

A study on estimating the eyeball volume using a truncated cone template based on CT images

원뿔대 템플릿을 활용한 CT 이미지 기반의 안구 부피 추정 연구

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25th May, 2023



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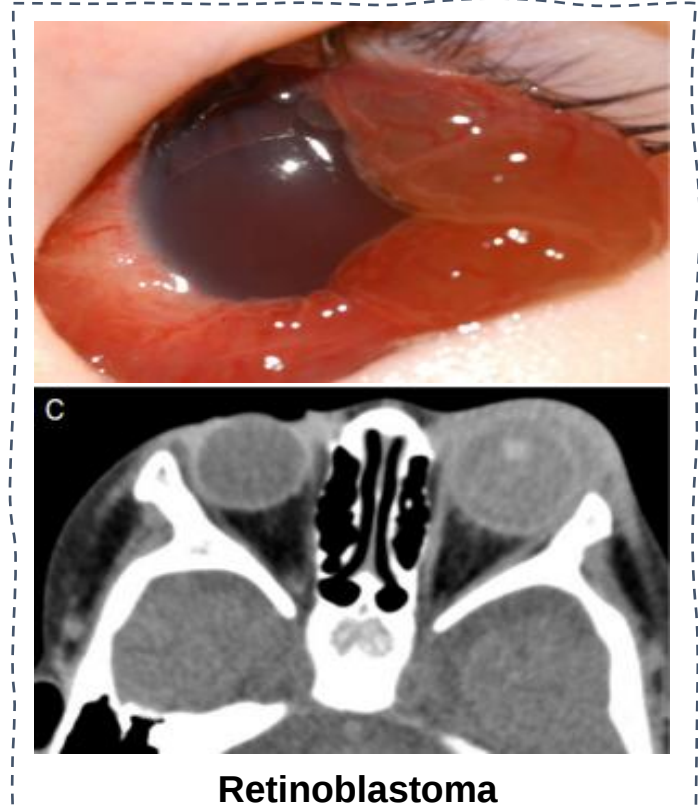
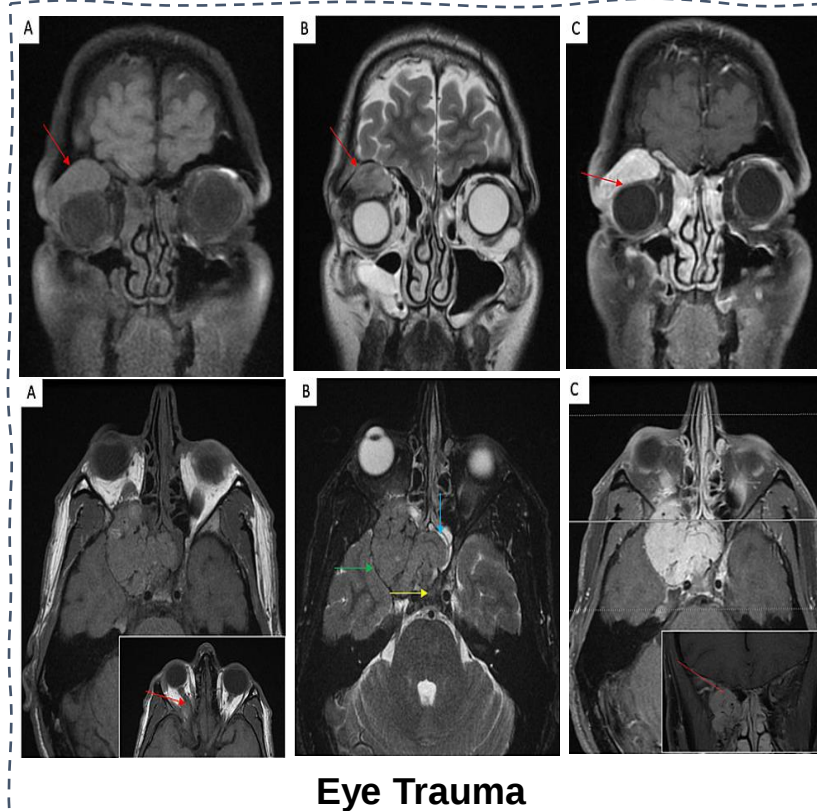
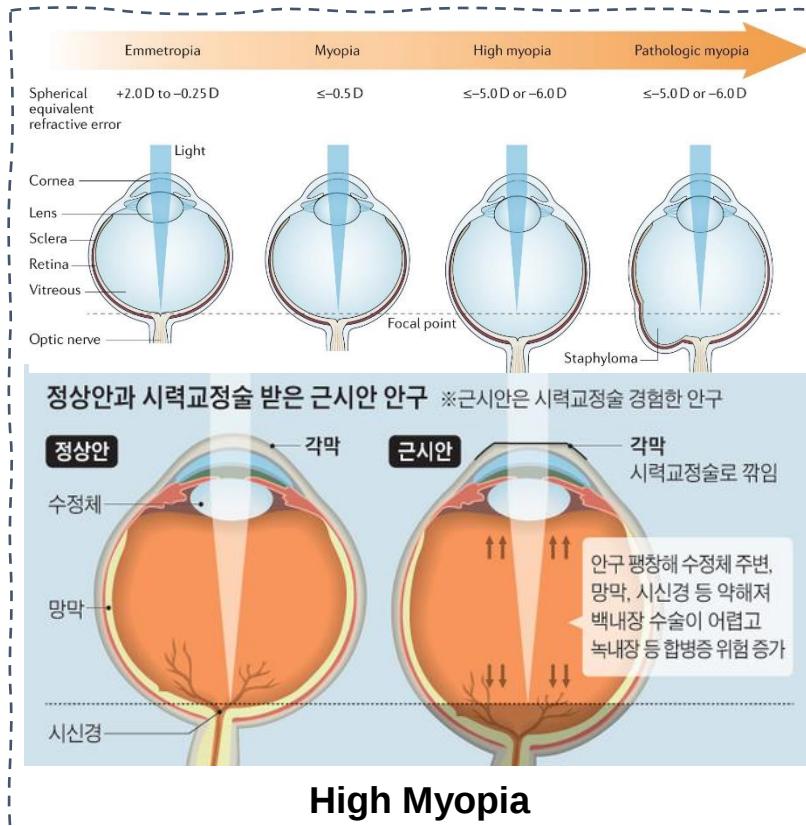
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Introduction

