가천대학교
Gachon University

ECG PPG
개인인식 방식 비교

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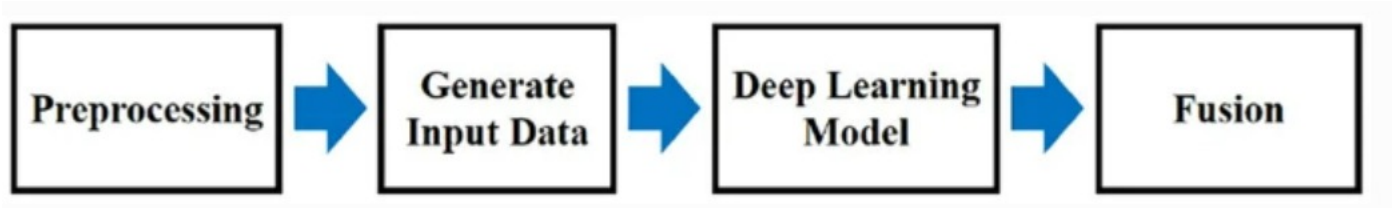
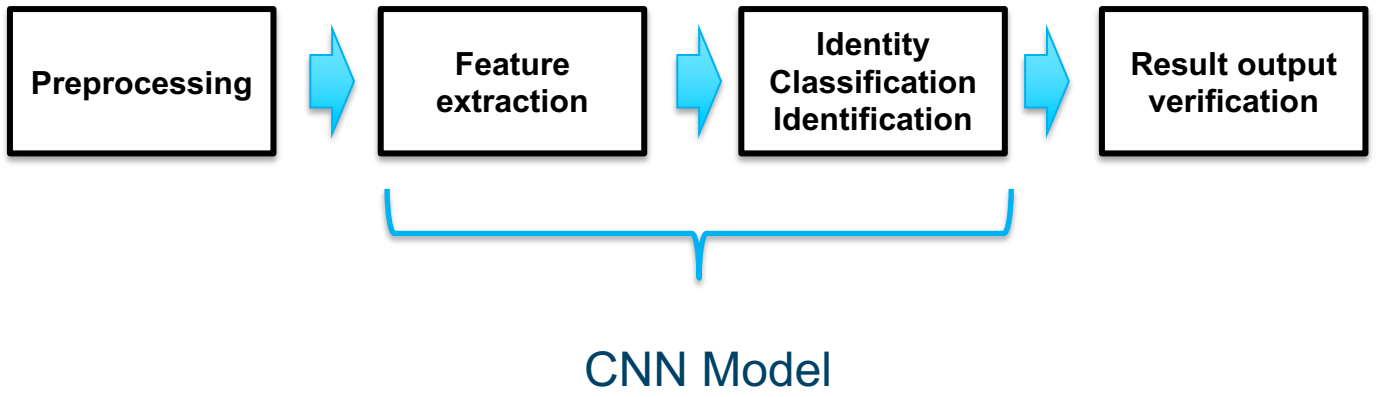
- PPG

