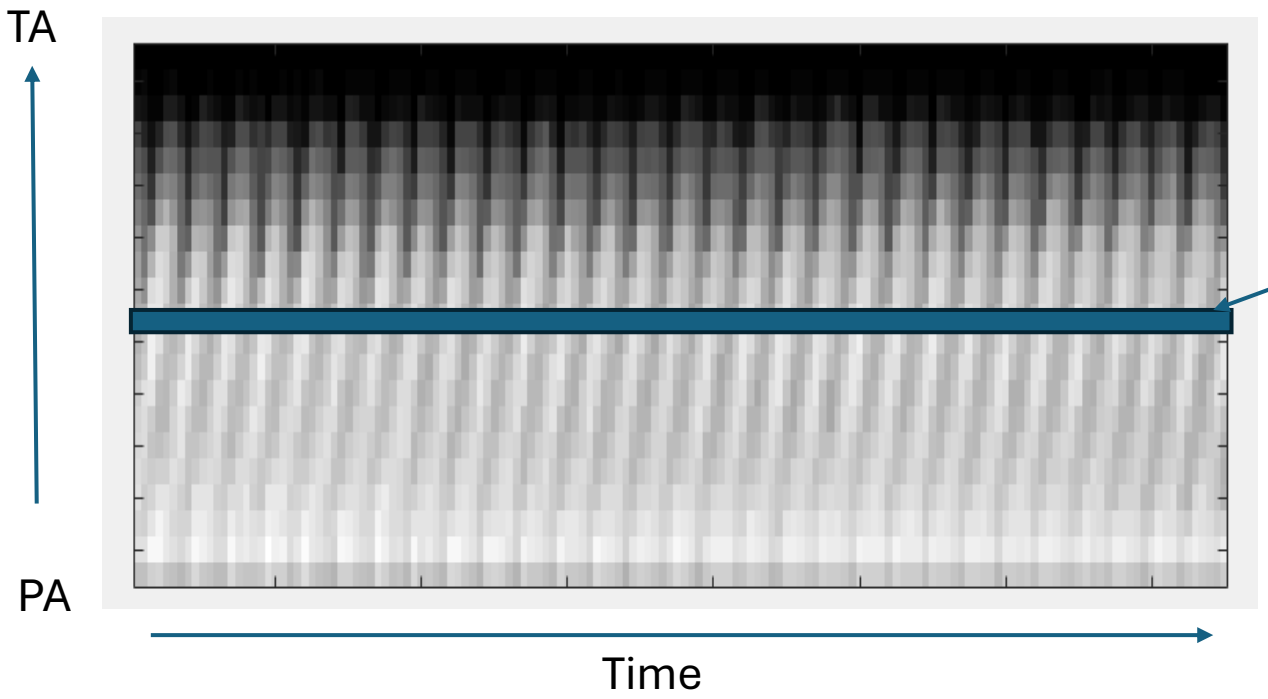
MRI Analysis-Spatial-temporal image

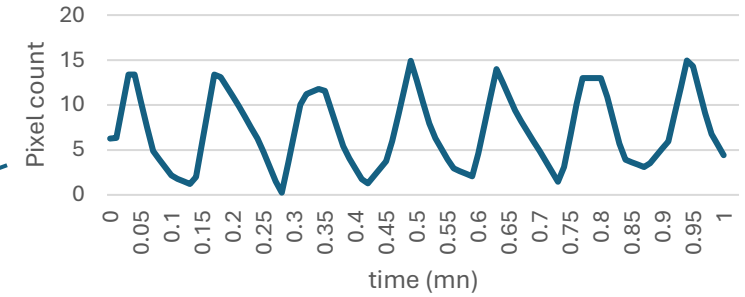
- From 4D to 2D image
- F(X+Y+Z,t) = Spatial Temporal graph

