Medical Image Analysis

2. Medical image classification(1)

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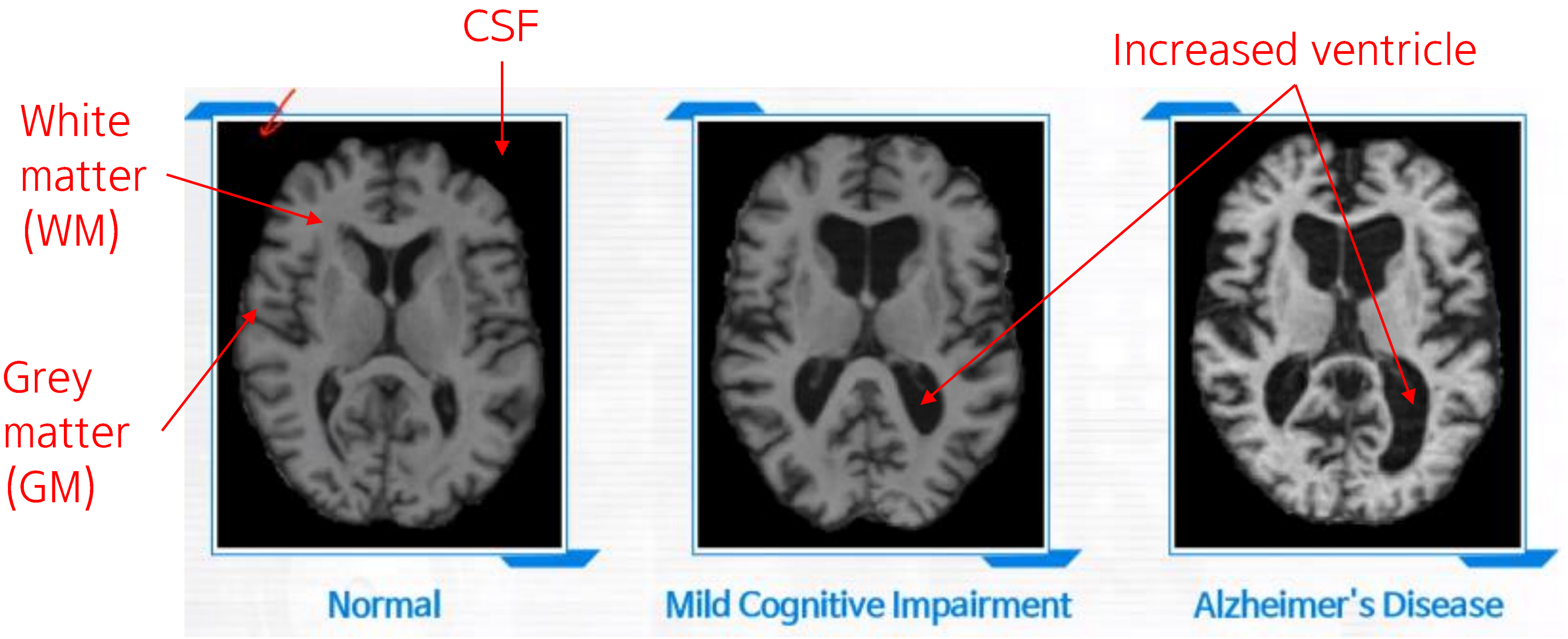
https://www.edwith.org/medical-20200327/joinLectures/30437

1. Introduction to medical image classification

- 의료 영상 분류
- 공부할 기법들
- Logistic regression, Neural network 의료영상에의 활용 방법
- Demographic score
  - 환자 정보들을 의료영상 분류에 효과적으로 이용할 수 있는 방법

1. Introduction to medical image classification

Medical image classification



WM/GM/CSF 등이 잘 안 보이는 경우가 있음

Large (3D) image

나이만 줄어도 GM이 줄거나 Ventricle이 커지거나 하는게 있음

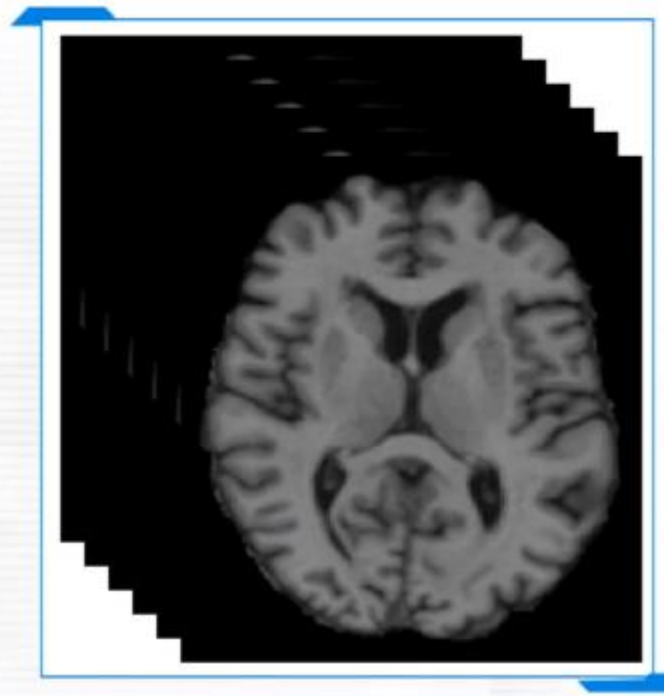
Alzheimer’s disease는 조기 진단이 중요함

보수적인 Screening. Normal을 AD라고 하는 건 괜찮지만, AD를 normal로 구분하면 안 됨

1. Introduction to medical image classification

Medical image classification

Subject	Age	Gender
Normal	40	M
Normal	50	F
Normal	60	M
Normal	70	M
AD	70	F
AD	90	F
AD	80	F
AD	50	M