✓ **Eyeball volume estimation provides important information for diagnosis degree of ocular diseases.**

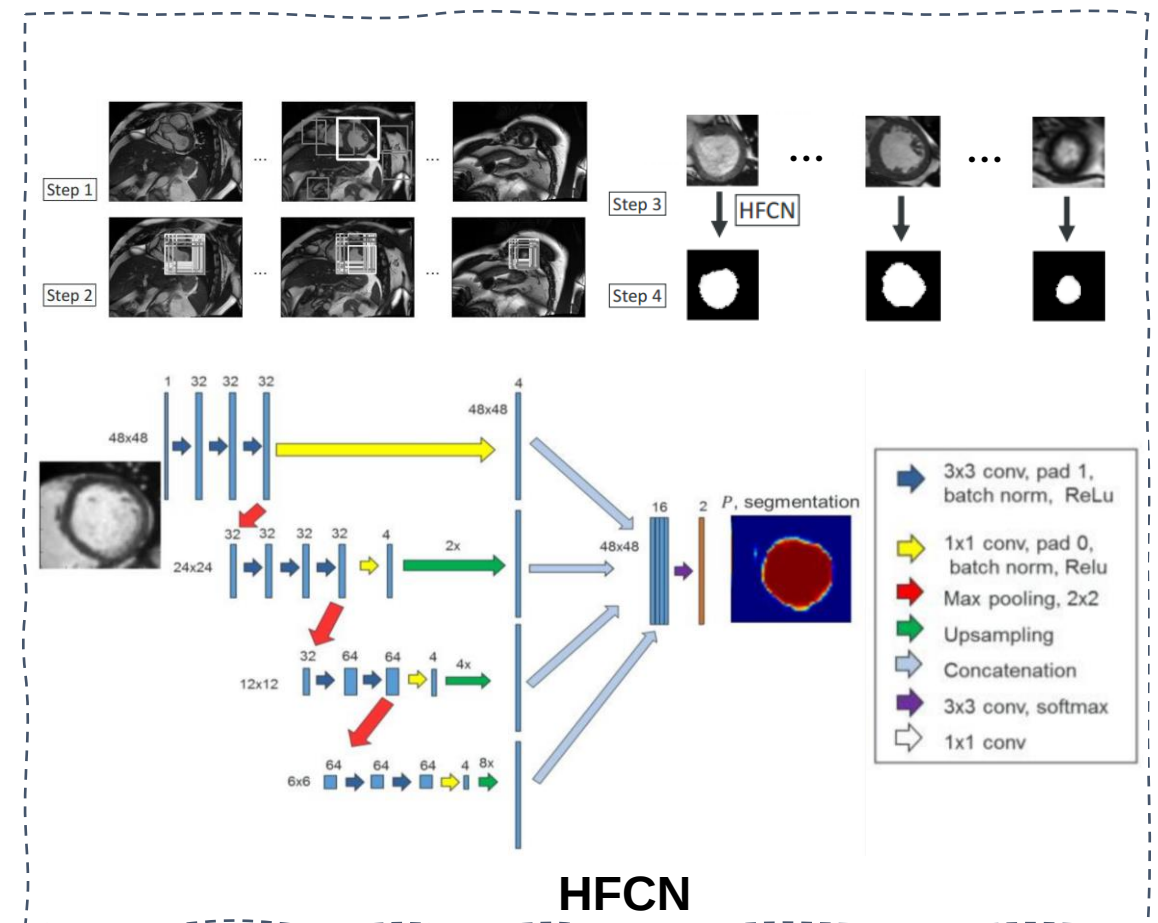
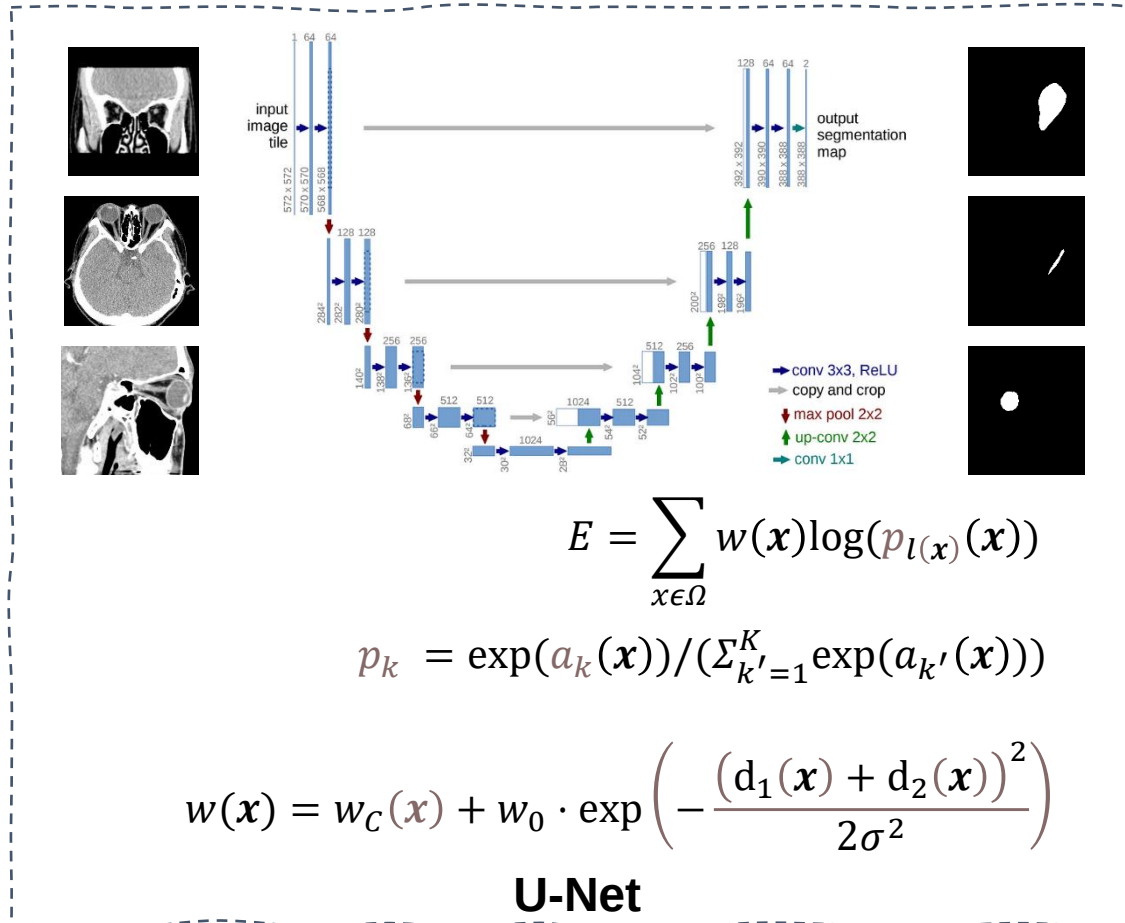
- High Myopia, in which there is a very high risk of ocular complications, is related to eye size.
- In case of eye trauma, fast and accurate eyeball volume estimation can provide clinicians with valuable diagnostic information.
- Eyeball volume estimation can help medical staff in the early diagnosis of retinoblastoma.