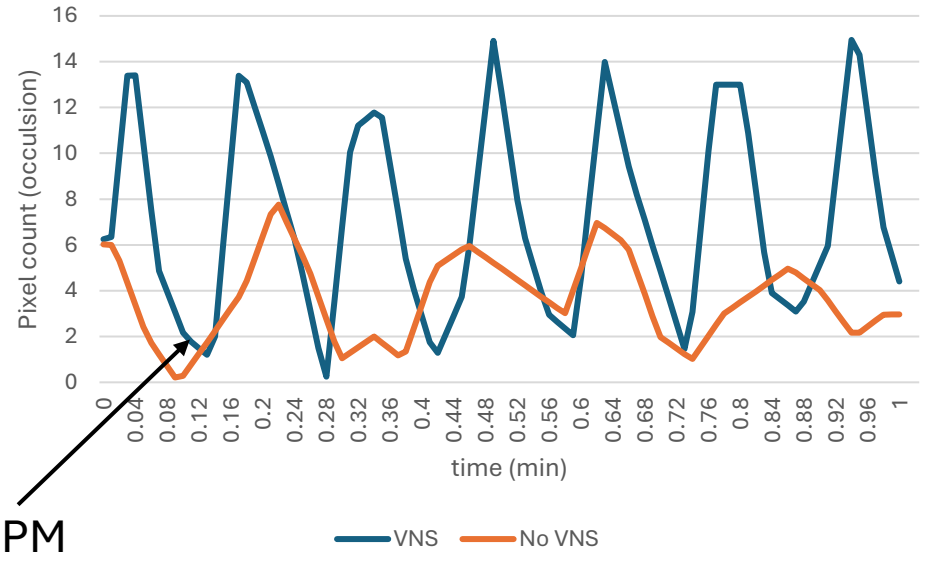




MRI Analysis-Spatial-temporal image







CPM

Data set

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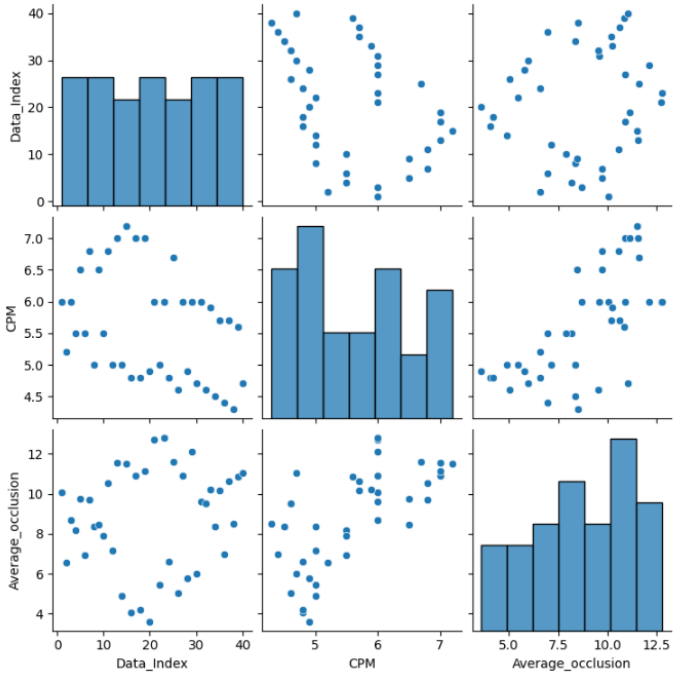
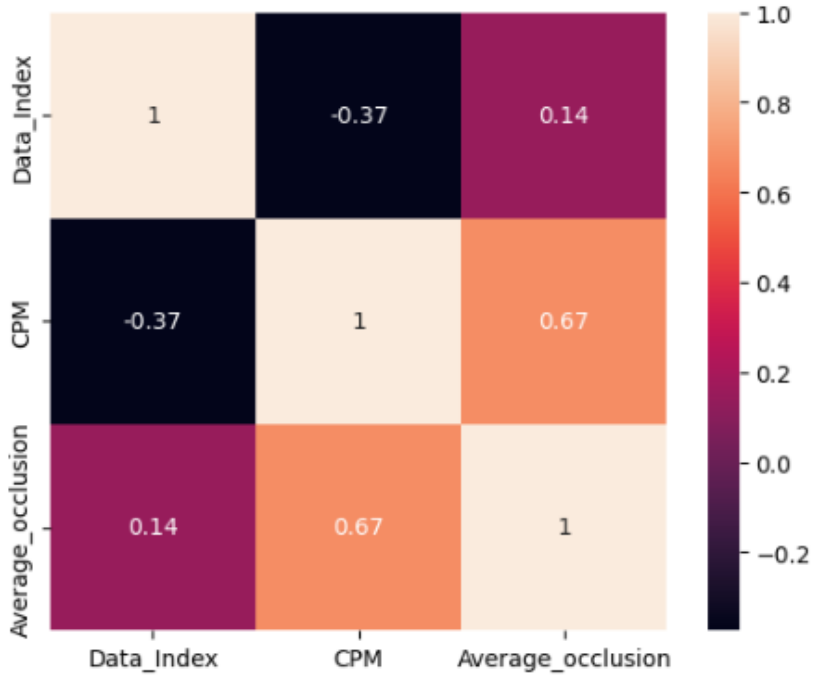