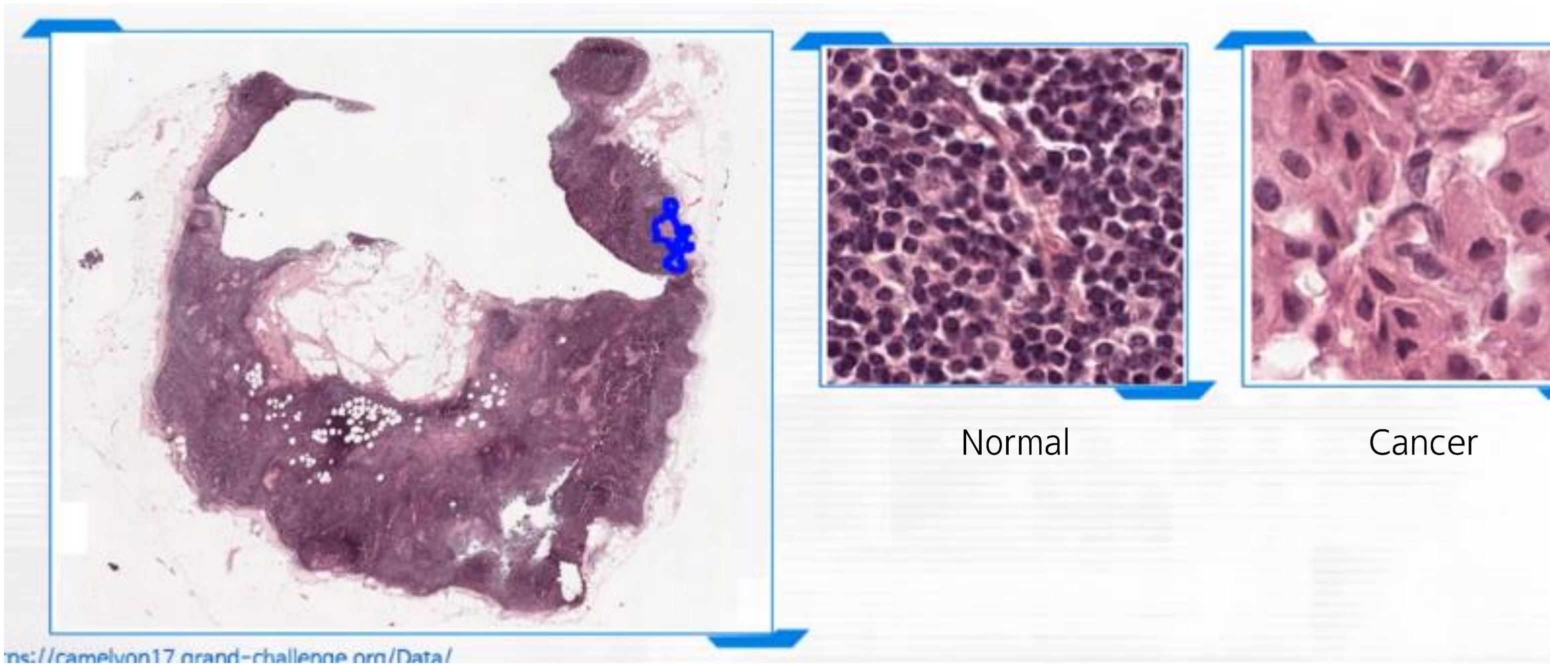


환자의 정보 (Demographic score)와 영상을 함께 사용하여 Classification이 필요함.

1. Introduction to medical image classification

Pathology image classification

Low magnification High magnification



High magnification으로 가서 하나하나 확인을 해야 하는데, manually하면 시간이 상당히 오래 걸림. → 이를 자동화하는데 AI 활용

1. Introduction to medical image classification

Medical image classification

- Limited data
  - 환자 개인 정보라 보안이 철저함
  - 병원끼리 교류가 적음
  - 대규모로 모으기가 힘듦 → ADNI/TCGA 등 사이트에서 모아 진행함
- Large image size
  - 3D
  - High resolution pathology image
  - 문제 있는 부분의 비율이 매우 적음
- Small changes
  - 변화량이 적음
- Demographic scores
  - 영상 자체로만 판단하기에는 힘듦. Demographic score가 필요함

http://adni.loni.usc.edu/data-samples

https://www.cancer.gov/about-nci/organization/ccg/research/structural-genomics/tcga

1. Introduction to medical image classification

Medical image classification

	Conventional methods	Deep learning methods
Classification	Logistic regression Neural network Support vector machine Random forest	Deep neural network Convolutional neural network

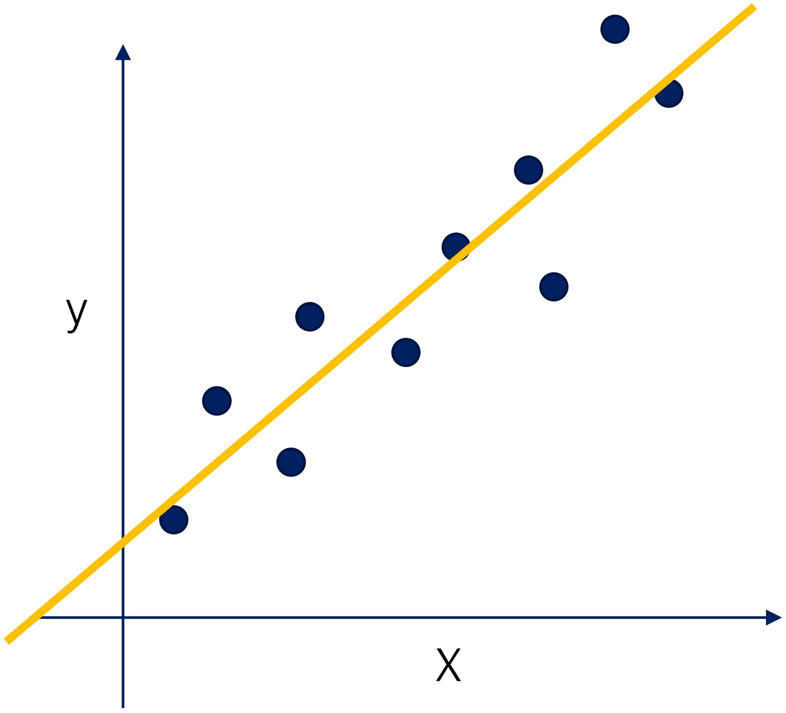
Logistic regression, Neural network, Deep neural network, CNN 다룰 예정

