

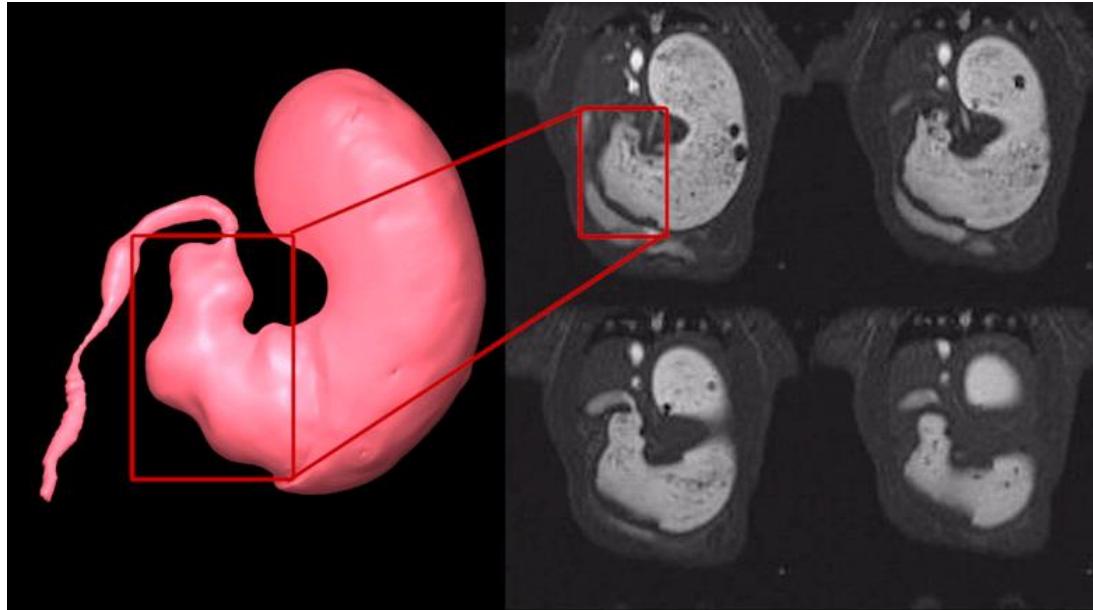
Stomach Motility: Effect of VNS

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LEHIGH
UNIVERSITY

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



Stomach motility [1]

M – Stomach motility

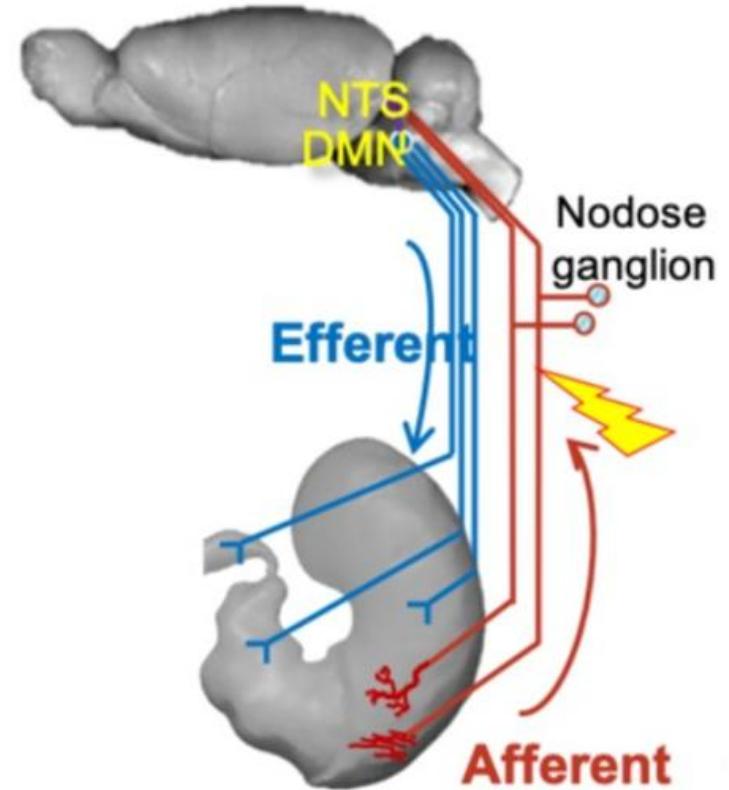
$$M = f(X_1, X_2, X_3, X_4)$$

X_1 = Pyloric Sphincter opening

X_2 = Antral contraction amplitude

X_3 = Peristaltic velocity

X_4 = Peristaltic frequency

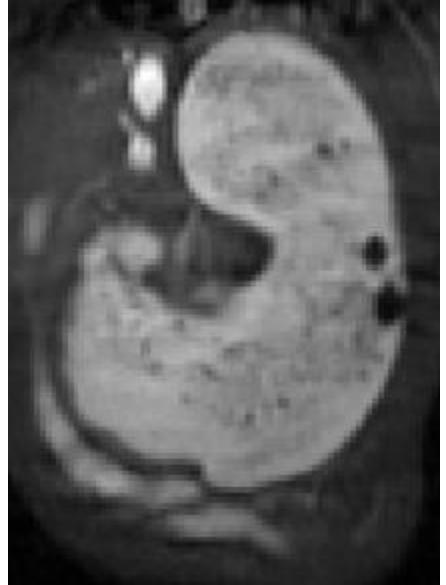


VNS pathway [1]

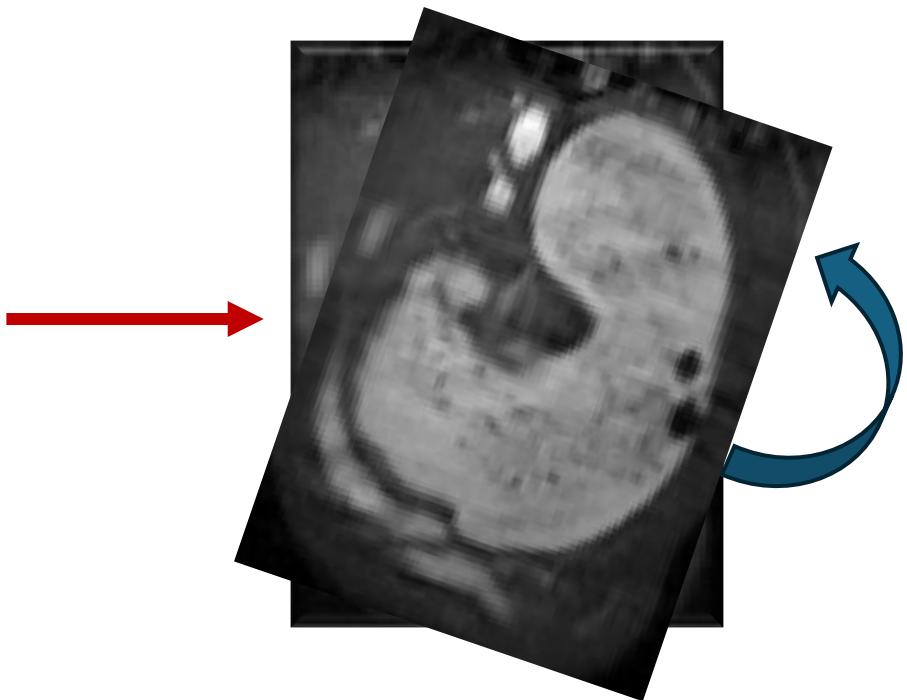
Data science question

If we have values of $X_1/X_2/X_3/X_4$, can we predict using a model if the data belongs to VNS or not?