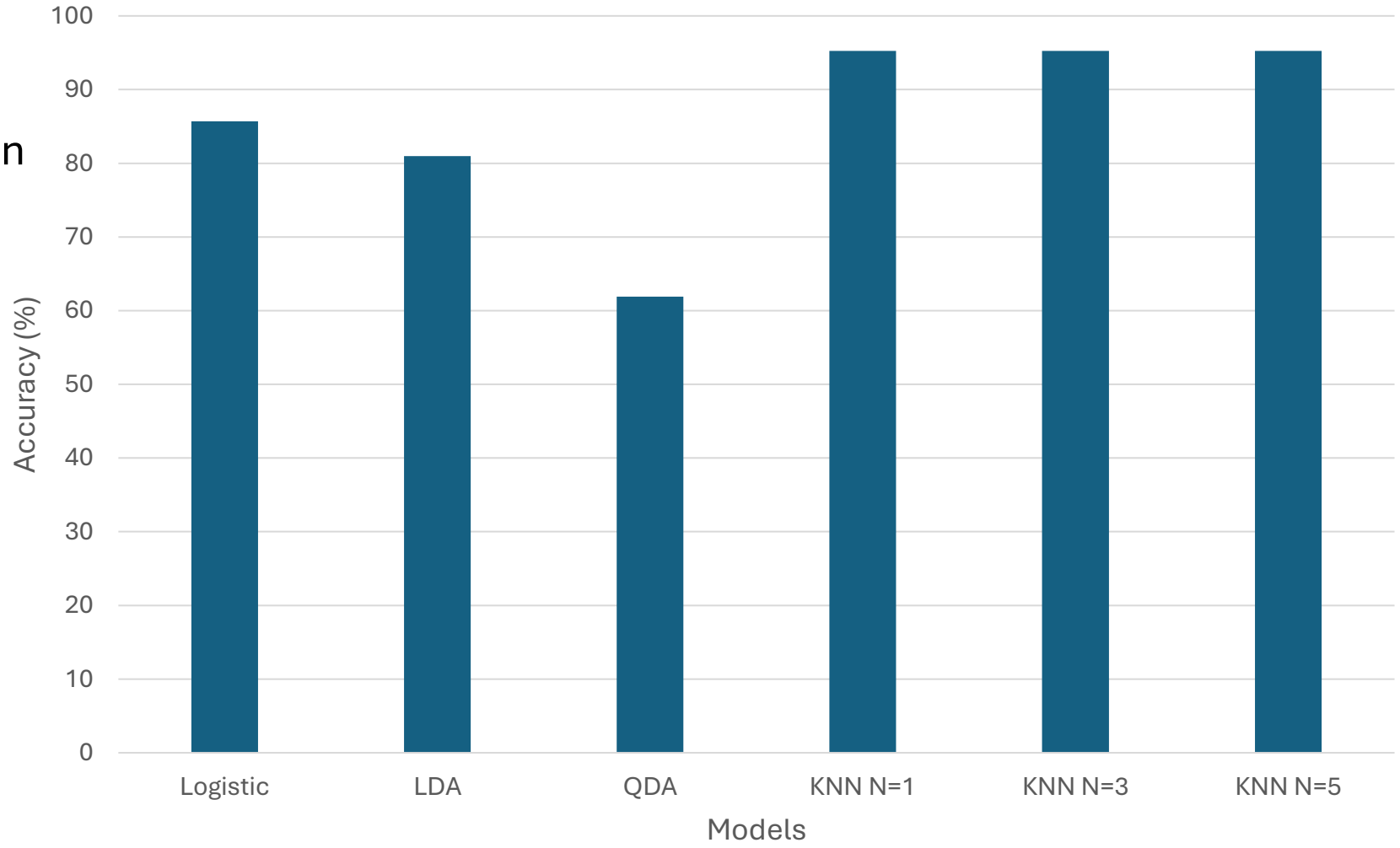


Analysis-1

Predictors : CPM, Average_occlusion
Training: [1-19]
Test: [20-40]