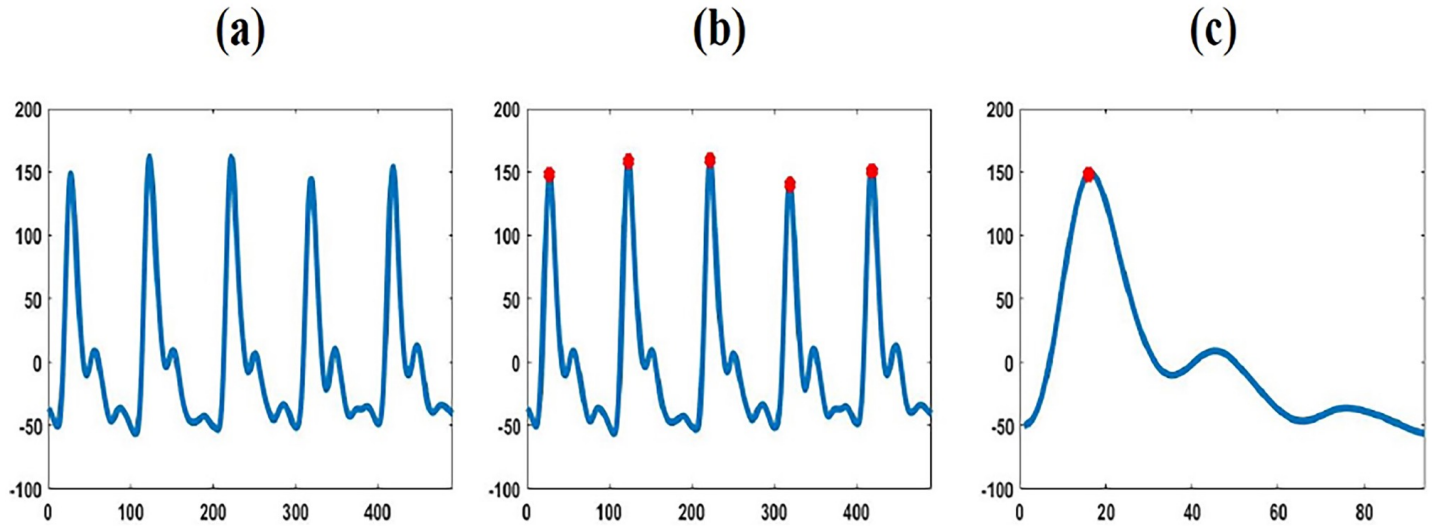

Preprocessing
Generate Input Data
Deep Learning Model
Fusion

- ECG


Preprocessing
Feature extraction
Identity Classification Identification
Result output verification
CNN Model

Preprocessing（PPG）

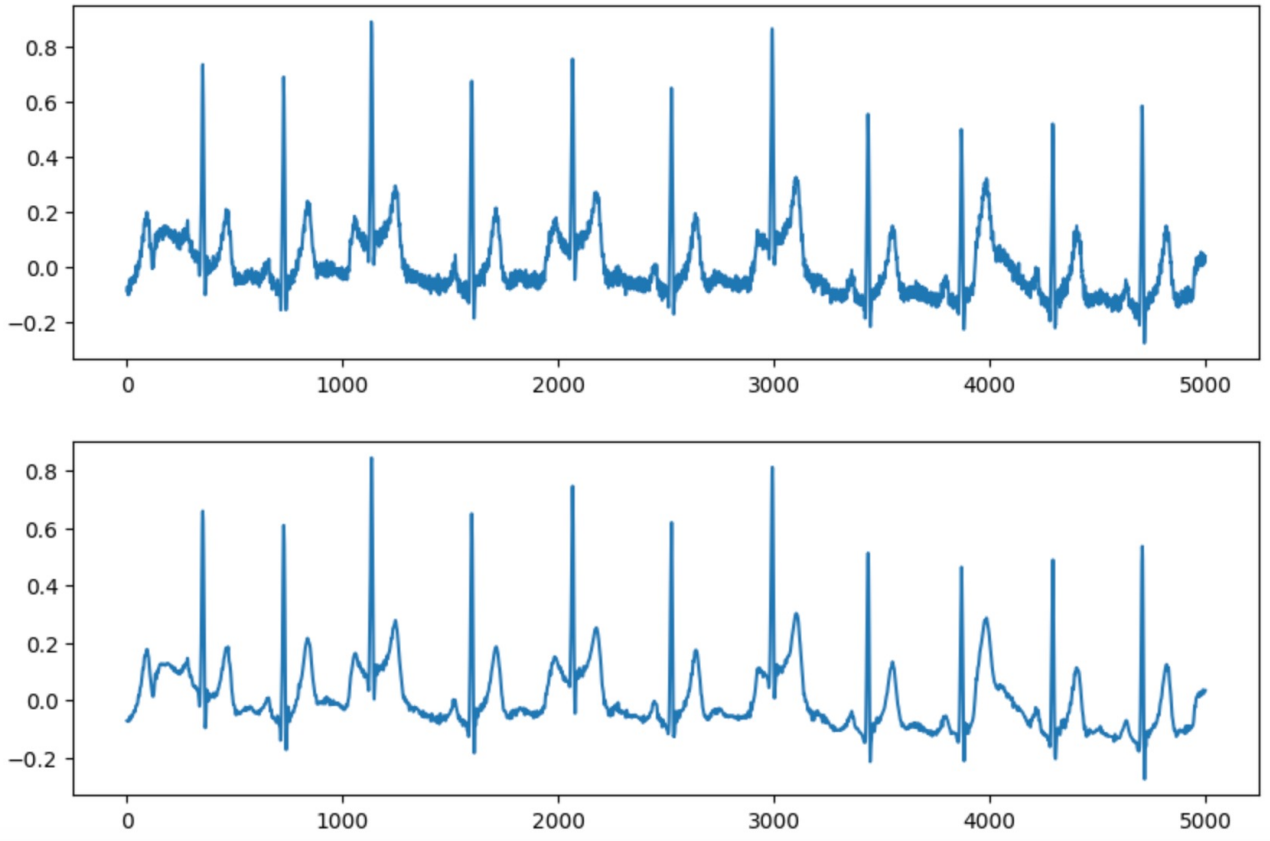
a. 4th order Butterworth filter
   - 0.5-18 Hz
b. Systolic peak detection
c. Identify single heartbeat waveforms