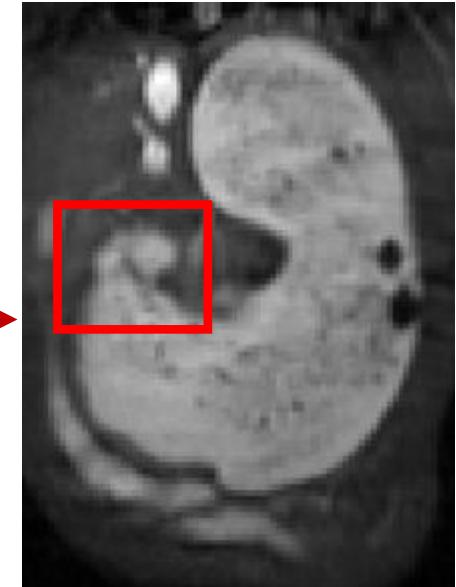
Procedure



Nifti file



Motion correction

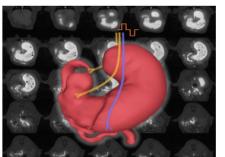


Antrum segmentation



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Effects of vagal efferent blockade on gastric motility and emptying during cervical vagus nerve stimulation measured with magnetic resonance imaging in rats



Effects of vagal efferent blockade on gastric motility and emptying during cervical vagus nerve stimulation measured with magnetic resonance imaging in rats

Contributors: [Kun-Han Lu](#), [Terry Powley](#), [Zhongming Liu](#), [Deborah Jaffey](#), [Bartek Rajwa](#)

Description: This study aims to evaluate the effects of cervical VNS on gastric emptying and motility in rats.

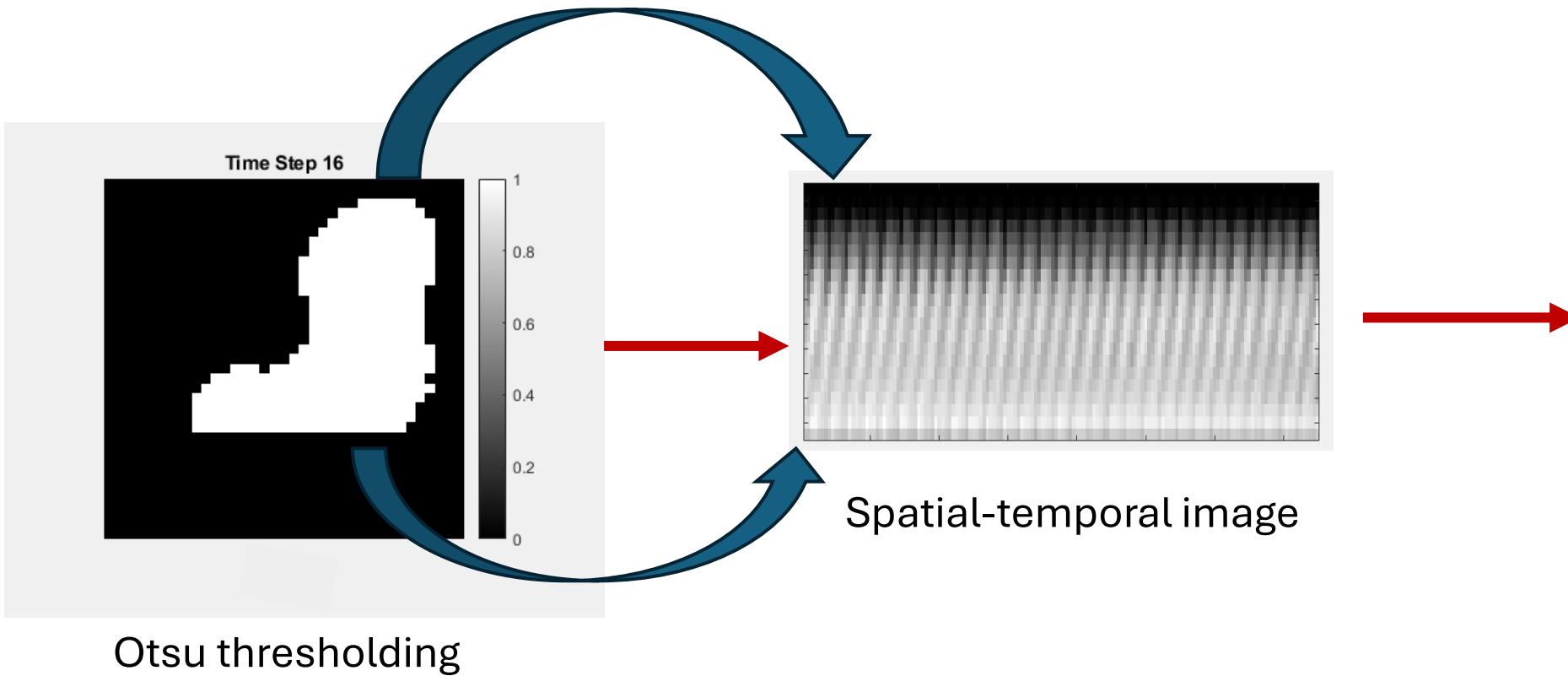
Get Dataset

Cite Dataset

Explore in SDS Viewer

Data

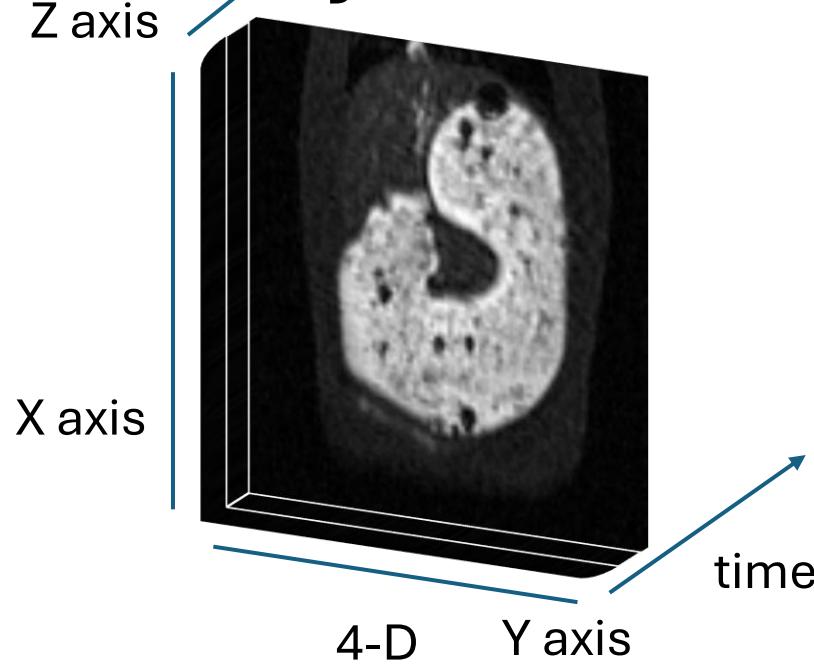
Procedure



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)