Best result: KNN 95.24%

Truth	No VNS	VNS
Predicted		
No VNS	10	0
VNS	1	10

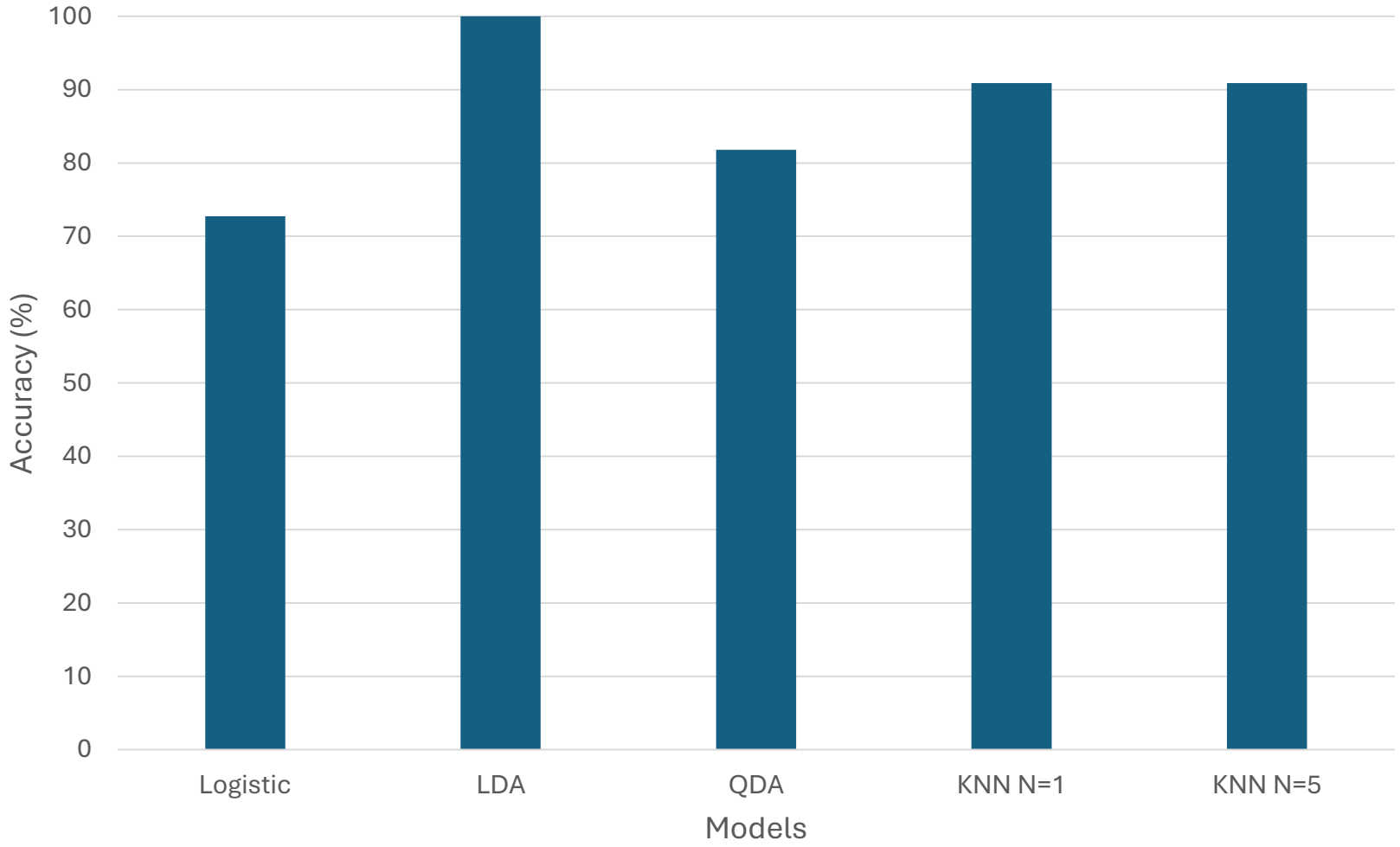


Analysis-2

Predictors : CPM, Average_occlusion
Training: [1-29]
Test: [30-40]