Related Work

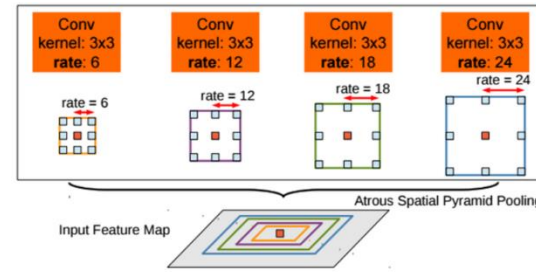
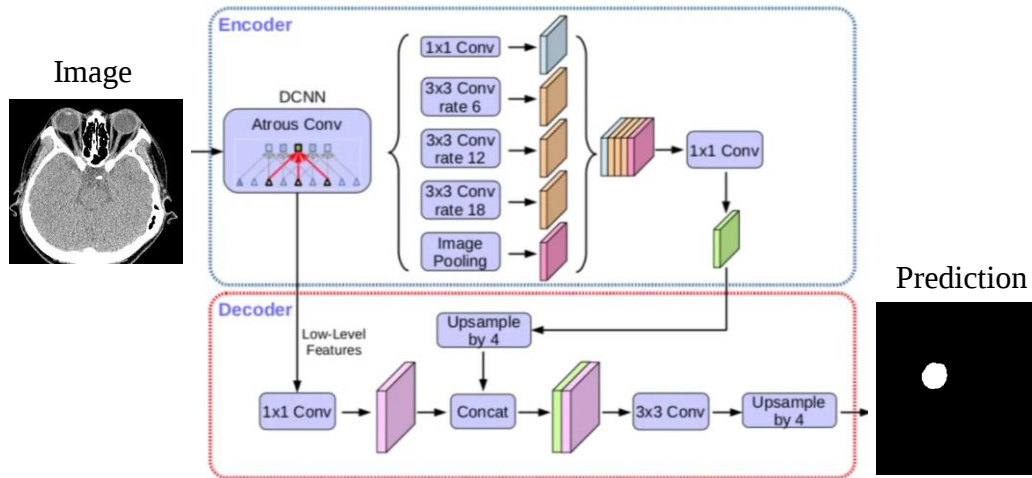
✓ Image Segmentation Model

- Image segmentation is the task of finding objects and object boundaries at the pixel level in an image.
- The five image segmentation models have an encoder-decoder structure for conveying semantic information.