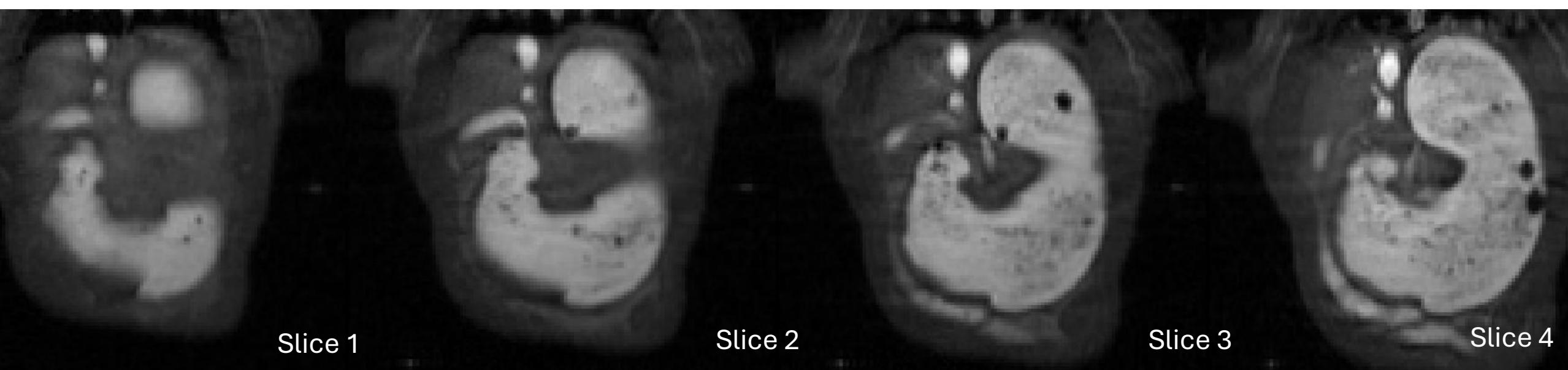


Greyscale images Pixel values (0-255)

A 28x28 pixel grayscale image of a handwritten digit, which appears to be the number '4'. The digit is dark gray and has a slightly irregular shape. It is set against a background of white and light gray pixels. The entire image is framed by a thick black border.

0	2	15	0	0	11	10	0	0	0	0	9	9	0	0	0
0	0	0	4	60	157	236	255	255	177	95	61	32	0	0	29
0	10	16	119	238	255	244	245	243	250	249	255	222	103	10	0
0	14	170	255	255	244	254	255	253	245	255	249	253	251	124	1
2	98	255	228	255	251	254	211	141	116	122	215	251	23	255	49
13	217	243	255	155	33	226	52	2	0	10	13	232	255	255	36
16	229	252	254	49	12	0	0	7	7	0	70	237	252	235	62
6	141	245	255	212	25	11	9	3	0	115	236	243	255	137	0
0	87	252	250	248	215	60	0	1	12	252	255	248	144	6	0
0	13	113	255	255	245	255	182	181	248	252	242	208	36	0	19
1	0	5	117	251	255	241	255	247	255	241	162	17	0	7	0
0	0	0	4	58	251	255	246	254	253	255	120	11	0	1	0
0	0	4	97	255	255	255	248	252	255	244	255	182	10	0	4
0	22	206	252	246	251	241	100	24	113	255	245	255	194	9	0
0	111	255	242	255	158	24	0	0	6	39	255	232	230	56	0
0	218	251	250	137	7	11	0	0	0	2	62	255	250	125	3
0	173	255	255	101	9	20	0	13	3	13	182	251	245	61	0
0	107	251	241	255	230	98	55	19	118	217	248	253	255	52	4
0	18	146	250	255	247	255	255	249	255	240	255	129	0	5	0
0	0	0	23	113	215	255	250	248	255	252	248	248	118	14	12
0	0	6	1	0	52	153	233	255	252	147	37	0	4	1	0
0	0	5	5	0	0	0	0	0	14	1	0	6	6	0	0

[2]

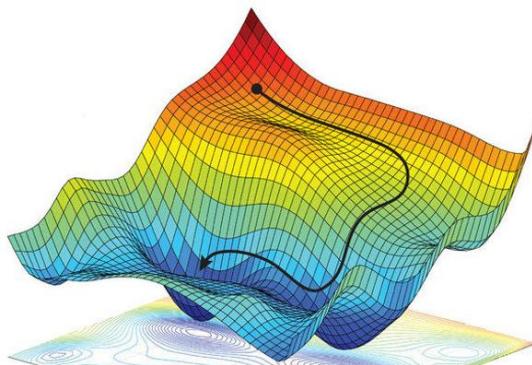


MRI Analysis-Image motion correction (Rigid registration)

Mean square –
Similarity Metric

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

Optimizer: gradient
descent



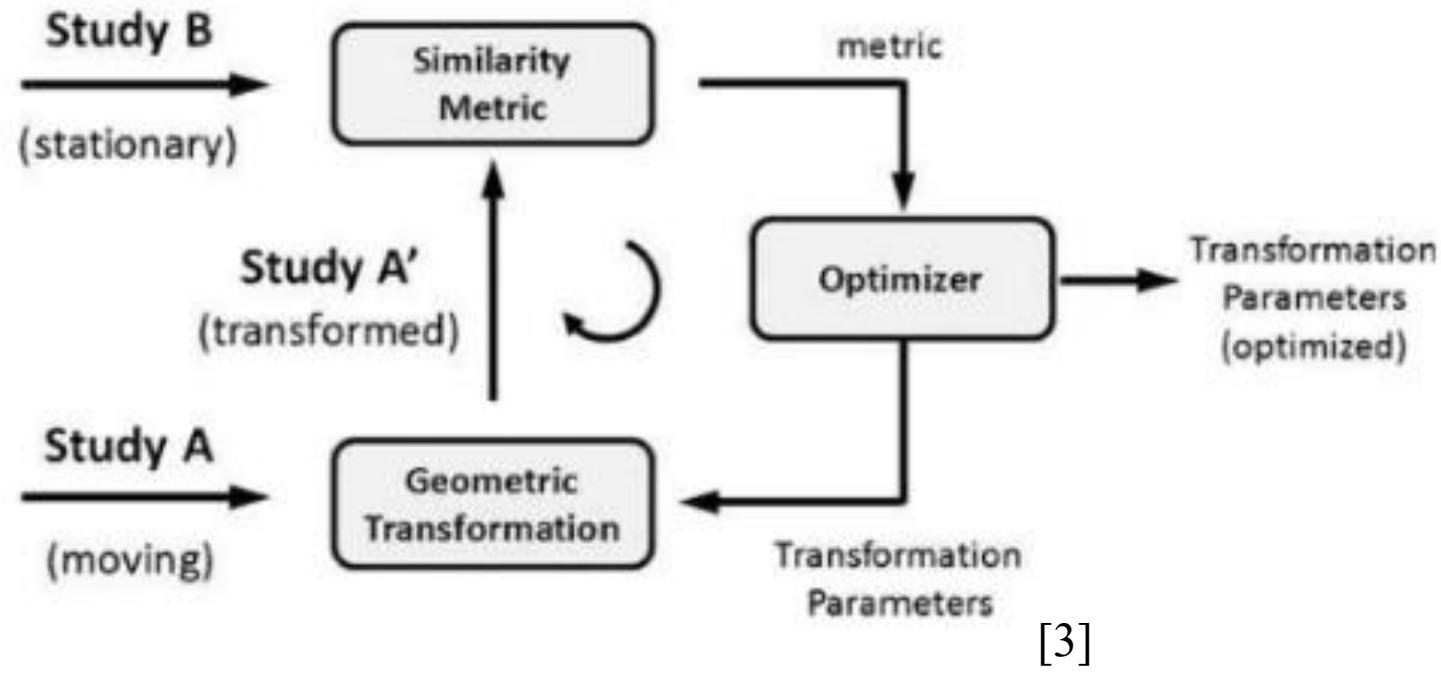
[4]