2. Linear Regression

Linear function

- 입력 X로부터 출력 y를 예측
- 예측 모델이 Linear한 1차 함수

$$\boldsymbol{h_{w,b}(x) = wx + b}$$



Cost function

$$\boldsymbol{J(w,b) = \frac{1}{2m}\sum\left(h_{w,b}(x_i) - y_i\right)^2}$$

$$\underset{\boldsymbol{W,b}}{\text{minimize}}\,\boldsymbol{J(w,b)}$$

Repeat

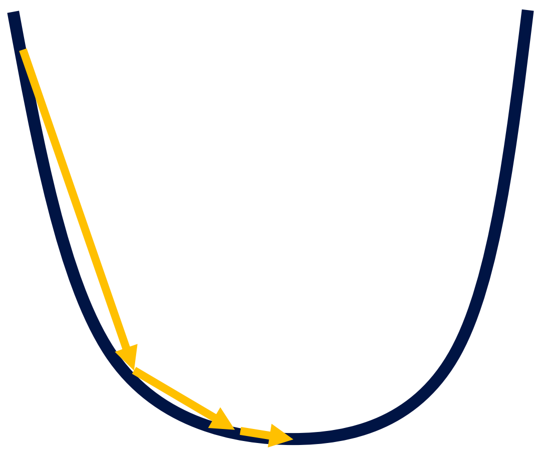
$$\boldsymbol{w_j = w_j - \alpha\frac{\partial}{\partial w_j}J}$$