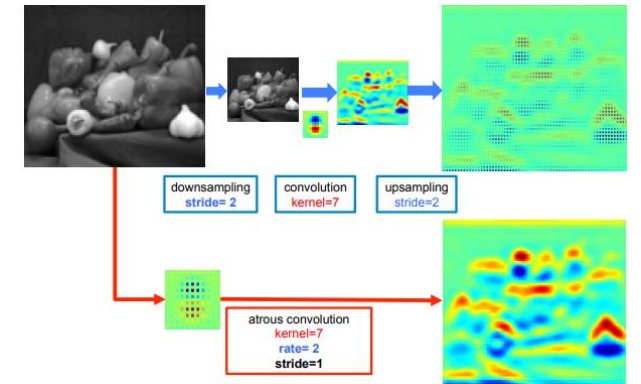
Related Work

✓ Image Segmentation Model

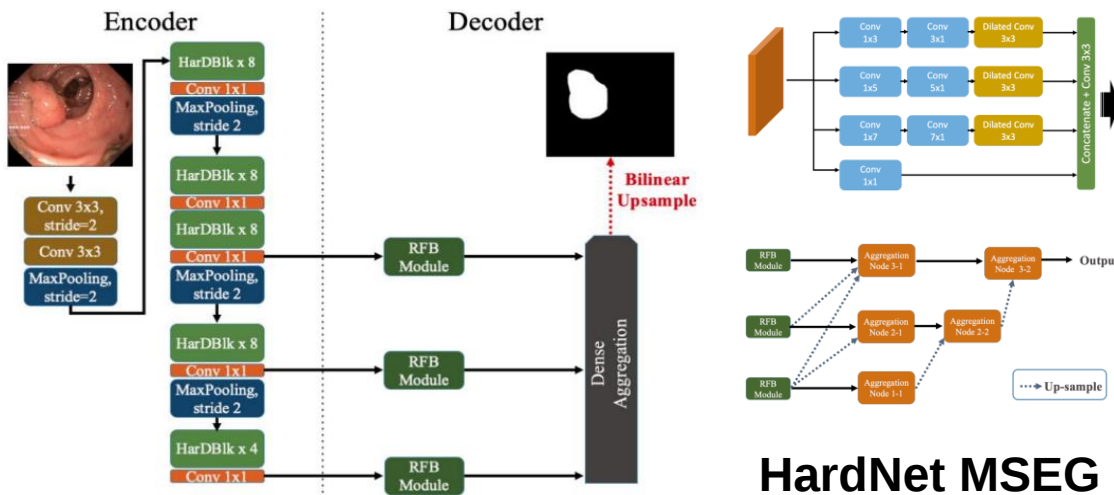


$$y[i] = \sum x[i + r \cdot k]w[k]$$

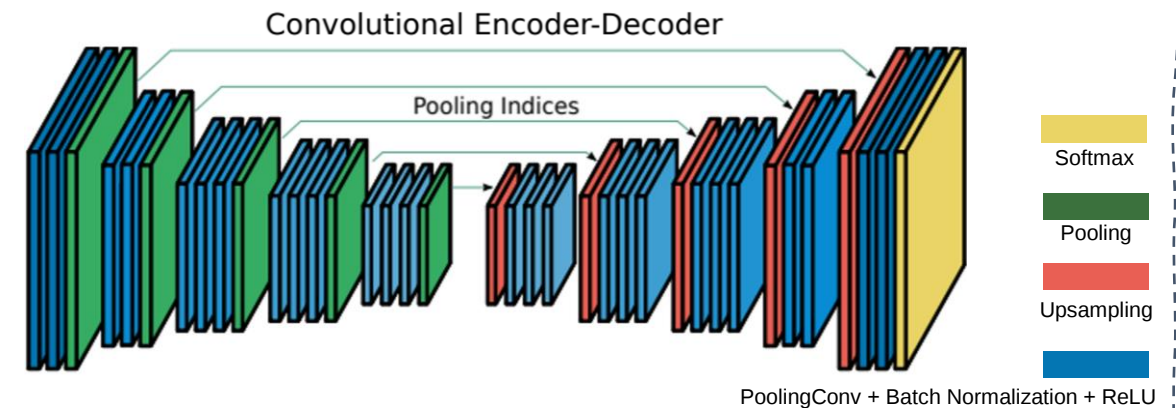
$r > 1$: atrous convolution,
 $r = 1$: standard convolution



