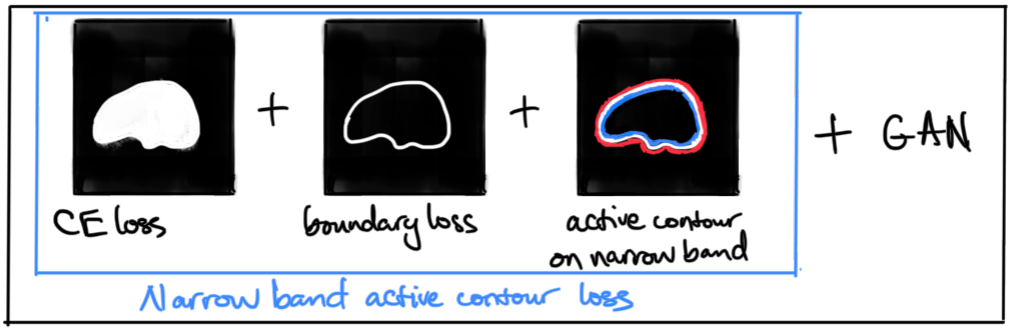
Self-supervised dilated nested unet with attention mechanism for brain tumor

I. Problem statement

Current major problems in 3D MRI images segmentation:

+ less annotation (3)→ transfer learning by GAN
+ imbalanced data (2)→ focus on the narrowband around the contour under level set energy minimization
+ weak boundary (1)→ attention gate on the edge

⇒ altogether, we will have:



II Explanation

Why???

- imbalanced data:

  significantly larger / higher occurence frequency instances

  ⇝ more likely to have higher impact on the objective function comparing to relatively smaller / less occurent labels

  ⇒ lessen this impact by calculating the thick-sized boundary loss as additional weights for pixels on the boundary

  note: CE treats all pixels equally

- active contour on narrow band

the intra-class variance based energy (also with the score reflecting the smoothness and density of the considered curve)

active contour here will try to minimize this energy, in other words, it aims to

- minimize the intra-class variance

→ intensities within will be more likely to be more separable from those outside

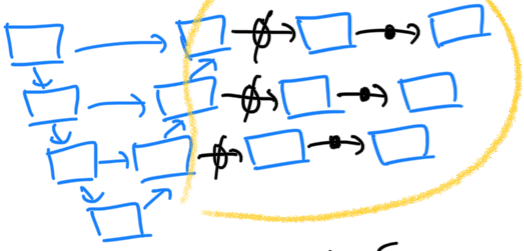
⇝ drag the boundary to the high intensity gradient region

(more likely to be the boundary of the considered object)

- smoothess and density

keep the "elasticity" & "rigidity" of the curve

detachable at inference time



⊘ extract contour

⊙ get narrow band energy

⇝ pls check for my note about classic snake, active contour, level set, narrow band and deep snake for more details