2. Linear Regression

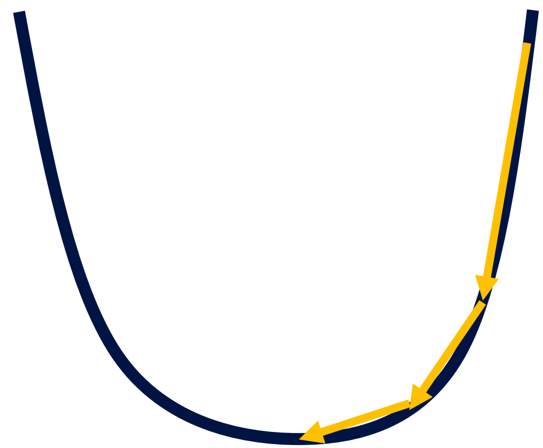
Gradient descent according to gradient

Repeat

$$w_j = w_j - \alpha \frac{\partial}{\partial w_j} J$$



$$\frac{J}{\partial w_j} < 0$$



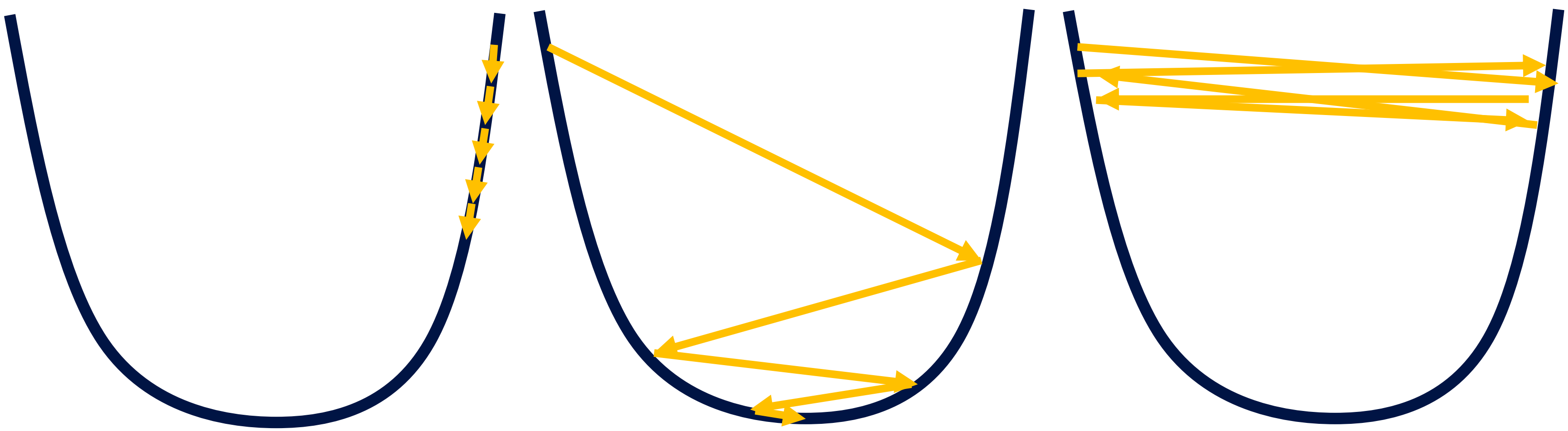
$$\frac{J}{\partial w_j} > 0$$

2. Linear Regression

Gradient descent according to learning rate

Repeat

$$w_j = w_j - \alpha \frac{\partial}{\partial w_j} J$$



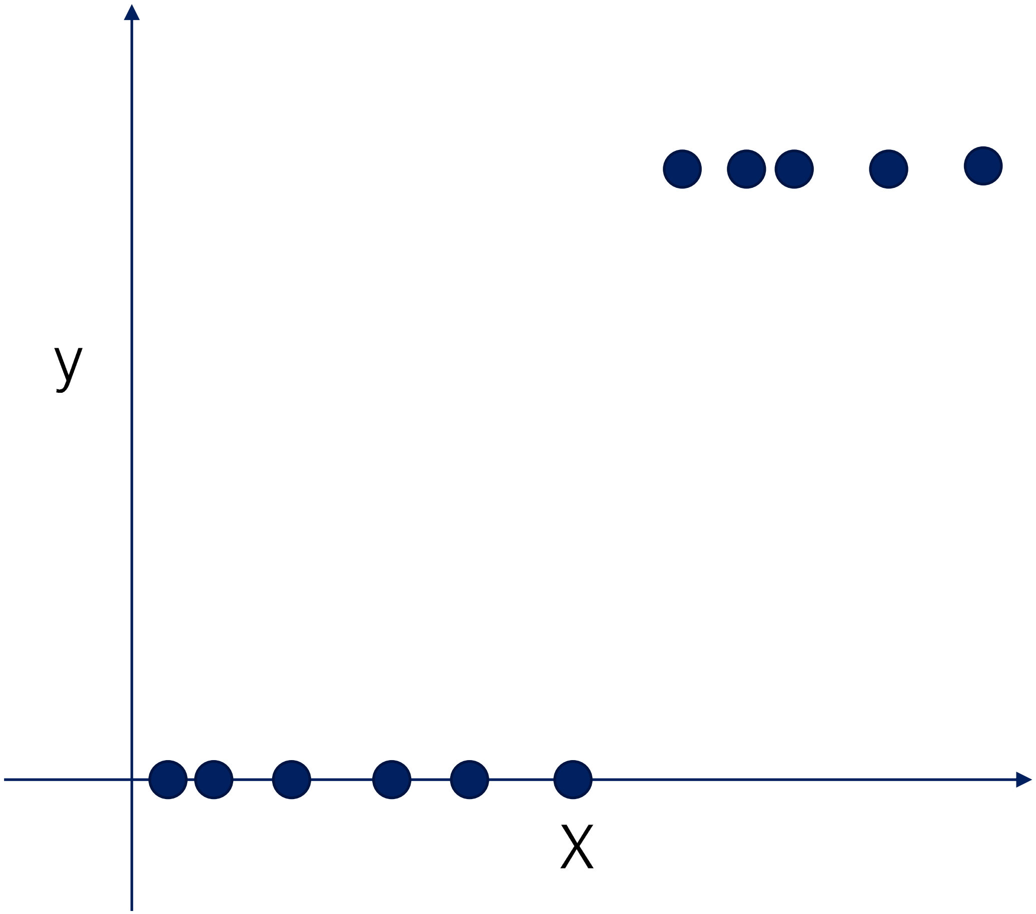
Low
learning rate

Adequate
learning rate

High
learning rate

3. Logistic Regression

Logistic function



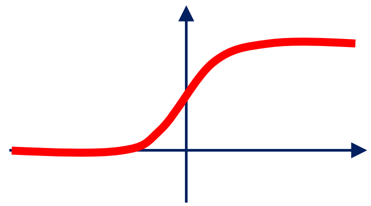
3. Logistic Regression

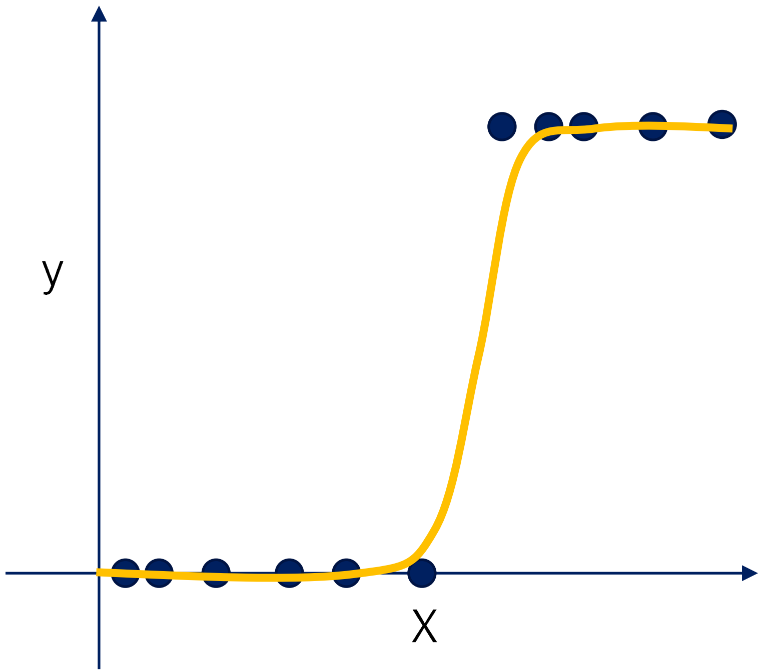
Logistic function

- Logistic function이 추가되면서 단순 미분이 힘들어진다
  - ➔ Cross entropy 같은 Cost function을 사용함

Logistic function

$$g(z) = \frac{1}{1+e^{-z}}$$





$$h_{w,b}(x) = g(wx+b)$$

Cost function

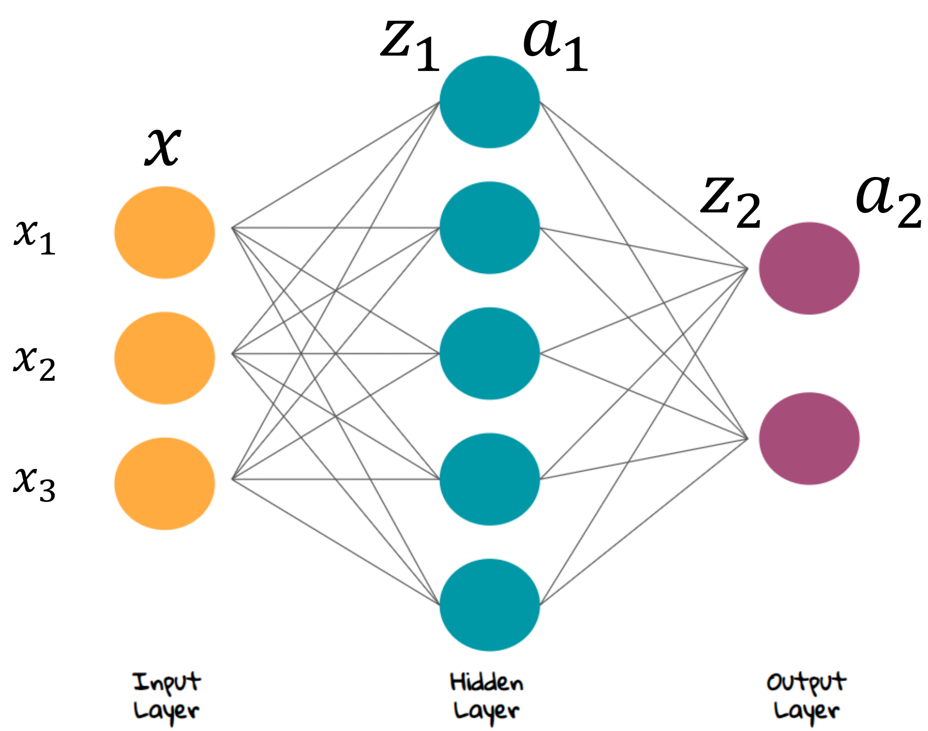
$$J(w) = \frac{1}{m}\sum_{i=1}^{m} cost(h_w(x_i), y_i)$$

$$= -\frac{1}{m}\left[\sum_{i=1}^{m} y_i \log h_w(x_i) + (1-y_i)\log\big(1-h_w(x_i)\big)\right]$$

$$\underset{\boldsymbol{W},\boldsymbol{b}}{\text{minimize}}\, \boldsymbol{J}(\boldsymbol{w},\boldsymbol{b})$$