MATLAB command

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

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

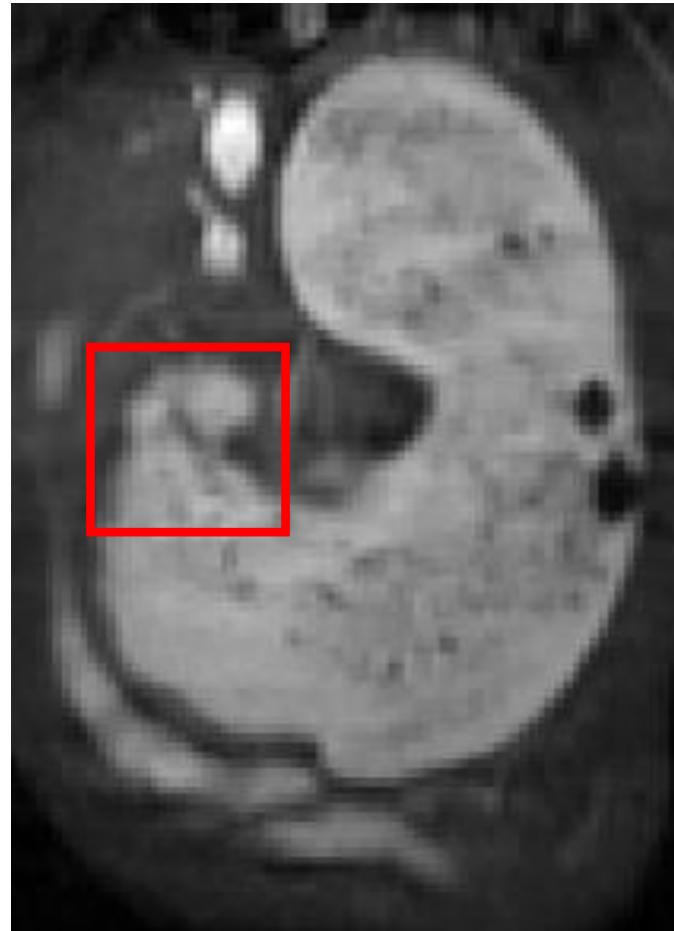
0	0	0
1	4	0
3	8	0
0	0	0
0	0	0



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

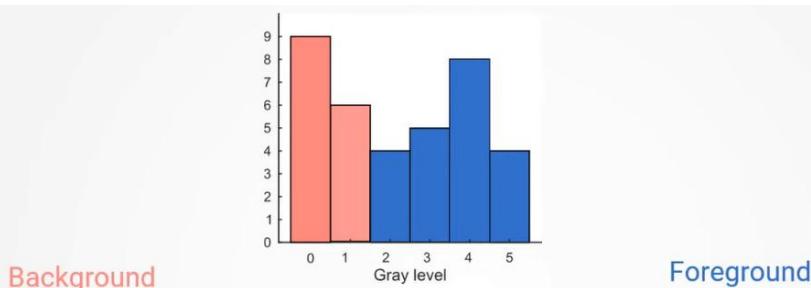
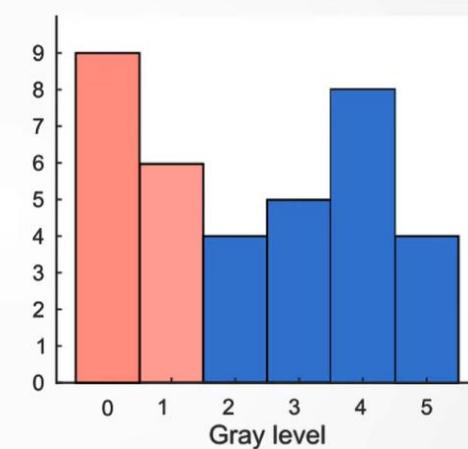
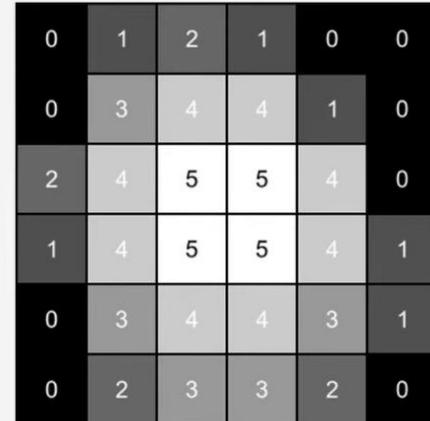
MRI Analysis-Otsu thresholding

- 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)



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

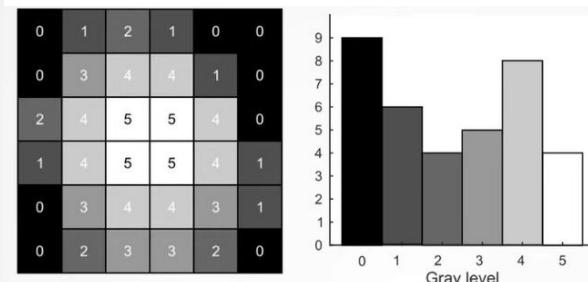
$$W_f = \frac{4+5+8+4}{36} = 0.58$$

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

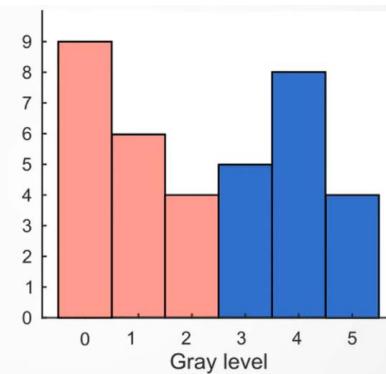
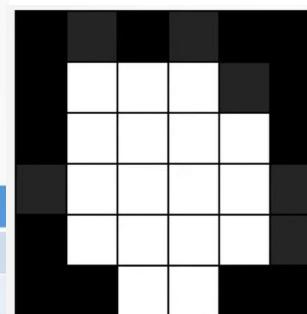
$$\mu_f = \frac{(4 \times 2) + (5 \times 3) + (8 \times 4) + (4 \times 4)}{4+5+8+4} = 3.57$$

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

Foreground



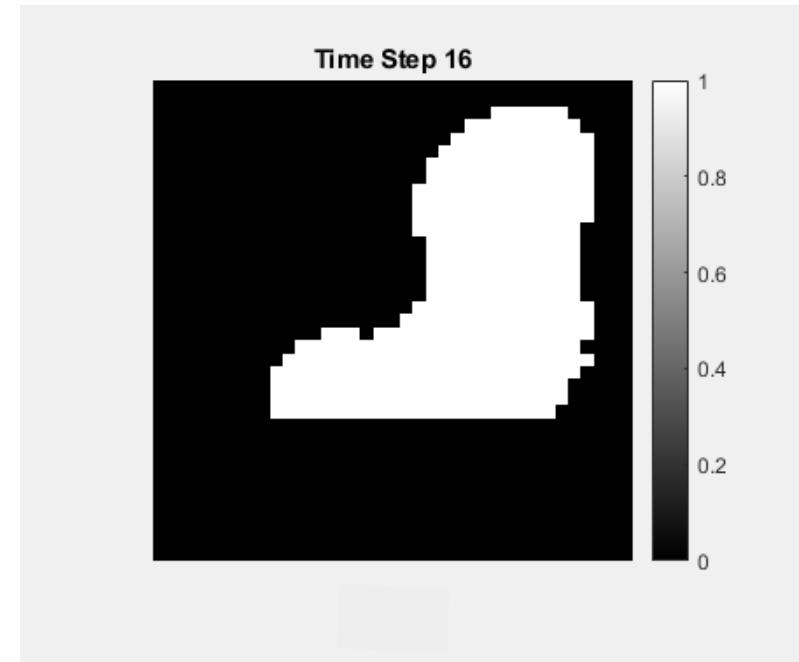
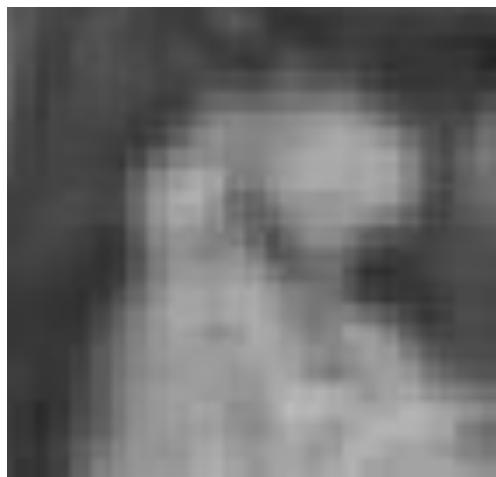
I_t	0	1	2	3	4	5
W_b	0	0.25	0.42	0.53	0.67	0.89
μ_b	0	0	0.40	0.74	1.21	1.91
W_f	1	0.75	0.58	0.47	0.33	0.11
μ_f	2.25	3.00	3.57	3.94	4.33	5.00
σ_b^2	0	1.69	2.44	2.56	2.17	0.95