DeepLab V3+



HardNet MSEG

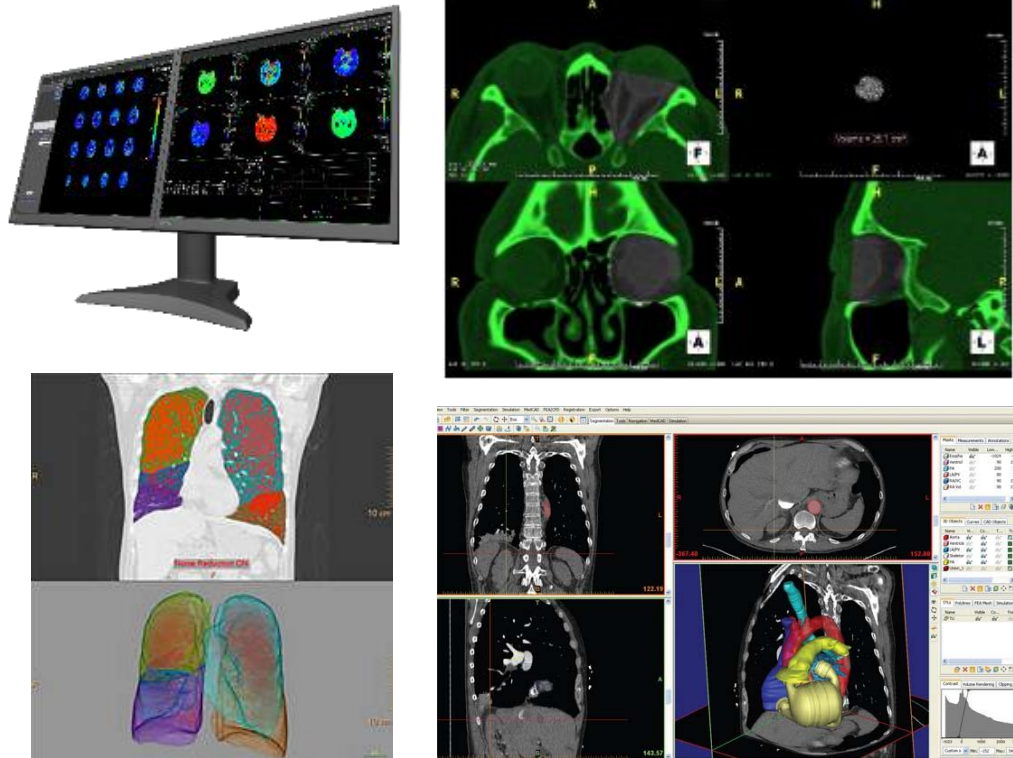


SegNet

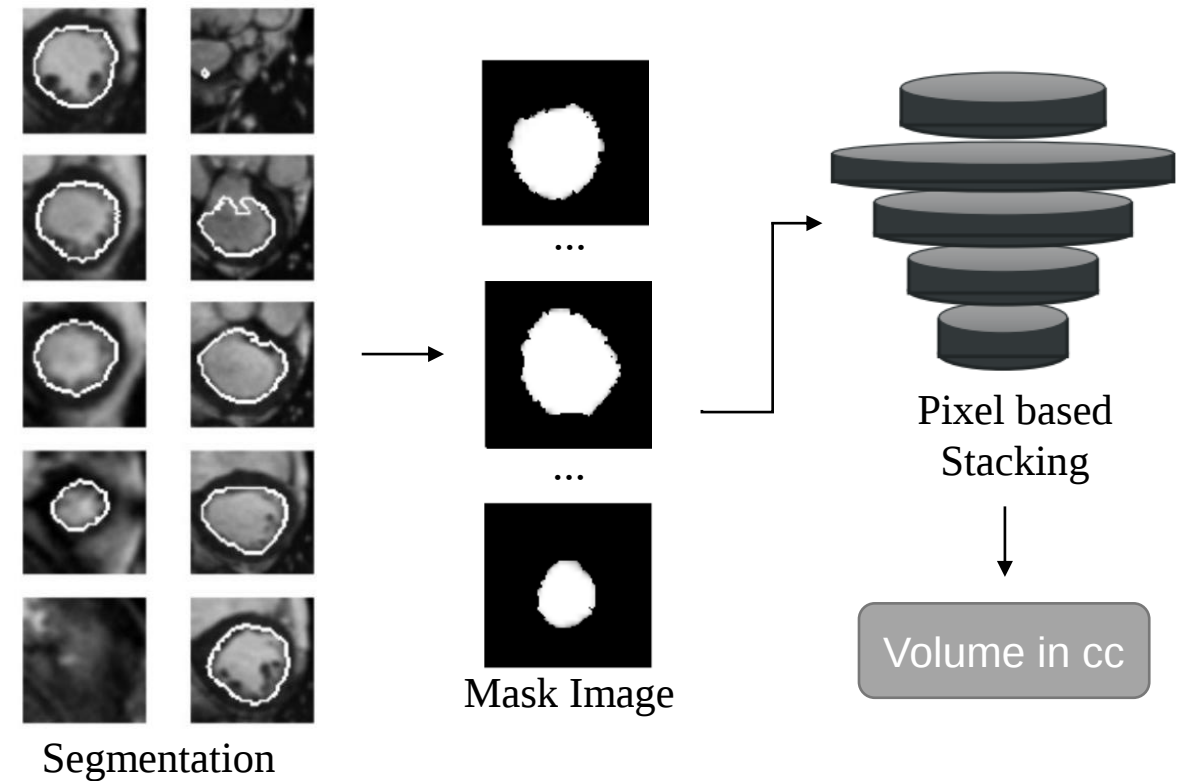
Related Work

✓ Typical Volume Estimation Method

- Measurement of the eyeball volume is performed using special medical software. ➔ Limitations in time and cost
- Research on the eyeball volume estimation through deep learning-based medical image processing is attracting attention.



Specialized Medical Software



Pixel based Volume Estimation

Experimental Settings : Segmentation Model

✓ Dataset

- Number of samples: 1,237 subjects
- Input: 15,818 images of 512 × 512 size

✓ Cross validation

- 10 iteration
- Data split: (Train : Validation : Test) = (0.6 : 0.2 : 0.2)

✓ Hyperparameters

Model	Batch Size	Epochs	Loss Function	Optimizer	LR	Weight Decay
UNet, Deeplab V3+, SegNet, HarDNet-MSEG, HFCN	16	50	Focal Loss	AdamW	1e-3	1e-4

✓ Evaluation measures

$$Dice = \frac{2 * |A \cap B|}{|A + B|} = \frac{2 * TP}{(TP + FP) + (TP + FN)}$$

$$IoU = \frac{Area\ of\ Overlap}{Area\ of\ Union} = \frac{A \cap B}{A \cup B}$$

Experimental Settings : Volume Estimation

✓ Datasets

- Eyeball segmented CT images from 200 patients
- Consists of slices for each patient
- Input Data : CT Image

✓ Performance measure

- Correlation Coefficient (r)
- Mean Absolute Error (MAE)
- Mean Squared Error (MSE)

< Demographic Data >

Age (years, range)	Sex		Total (n, %)
	Male (n, %)	Female(n, %)	
29 and under	27 (13.5)	42 (21)	69 (34.5)
30-39	17 (8.5)	52 (26)	69 (34.5)
40-49	13 (6.5)	25 (12.5)	38 (19)
50-59	5 (2.5)	13 (6.5)	18 (9)
60 and over	3 (1.5)	3 (1.5)	6 (3)
Total	65 (32.5)	135 (67.5)	200 (100)

$$Corr = \frac{\sum (x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum (x_i - \bar{x})^2 * \sum (y_i - \bar{y})^2}}$$

$$MAE = \frac{1}{n} \sum_{i=1}^n |x_i - x|$$

$$MSE = \frac{1}{n} \sum_{i=1}^n (\hat{Y}_i - Y_i)^2$$

Experimental Results of Conventional Methods

- ✓ All segmentation models showed good performance, and among them, U-Net showed relatively good performance.
- ✓ The performance of volume estimation yielded a correlation coefficient of less than 0.8 between the ground truth value and the predicted value.

< Segmentation Model Experimental Results >

MODEL	mIoU	mDice
UNet	0.912	0.952
HFCN	0.909	0.94
Deeplab V3+	0.911	0.951
SegNet	0.906	0.947
HardNet_MSEG	0.906	0.948

< Volume Estimation Experimental Results >

	Corr	MAE	MSE
Fangzhou et al.(2019)	0.769	0.684	0.710
Pixel Count	0.763	0.693	0.729

Common Drawback of Conventional Methods

✓ Conventional Methods

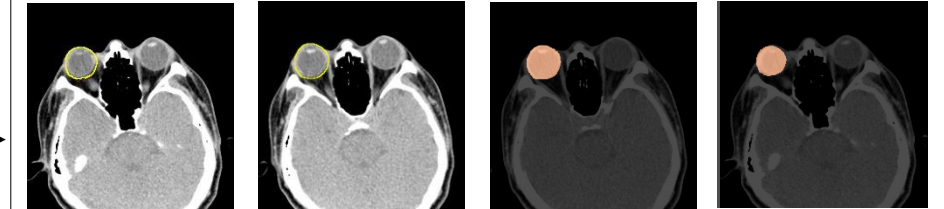
- Few studies related to eyeball volume estimation have been done on estimating eye volume.
- Estimation of eye volume is important, but there is no template that reflects the information of the actual eye shape.
- Pixel-based volume estimation method ➡ Heavily influenced by segmentation images.