4. Neural Network

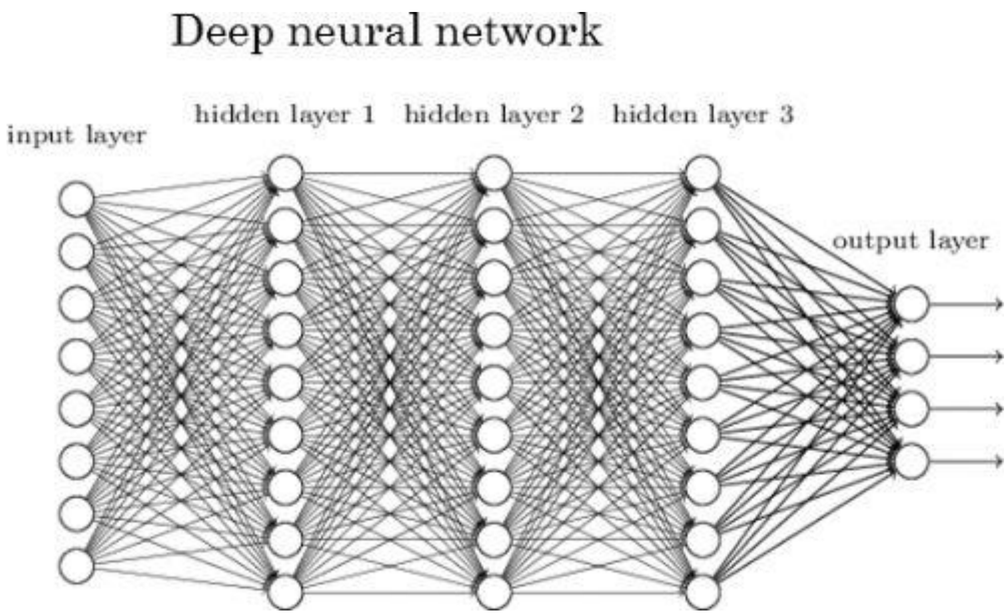
Neural network



$$z_1 = w_1 x + b_1$$
$$a_1 = \sigma(z_1)$$
$$z_2 = w_2 a_1 + b_2$$
$$a_2 = \sigma(z_2)$$

4. Neural Network

Deep Neural network



$$z_1 = w_1 x + b_1$$
$$a_1 = \sigma(z_1)$$
$$z_2 = w_2 a_1 + b_2$$
$$a_2 = \sigma(z_2)$$

$$\vdots$$

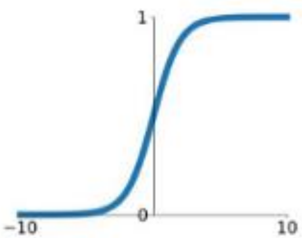
$$z_n = w_n a_{n-1} + b_n$$
$$a_n = \sigma(z_n)$$