[5]

Highest value chosen

MRI Analysis-Otsu thresholding

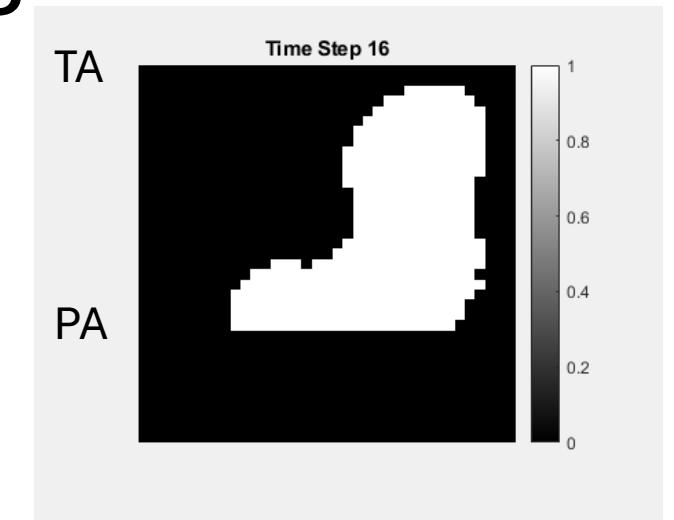
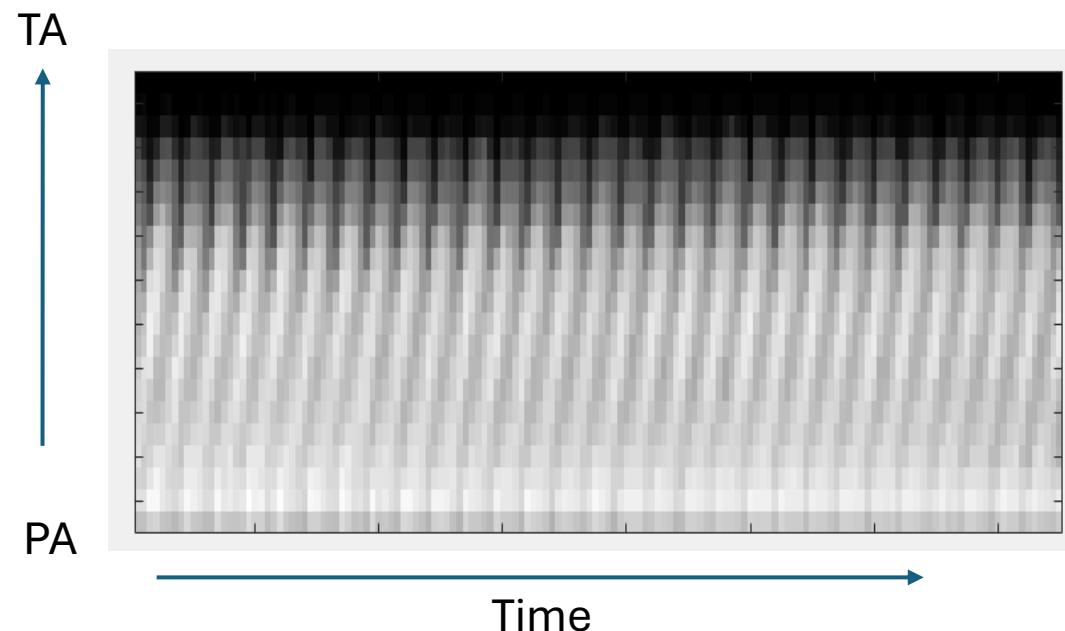