Preprocessing（ECG）

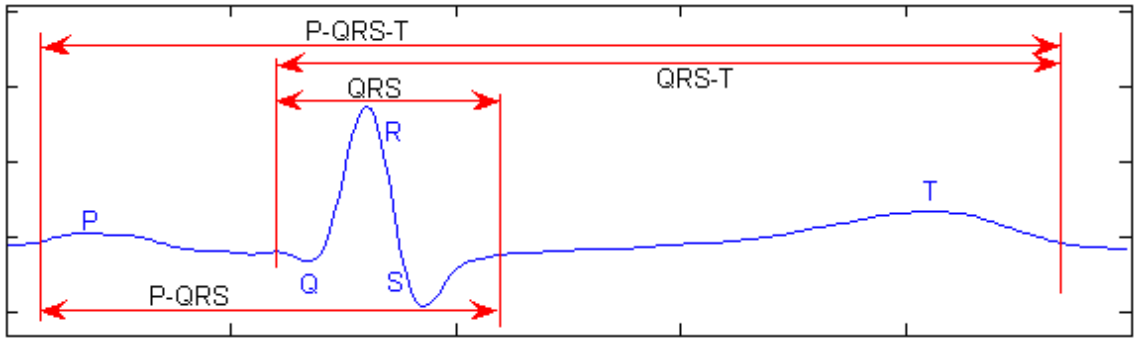
- Wavelet Drift Correction
- 심전도 노이즈는 주로 D1과 D2에 집중되어 있다.(power-line and high-frequency noise)
  - pywt.threshold() 함수로 임계값 필터링 사용

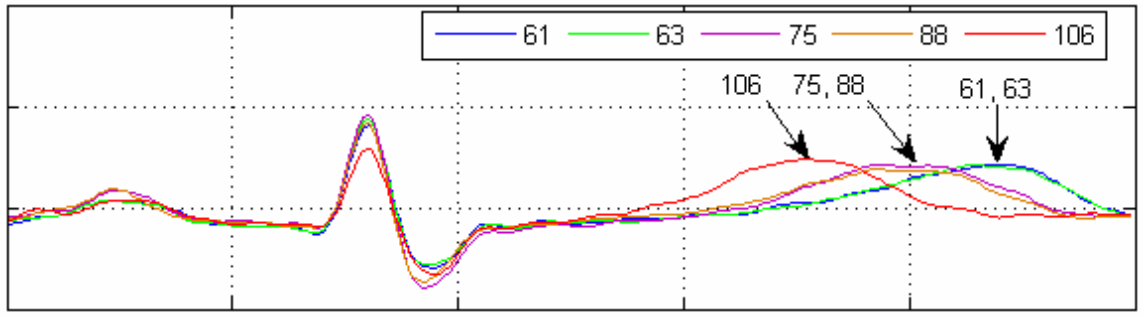
	주파수 범위(Hz)
D1	90~180
D2	45~90
D3	22.5~45
D4	11.25~22.5
D5	5.625~11.25
D6	2.8125~5.625
D7	1.40625~2.8125
D8	0.703125~1.40625
D9	0.3515625~0.703125
A9	0~0.3515625