4. Neural Network

Activation functions

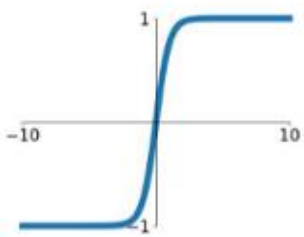
Sigmoid

$$\sigma(x) = \frac{1}{1+e^{-x}}$$



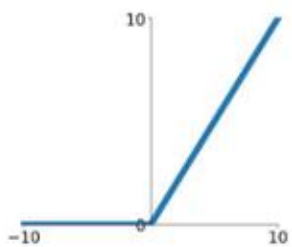
tanh

$$\tanh(x)$$



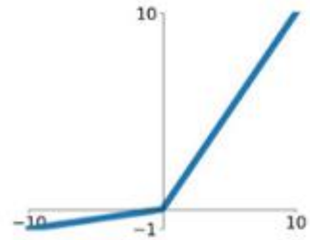
ReLU

$$\max(0, x)$$



Leaky ReLU

$$\max(0.1x, x)$$

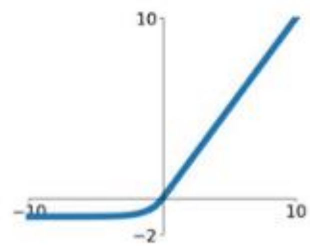


Maxout

$$\max(w_1^T x + b_1, w_2^T x + b_2)$$

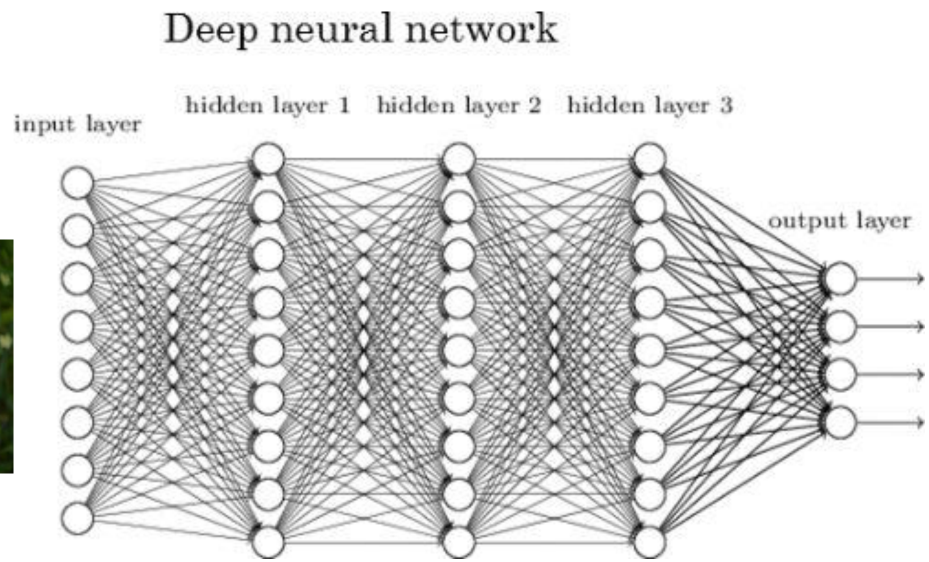
ELU

$$\begin{cases} x & x \geq 0 \\ \alpha(e^x - 1) & x < 0 \end{cases}$$



5. Image Classification

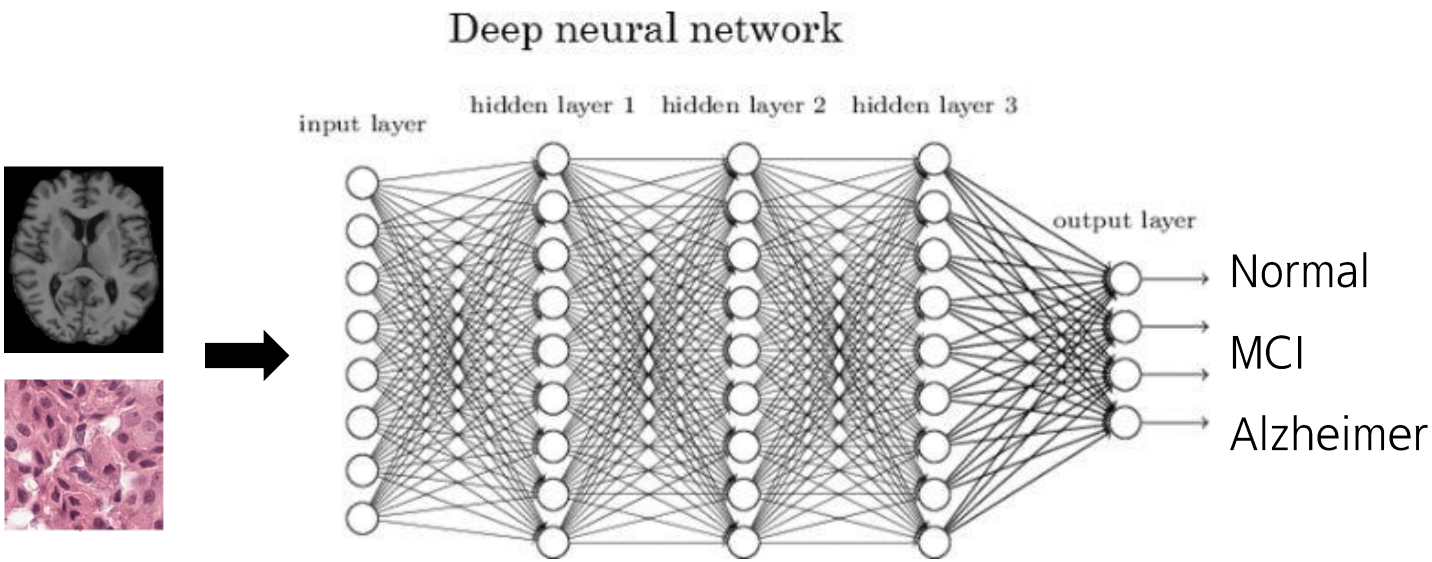
Input = Image



Dog
Cat
Cow
Horse

6. Medical image classification

Input = Medical image



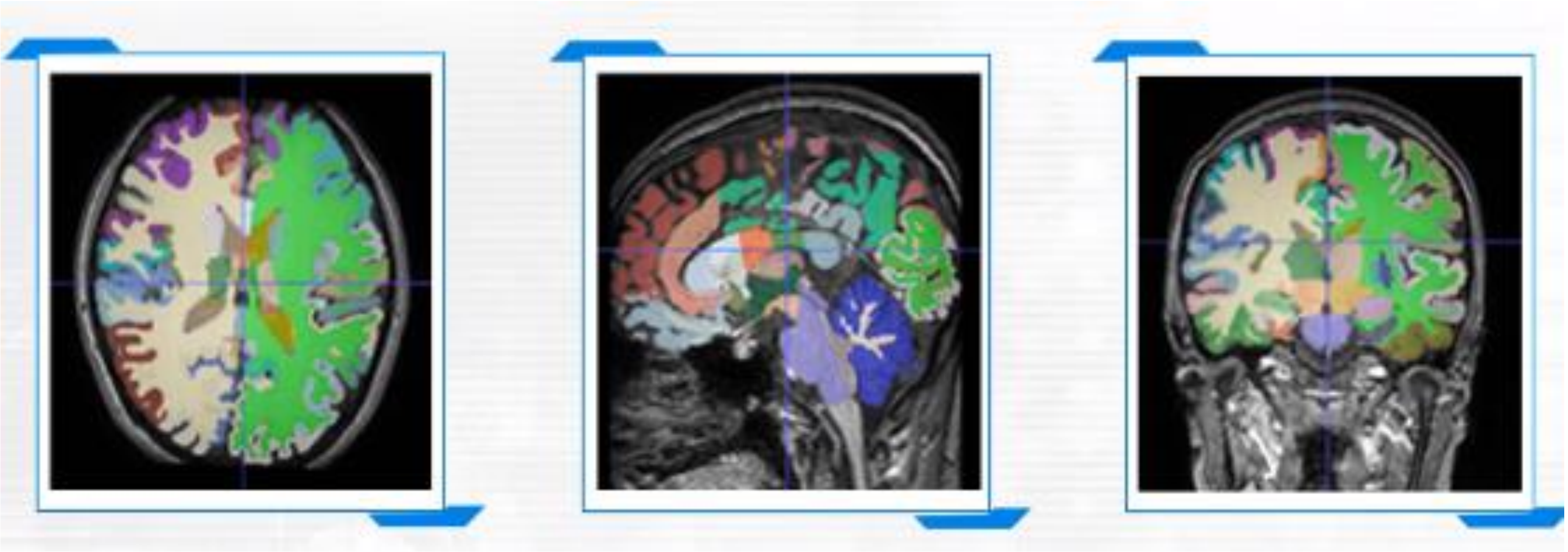
1) High parameter, Low sample ➔ Overfitting
2) 외곽 검은 부분 = 필요 없는 부분
➔ 무의미한 곳은 없애고, 의미 있는 부분들만 추출하는 과정 필요