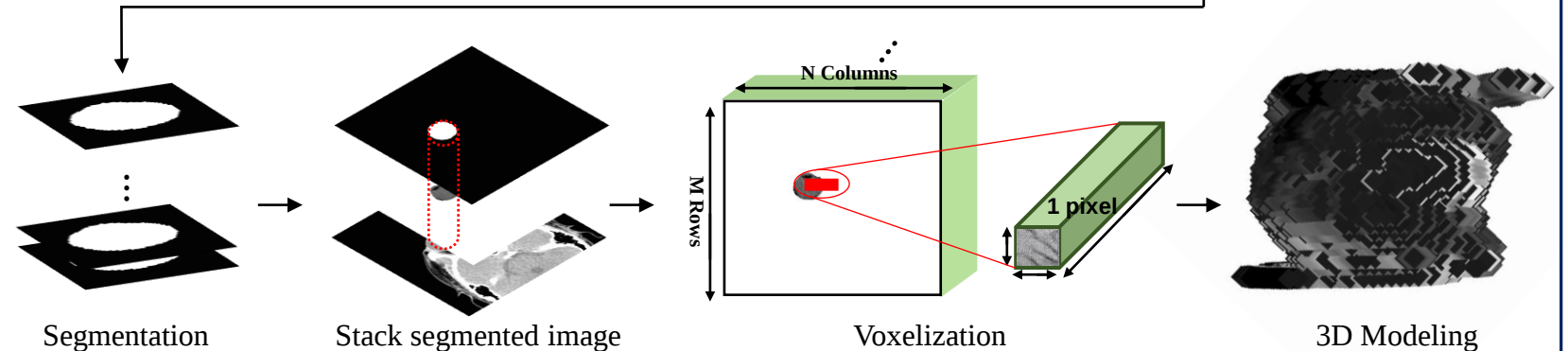
Real Eye eyeball
- Round Shape

Conventional Methods

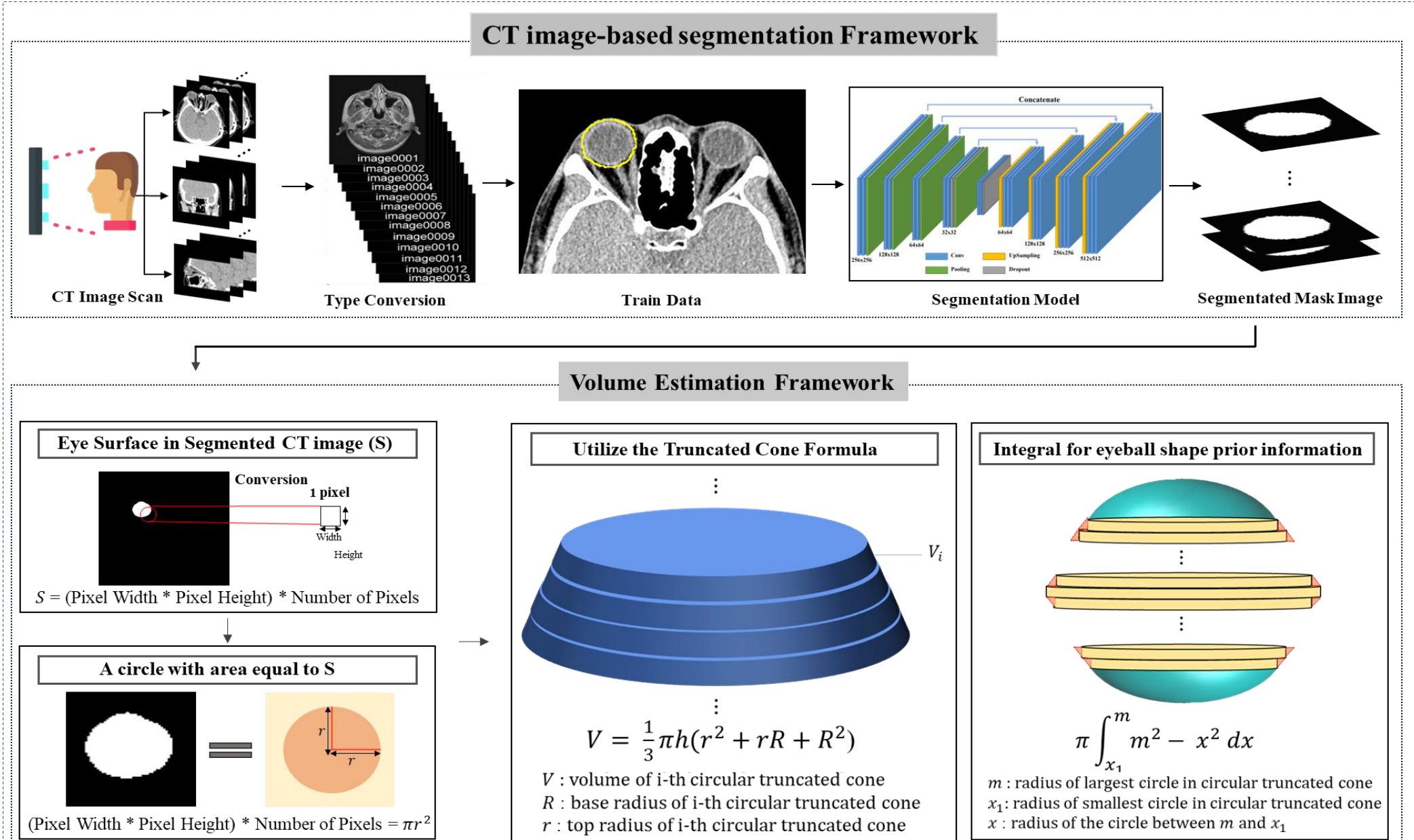
Segmentation Performance		
MODEL	mIoU	mDice
UNet	0.912	0.952