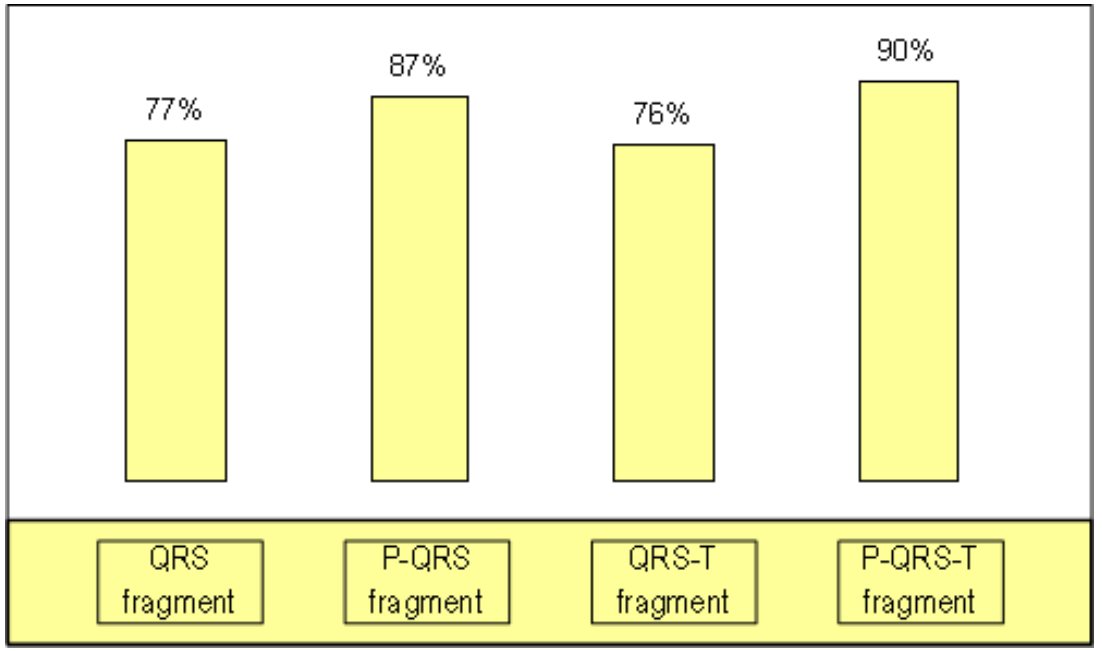


Feature extraction

- 심장 활동 정보는 주로 QRS파에 있다.
- P파 부분 정보 추가



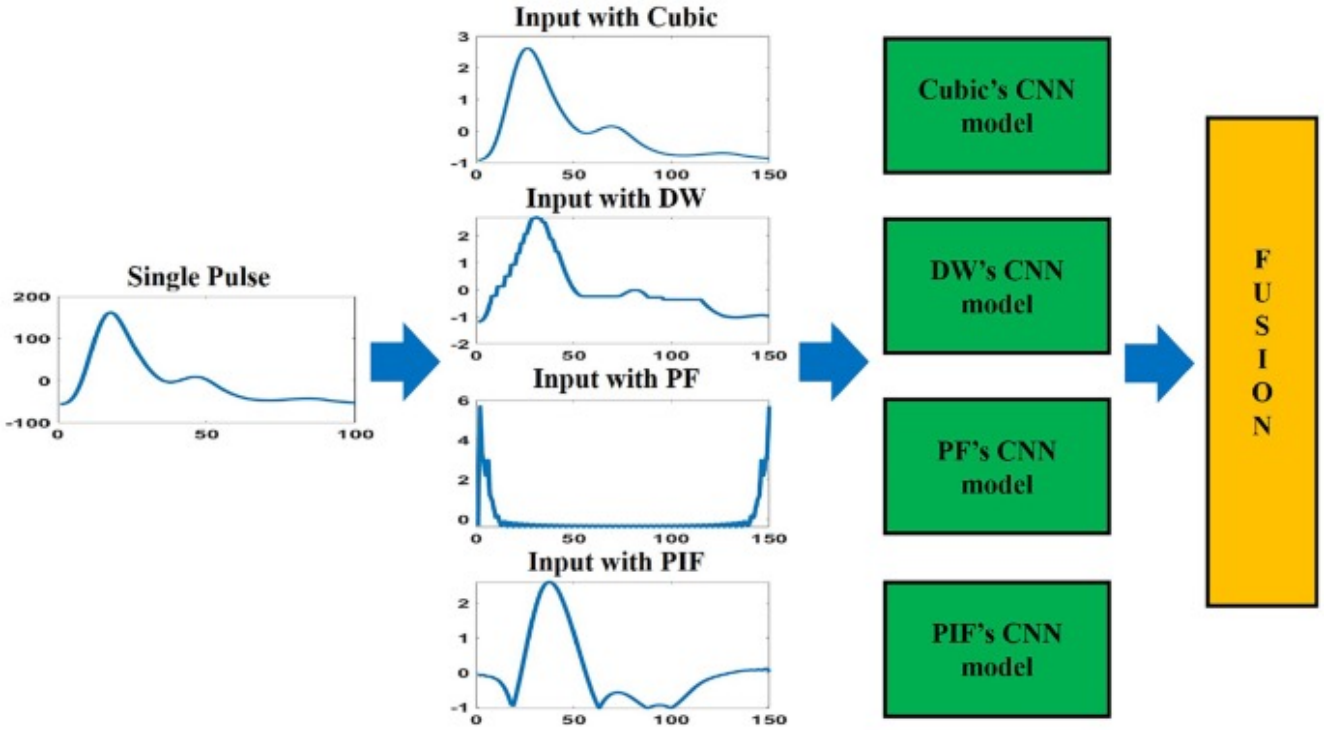




Lugovaya T.S. Biometric human identification based on electrocardiogram.
[Master's thesis] Faculty of Computing Technologies and Informatics, Electrotechnical University "LE TI", Saint–Petersburg, Russian Federation; June 2005.
https://physionet.org/files/ecgiddb/1.0.0/biometric.shtml