Best result: LDA 100 %

Truth	No VNS	VNS
Predicted		
No VNS	6	0
VNS	0	5

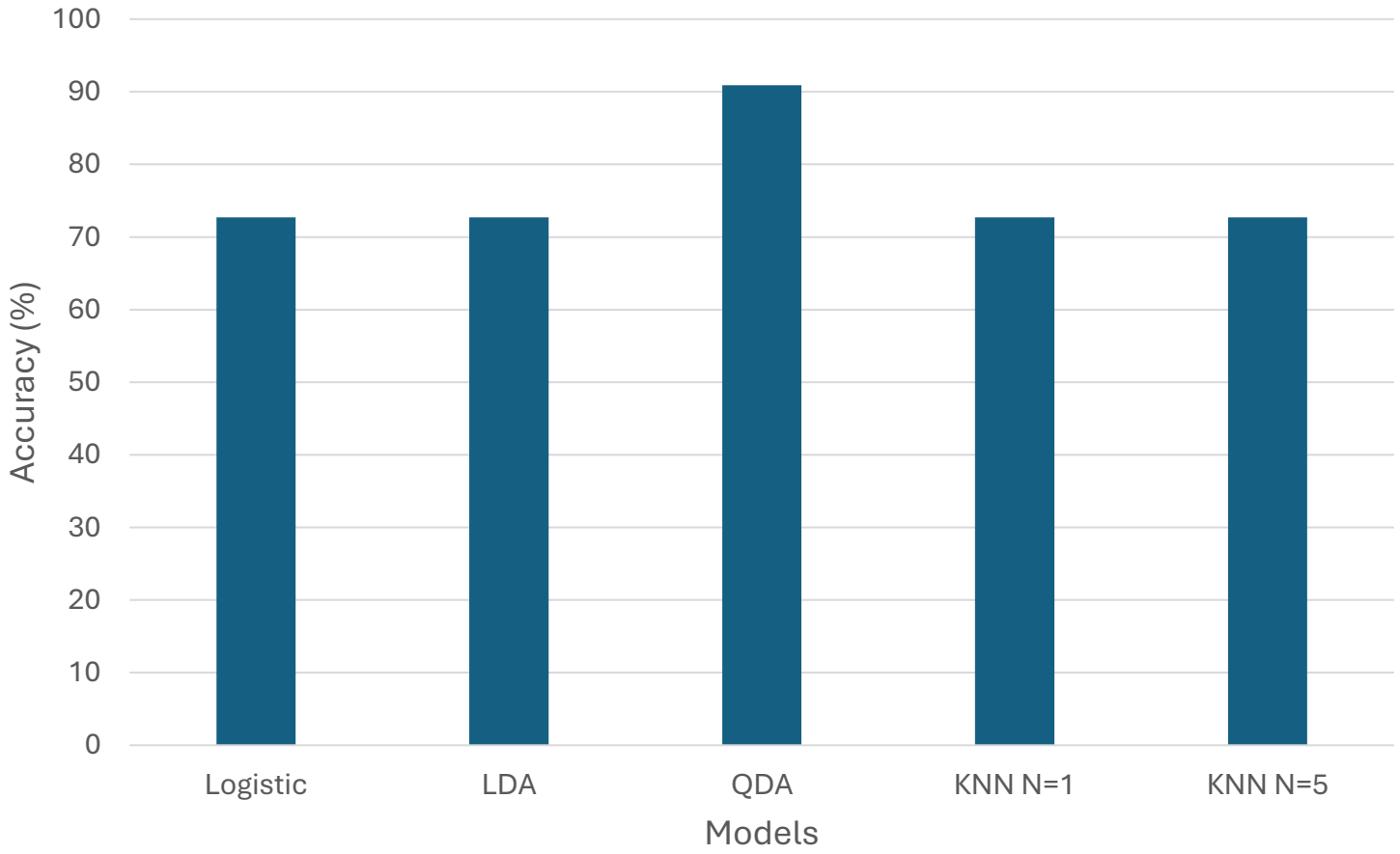


Analysis-3

Predictors : CPM
Training: [1-29]
Test: [30-40]