MATLAB command
`T = otsuthresh(counts)`

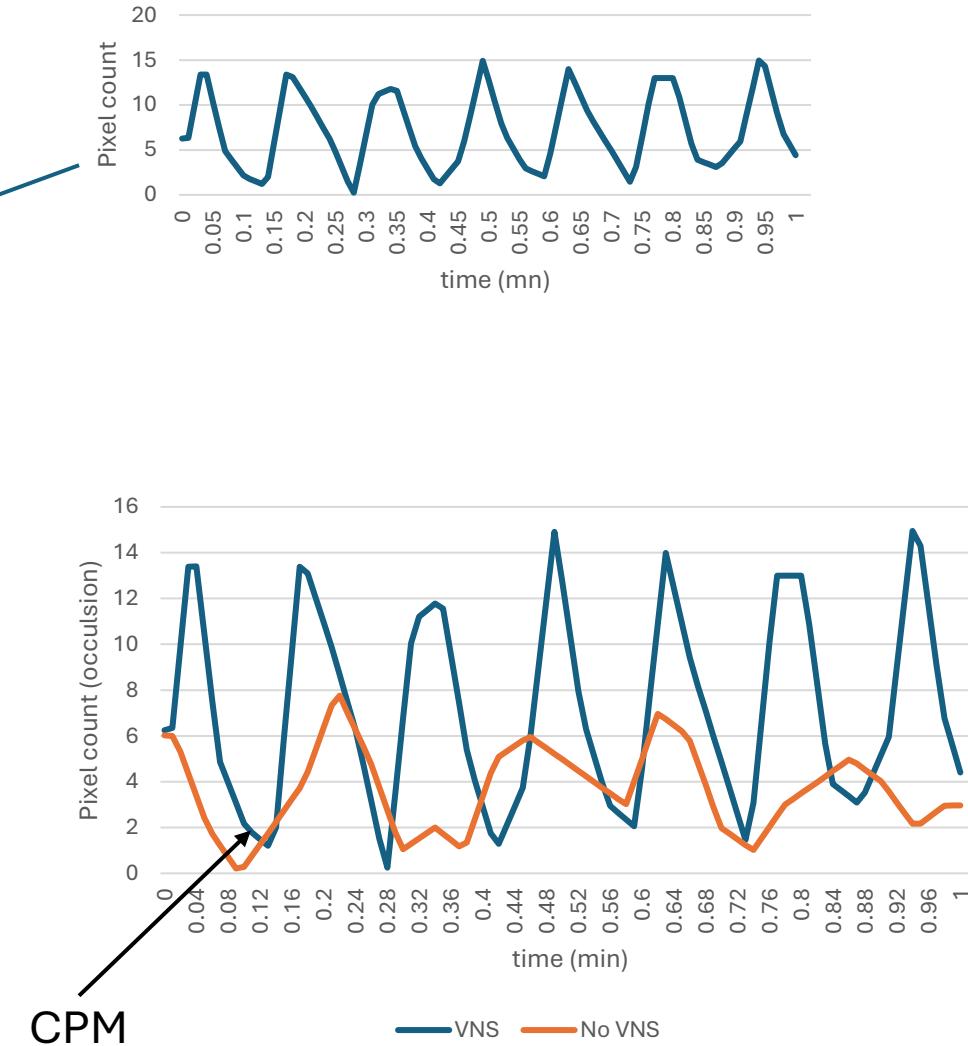
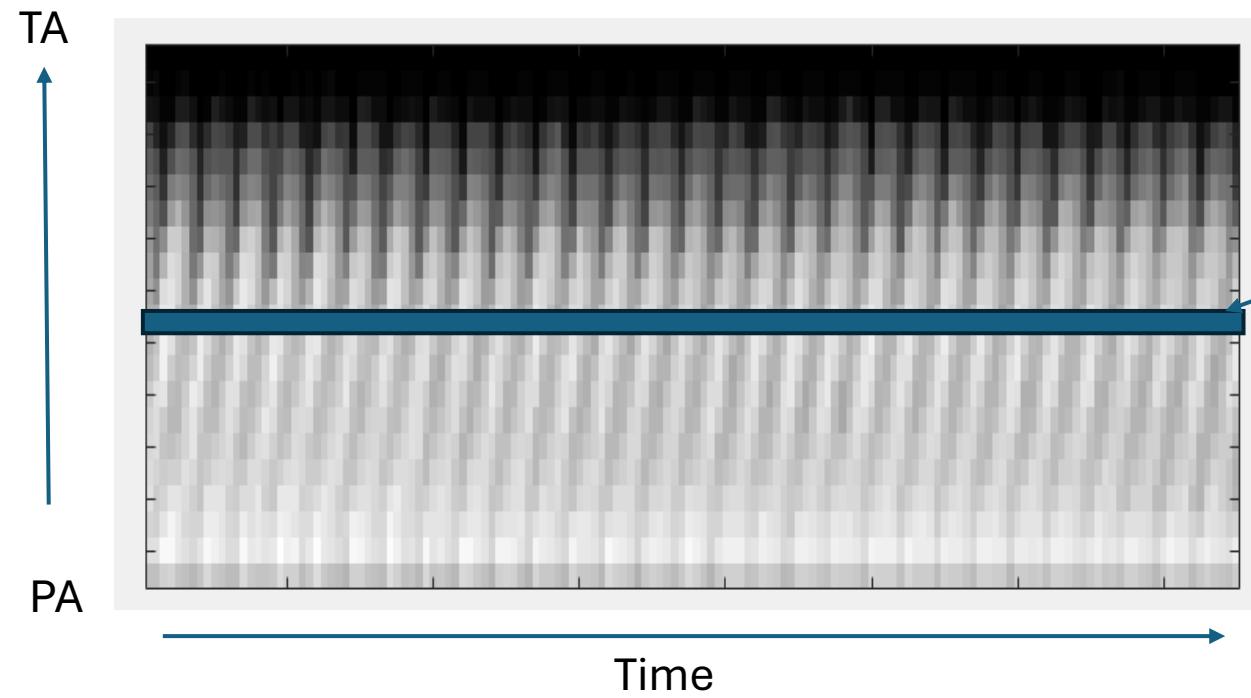
Otsu thresholding