Example of a segmentation model



Proposed Method - Overview

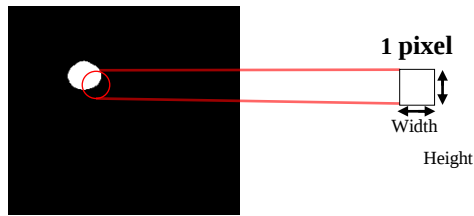


Proposed Method

✓ Estimation of volume using information about the actual shape of the eyeball

- The truncated cone is a simple and intuitive shape, it is widely used in volume estimation.
- In particular, it is possible to reduce errors that arise from a volume estimation approach based on pixel counting.

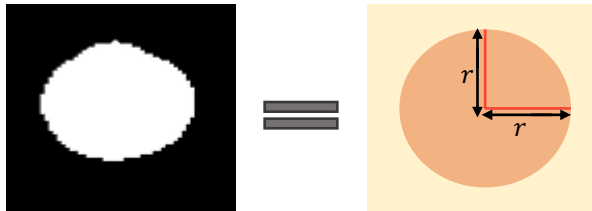
Eye Surface in segmented CT image (S)



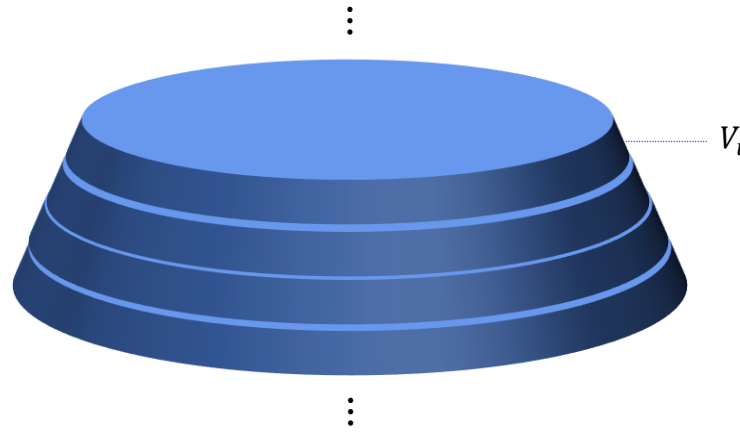
$$S = (\text{Pixel Width} * \text{Pixel Height}) * \text{Number of Pixels}$$



A circle with area equal to S

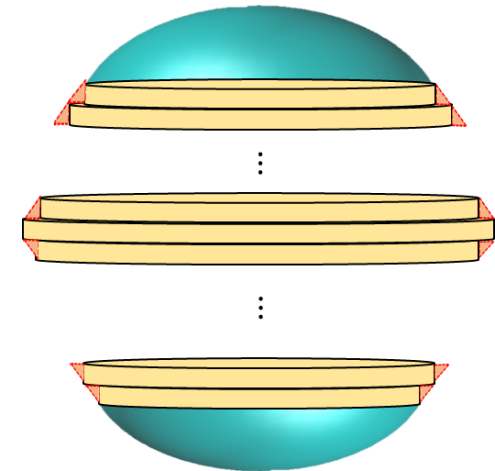


$$(\text{Pixel Width} * \text{Pixel Height}) * \text{Number of Pixels} = \pi r^2$$



$$V = \frac{1}{3} \pi h (r^2 + rR + R^2)$$

V : volume of i-th circular truncated cone
 R : base radius of i-th circular truncated cone
 r : top radius of i-th circular truncated cone



$$\pi \int_{x_1}^m m^2 - x^2 dx$$

m : radius of largest circle in circular truncated cone
 x_1 : radius of smallest circle in circular truncated cone
 x : radius of the circle between m and x_1

Overall Experimental Results

Result – MAE, MSE, Correlation

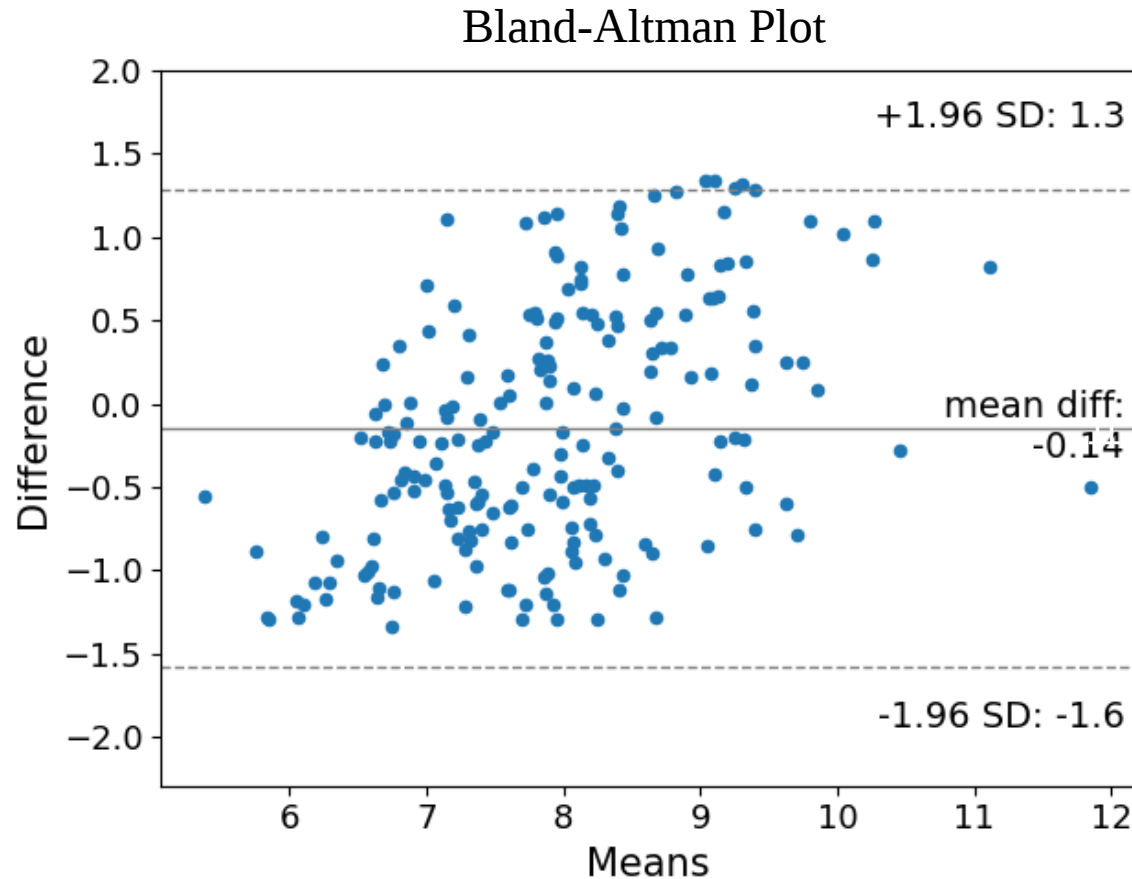
- ✓ The proposed model is statistically superior to the two comparison models in three indicators.