Best result: QDA 90.9 %

Truth	No VNS	VNS
Predicted		
No VNS	6	1
VNS	0	4



Conclusion

M – Stomach motility

$$M = f(X1, X2, X3, X4)$$

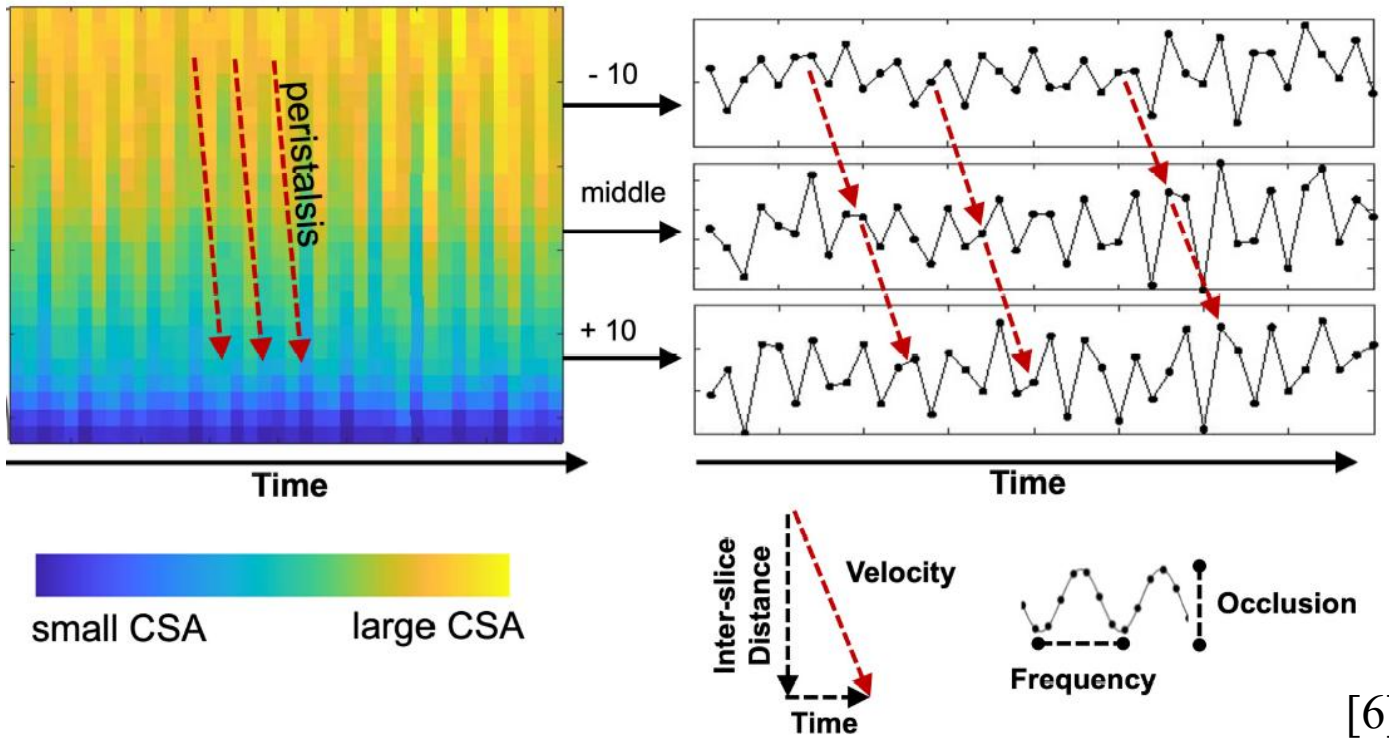
Dataset: Average_occlusion

Dataset: CPM

X1 = Pyloric Sphincter opening
X2 = Antral contraction amplitude
X3 = Peristaltic velocity
X4 = Peristaltic frequency

Predictors : CPM, Average_occlusion
Training: [1-29]
Test: [30-40]
Best result: LDA 100 %

Future work: For X3



[6]

References

- [1] https://www.embs.org/tbme/articles/contrast-enhanced-magnetic-resonance-imaging-gastric-emptying-motility-rats-2/
- [2] https://i.ytimg.com/vi/fTaJZO4-Q7E/maxresdefault.jpg
- [3] https://poissonisfish.com/wp-content/uploads/2020/11/non-convex-optimization-we-utilize-stochastic-gradient-descent-to-find-a-local-optimum.jpg
- [4] https://oncologymedicalphysics.com/image-registration/
- [5] https://www.youtube.com/watch?v=jUUkMaNuHP8&t=15s&ab_channel=JianWeiTay
- [6] Sclocco, R., Fisher, H., Staley, R., Han, K., Mendez, A., Bolender, A., … & Napadow, V. (2022). Cine gastric MRI reveals altered Gut–Brain Axis in Functional Dyspepsia: gastric motility is linked with brainstem-cortical fMRI connectivity. *Neurogastroenterology & Motility*, *34*(10), e14396
- Datasets https://sparc.science/datasets/270
  - https://sparc.science/datasets/183
- Code CREATED: Oct. 11, 2017, Kun-Han Lu