MRI Analysis-Spatial-temporal image

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

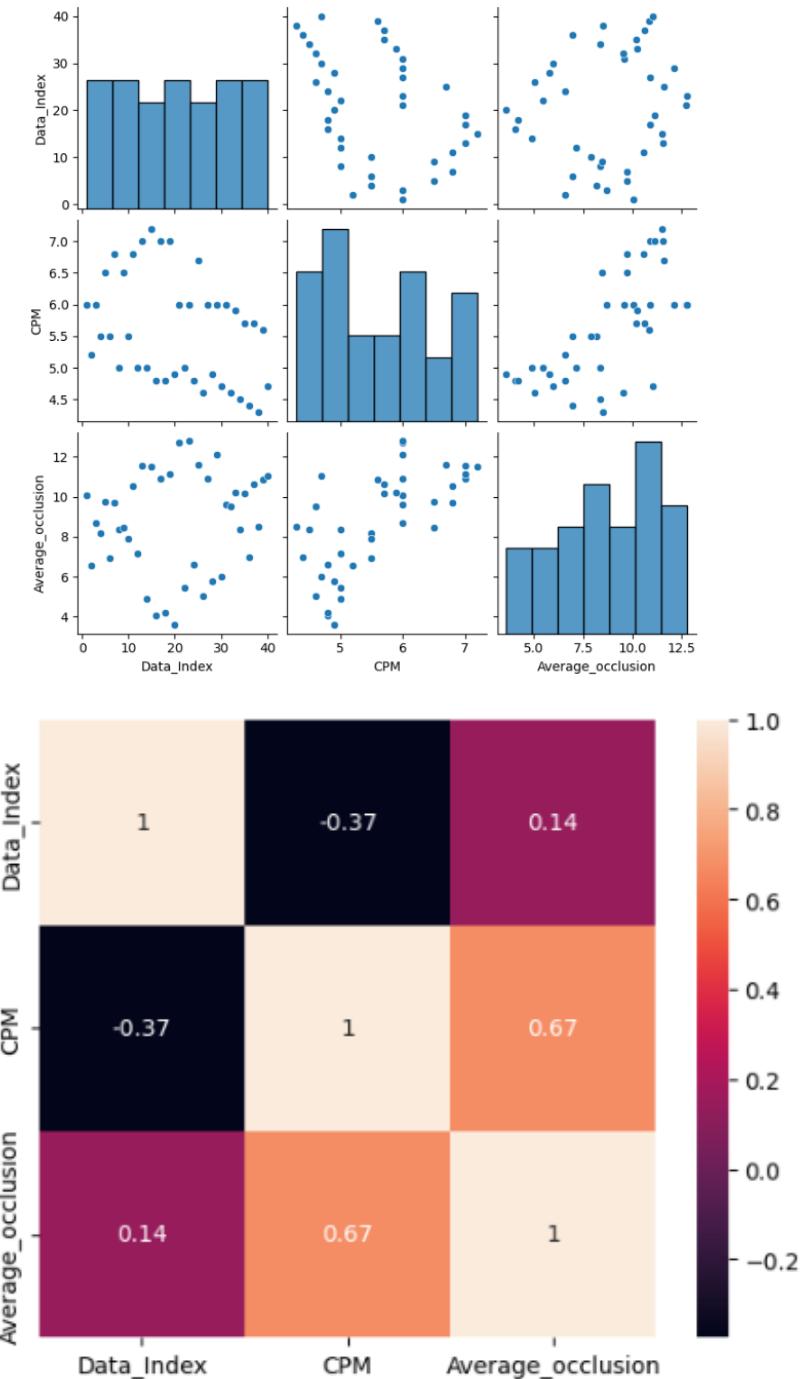


MRI Analysis-Spatial-temporal image



Data set

Data_Index	CPM	Average_occlusion	Stimulation
1	6	10.07480178	VNS
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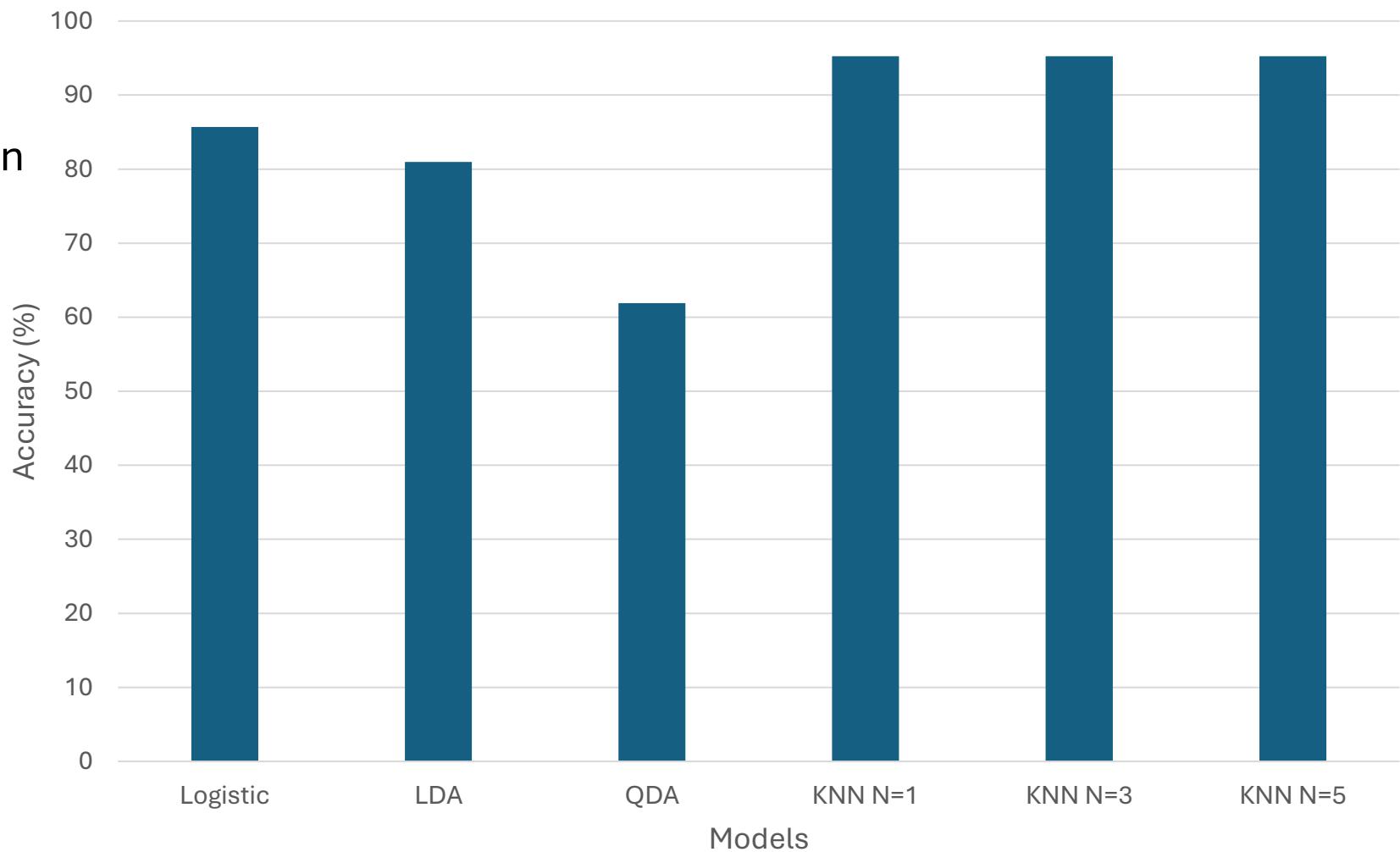


Analysis-1

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

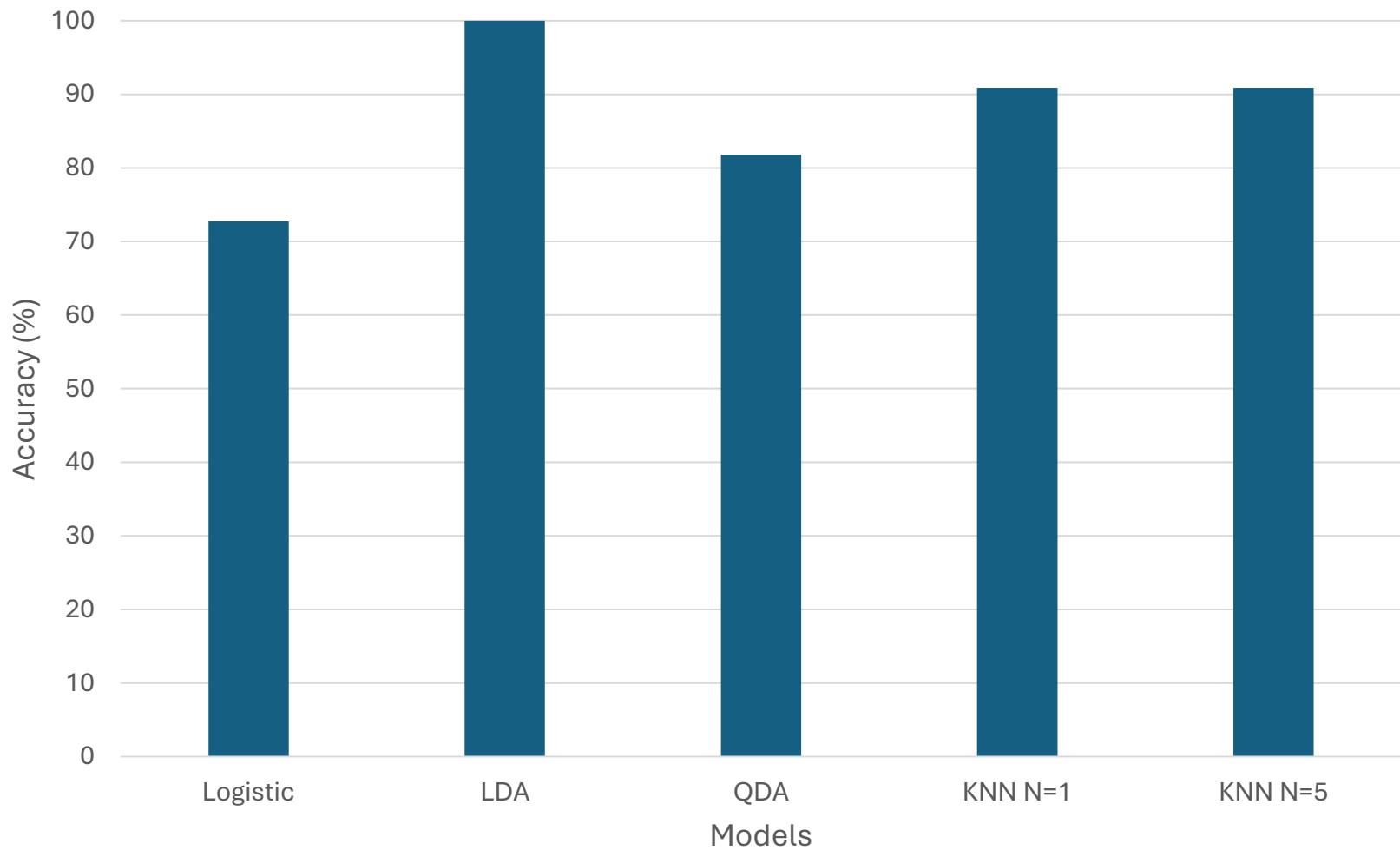
Predictors : CPM, Average_occlusion

Training: [1-29]