6. Medical image classification

Feature extraction

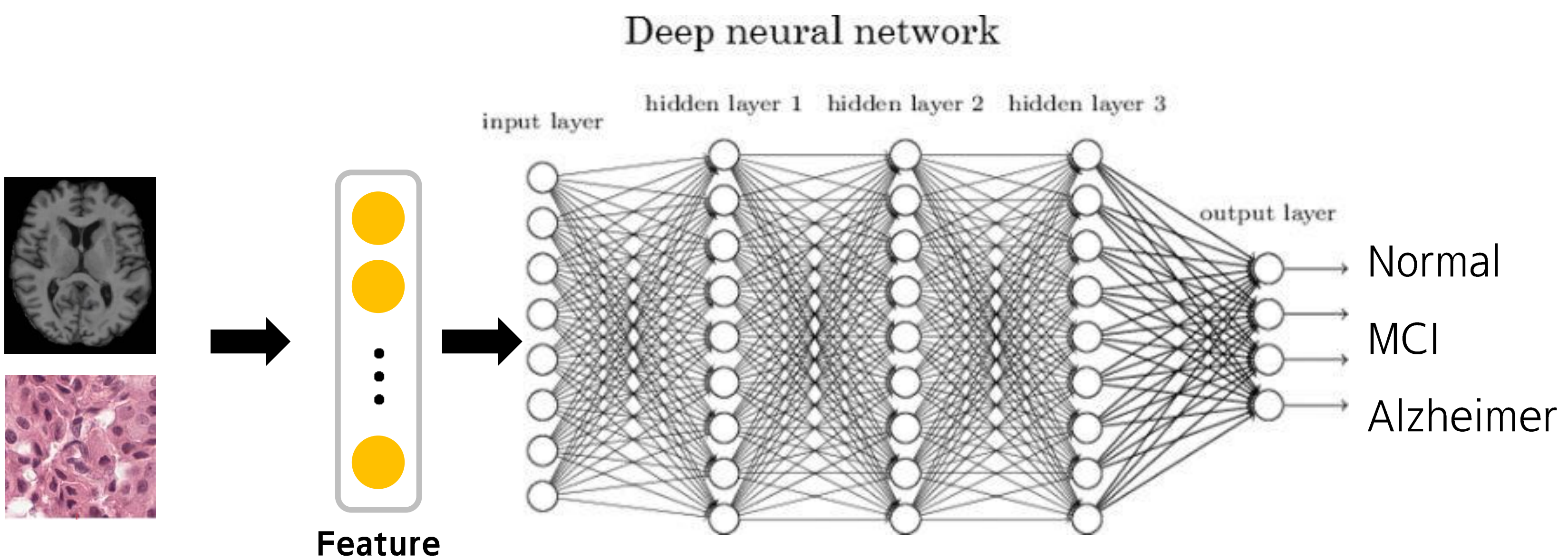
- Feature extraction: 불필요한 부분을 없애고, 의미 있는 부분들만 추출하는 과정
  - Parcellation
  - FSL & Freesurfer

- e.g., (brain) ROI별 Value, Thickness, Intensity …
- e.g., (pathology) cell size, color …



6. Medical image classification

Input = Medical image



Feature extraction 이 추가됨

7. Classification with demographic scores

Demographic scores (DS)

- Brain change is affected by multiple factors

Subject	Age	Gender	Feature 1	Feature 2	Feature 3
Normal	40	M	3	10	5.1
Normal	50	F	5	9	5
Normal	60	M	6	8	4.9
Normal	70	M	6.5	7	5.2
Normal	80	F	8	6	5
Normal	90	F	8.5	5	5
AD	50	F	9.2	20	4.8
AD	40	M	7.9	20	4.9

Feature 2 같으면 좋겠지만, 실상은 Feature 1 같은 것만 많음

7. Classification with demographic scores

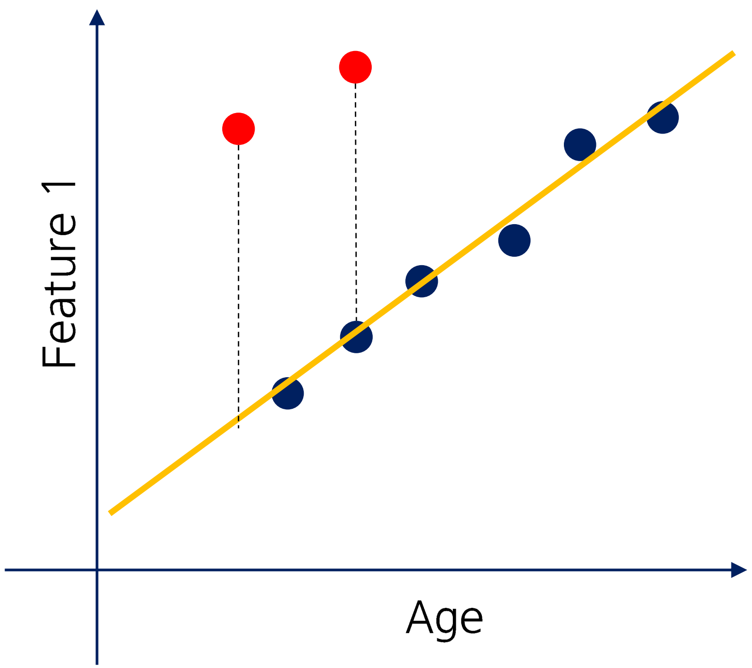
Feature normalizer

- Linear regression
  - (예를 들어) $Feature\ 1 = W \times Age\ +\ b$ 수식으로 Linear regression 시행
  - 이 때 Normal 그룹으로 Fitting 한 regression line 과 feature 간의 residual을 계산
  - Normal 그룹은 작은 residual 을 갖지만, AD 그룹은 큰 residual을 가짐 ➔ 변별력 증가
  - 위 예시에서는 Age만 썼지만, 실제로는 Age, Gender 등 모든 DS를 X로 두고 Feature normalization