Pixel Count: Volume estimation method through counting pixels of segmented image
Fangzhou et al. (2019): Conventional Method (Left ventricle Volume Estimation Method)
Proposed method

< Volume Estimation Experimental Results >			
	Corr	MAE	MSE
Proposed method	0.819	0.640	0.554
Fangzhou et al.(2019)	0.769	0.684	0.710
Pixel Count	0.763	0.693	0.729

Overall Experimental Results

Proposed method Bland - Altman Plot



- Crosses the boundary of some upper/lower values.
- Totally within the range of upper and lower limit values.
- Evaluation Index : Limit of agreement(LOA)
- Mean diff : - 0.14
- Upper LOA : $-0.14 + 1.96 * (1.3)$
- Lower LOA : $-0.14 + 1.96 * (-1.6)$

- Limit of agreement(LOA) : The mean difference is shown by the solid black line, the limits of agreement by the dashed lines.

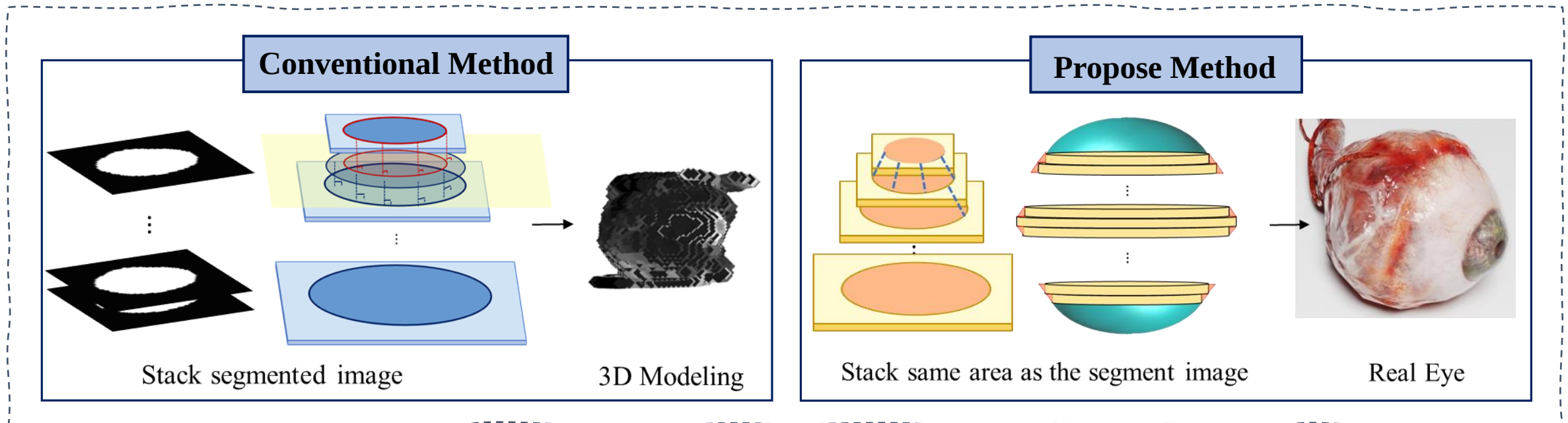
In-Depth Analysis

✓ Conventional Method

- : Calculate the volume of a structure depending on pixel information such as pixel size, area, and number
- : Stacking the segmented images in the conventional method does not capture the shape of actual eyeball

✓ Propose Method

- : Uses the truncated cone formula to make the most of information about the segmented images
- : Performance improvement through a template that reflects the actual shape of the eyeball



Conclusion and Contribution

✓ Conclusion

- In this thesis, the proposed model established a formula that reflected prior information on the shape of the actual eyeball, and through this, the accuracy of eyeball volume estimation was improved.
- The proposed model performed better than one volume estimation model and pixel count of segmented images for data obtained from 200 subjects.

✓ Contribution

- Comparison of Semantic Segmentation Models for Medial Rectus Muscle in Computed Tomography Images, ICEIC, 2023
- Interpretable Medical Diagnostic Pipeline using Multi-head Design, 2nd, IEIE, 2022
- Arrange CJ AI Center Meeting, Seoul, Korea, March 6, 2023
- S/W Registration 3 cases (1st : 1 case, Co. : 2 cases)

Reference

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Thank you