Test: [30-40]

Best result: LDA 100 %

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



Analysis-3

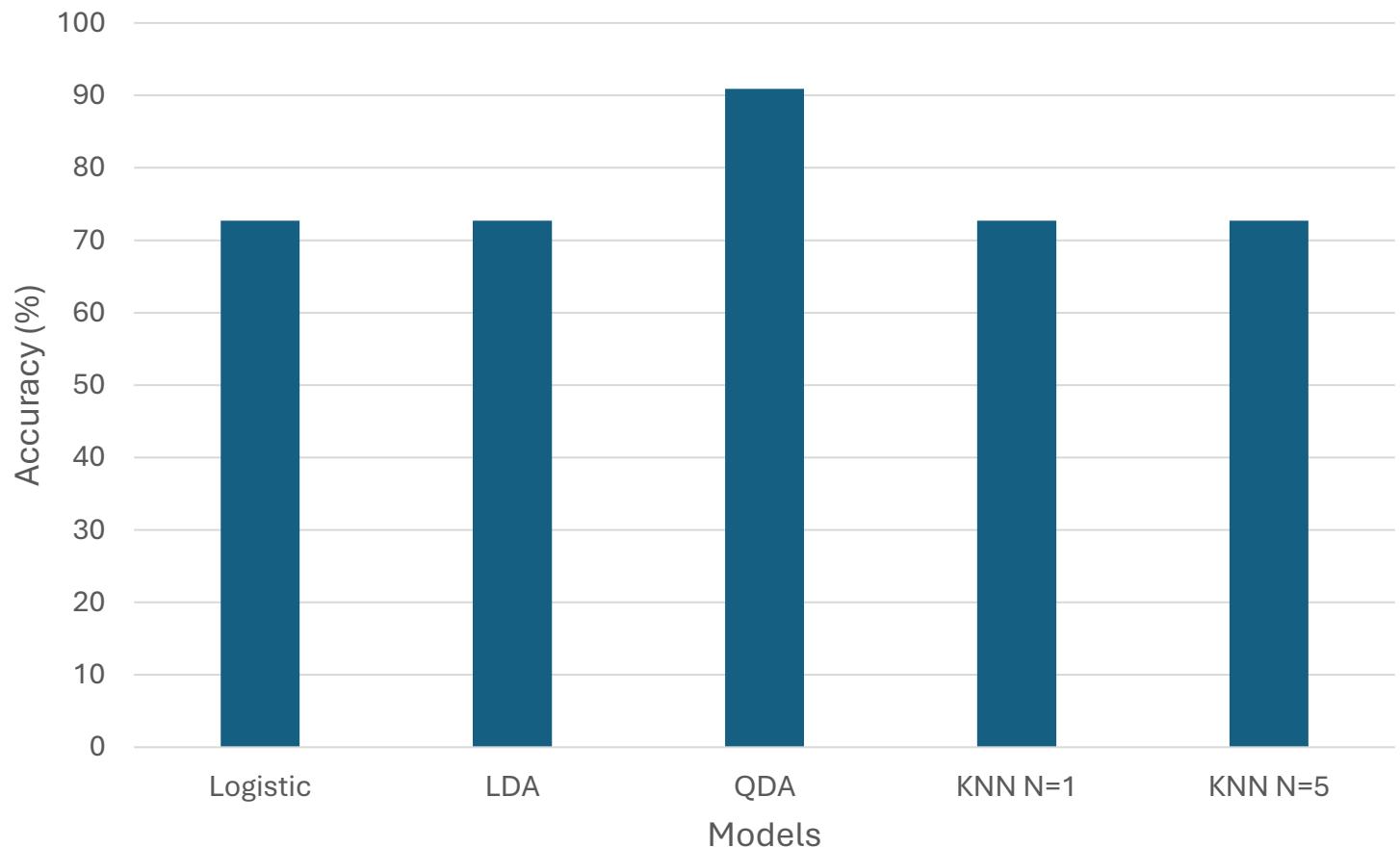
Predictors : CPM

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

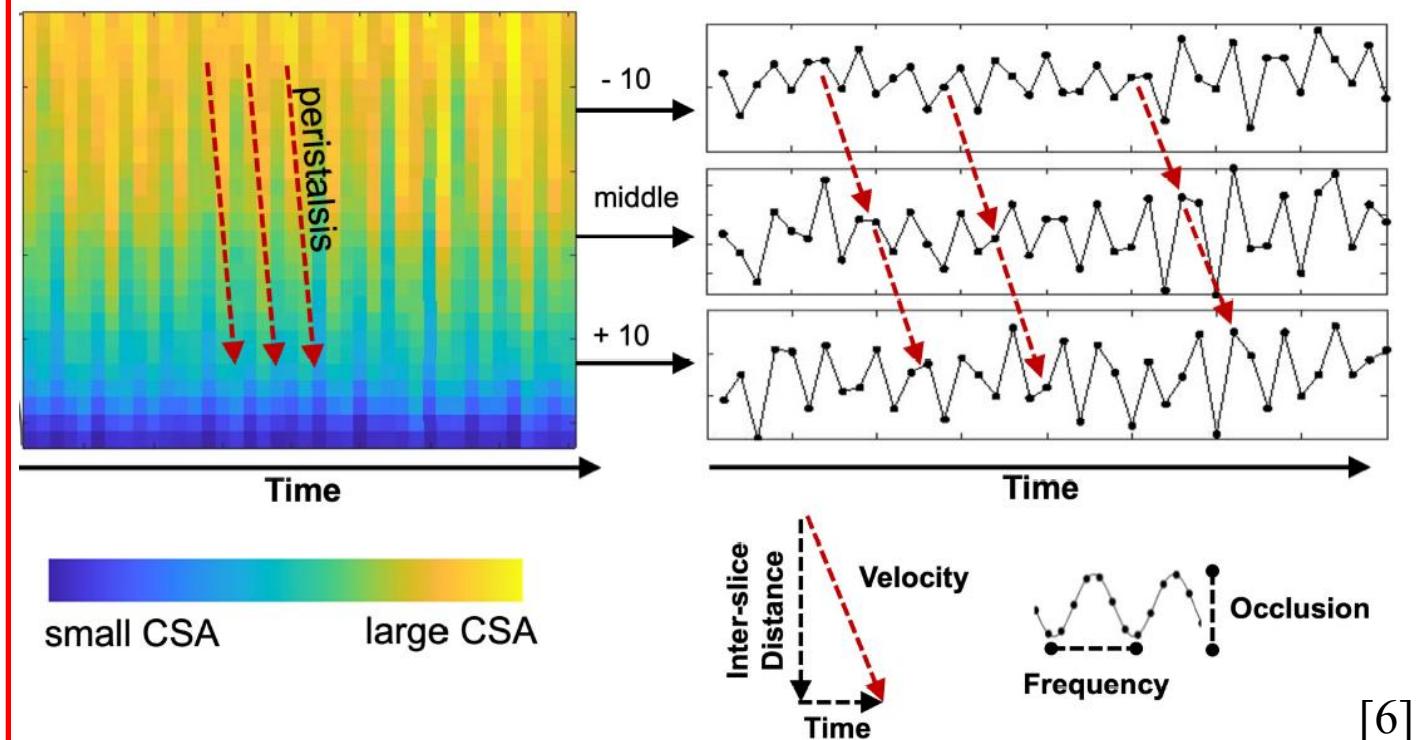
$$M = f(X_1, X_2, X_3, X_4)$$

Dataset: CPM
Dataset: Average_occlusion

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

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

Future work: For X3



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