    ➔ **최종 Feature 수는 고정된다 !**

X Y

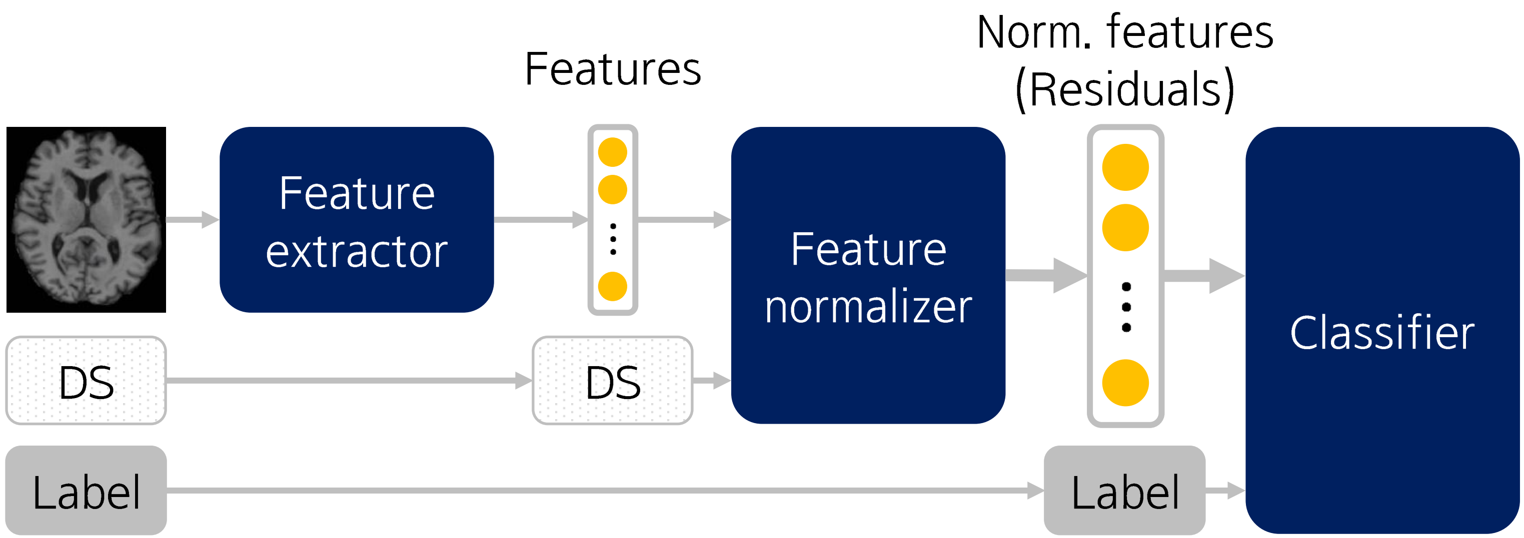
Subject	Age	Gender	Feature 1	Feature 2	Feature 3
Normal	40	M	3	10	5.1
Normal	50	F	5	9	5
Normal	60	M	6	8	4.9
Normal	70	M	6.5	7	5.2
Normal	80	F	8	6	5
Normal	90	F	8.5	5	5
AD	50	F	9.2	20	4.8
AD	40	M	7.9	20	4.9



7. Classification with demographic scores

Overall procedure (example)

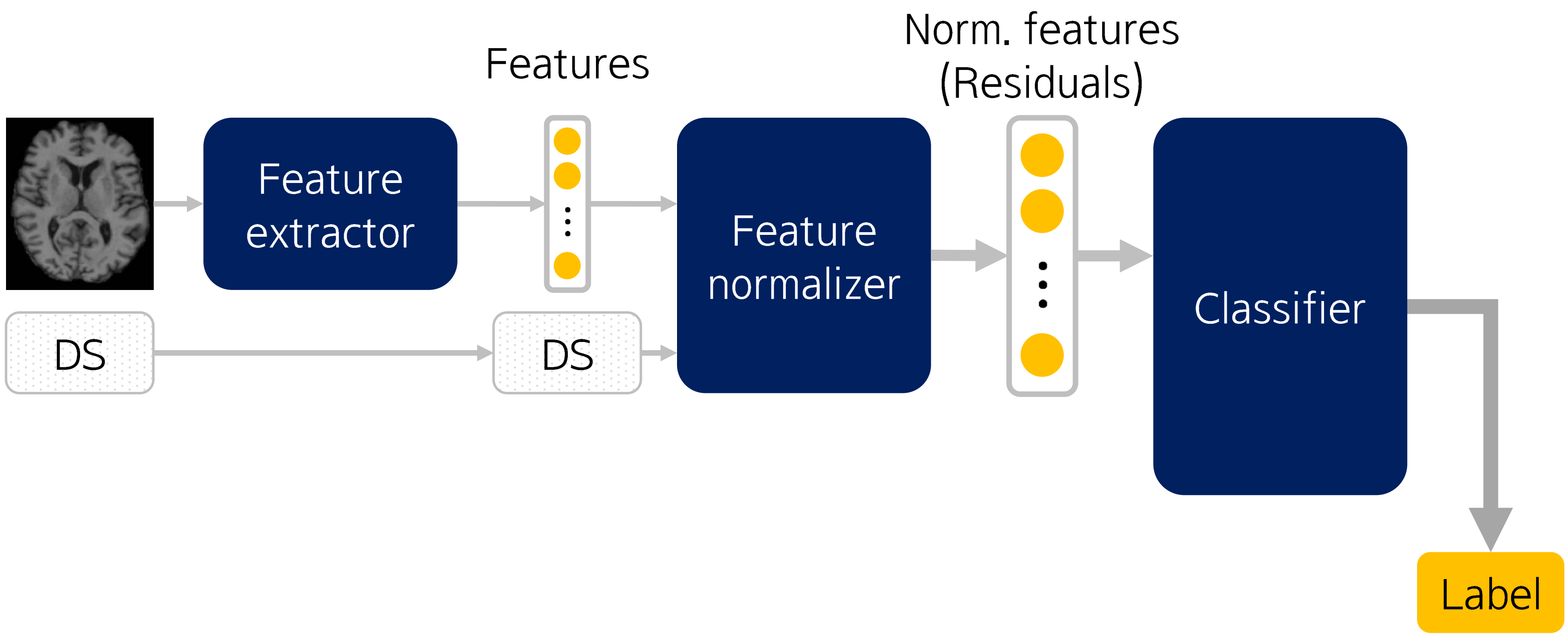
- Training



7. Classification with demographic scores

Overall procedure (example)

- Test



7. Classification with demographic scores

Overall procedure (example 2)

- Training
  - Demographic score 자체를 feature로 활용
  - 하지만 이 경우, DS 레벨 전 범위에 걸쳐, 충분한 수의 샘플 수가 확보가 되어야 한다.