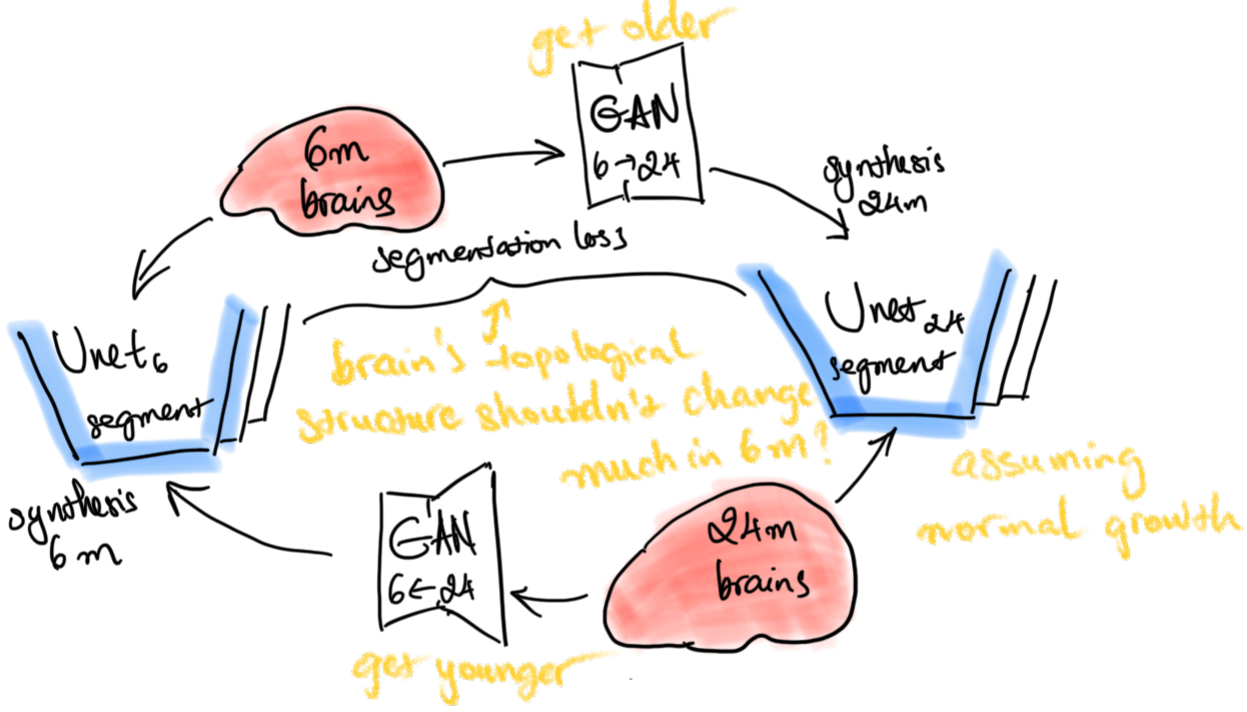
the narrow band is to keep the considered inside/outside regions from the noises. note that MRI images have pretty low intensity constrast between different regions (the cause of weak boundary)

⇝ multiple researches have also shown that active contour can also be using to deal with the weak boundary problem.

. GAN. How GAN is used here ???

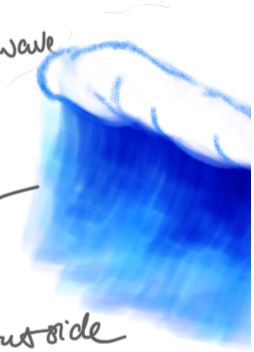
In the considered task, we are trying to segment the different regions of 6-month infant brains, where the intensity contrast is remarkably low due to the isointense phase and most important one ~ less annotation whereas the dataset of 24-month old "adult" is pretty "plenty" comparing to our target 6-month domain

⇝ assuming that the topological structure of human brains do not change much between the age of 6 and 24-month old.



III Snake and its relatives ^^

1. The classic snake



_physic objects with non-stop moving boundary? How to formulate this movement?

These objects actually have different forces apply on them. e.g fire ~ combustion causing distinct atmosphere pressure for the air inside and outside the fire due to the mass loss rate and flame temperature
~> there exist inner and outter forces dragging each point on the boundary of the object move toward the "temporarily" equilibrium (at each time t)

So supposed that the boundary of an object can be denoted by

$$\underbrace{C}_{\text{arc}}(\underbrace{s}_{\text{length } s}) = C(x(s), y(s))$$

the energy dragging this arc will be

$$E = \int E_{in} + E_{out}$$

where $E_{in} = \underbrace{\alpha |C'(s)|^2}_{\text{smoothness}} + \underbrace{\beta |C''(s)|^2}_{\text{density}}$

(E_{in}: control shape; α: elasticity; β: rigidity)

$$E_{out} = w_{line} E_{line} + w_{edge} E_{edge} + w_{term} E_{term}$$

(E_{out}: depends on the image intensity $I(x,y)$)

$$E_{out} = w_{line} E_{line} + w_{edge} E_{edge} + w_{term} E_{term}$$

- E_{line}: depends on the image intensity $I(x,y)$
- w_{line}: sign → guide the contour toward the lighter or darker region
- $E_{edge} = -|\nabla I(x,y)|^2$: attract to higher intensity gradient region
- E_{term}: termination of the curve segment → define using the curvature of the line

$$E_{term} = \frac{|\phi_x^2 \phi_{yy} - 2\phi_x \phi_y \phi_{xy} + \phi_y^2 \phi_{xx}|^2}{|\nabla \phi|^3}$$

~ to be continue ~

- snake
  - level set
    - chanvese
    - gca
  - active contour
    - regional
    - boundary
  - deep snake

implementation in computer

and proved Euler Larange equation