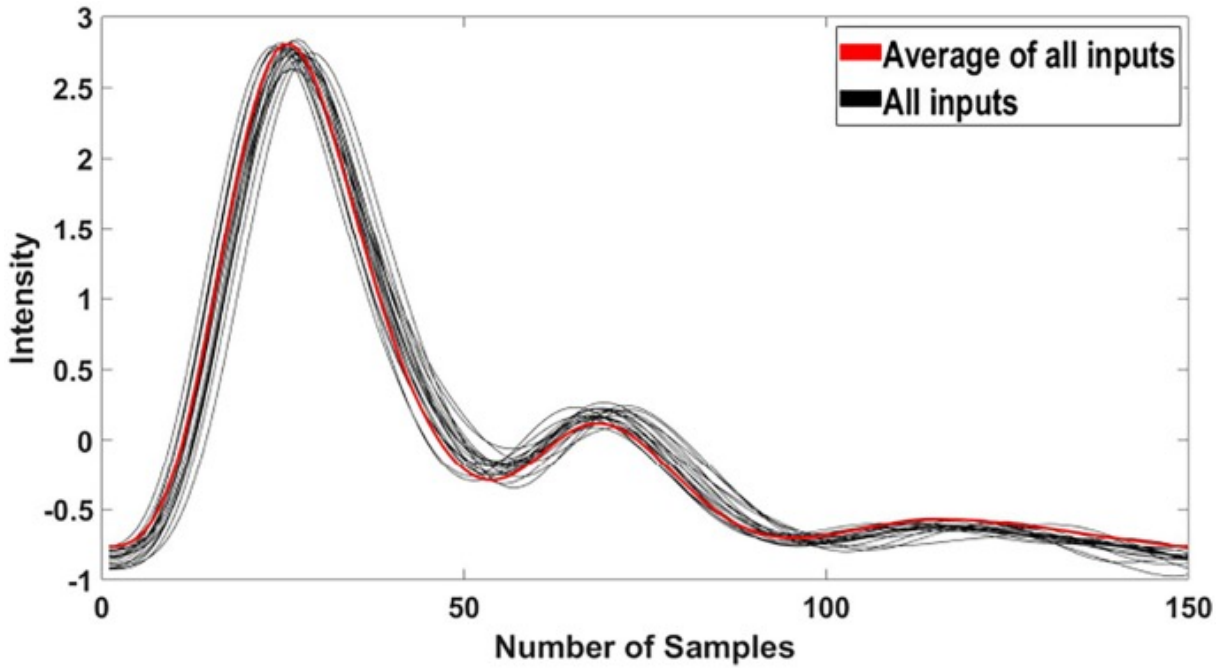
Generate Input Data

- 입력 데이터 길이는 동일하기 위해서
  - Cubic spline interpolation (Cubic)
  - Dynamic Time Warping (DTW)
  - Fourier (PF)
  - Padding with Inverse Fourier (PIF)



Generate Input Data(PPG)

- Outlier Removal
  - 입력 신호의 평균은 각 신호와 개별적으로 비교해서 대표 데이터 선정

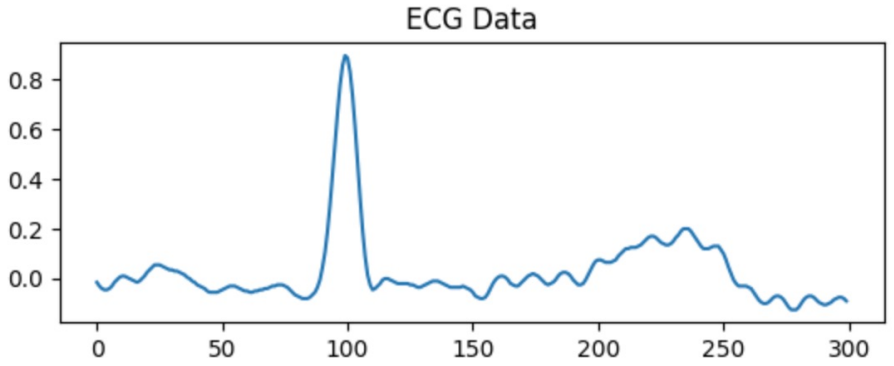


Generate Input Data(ECG)

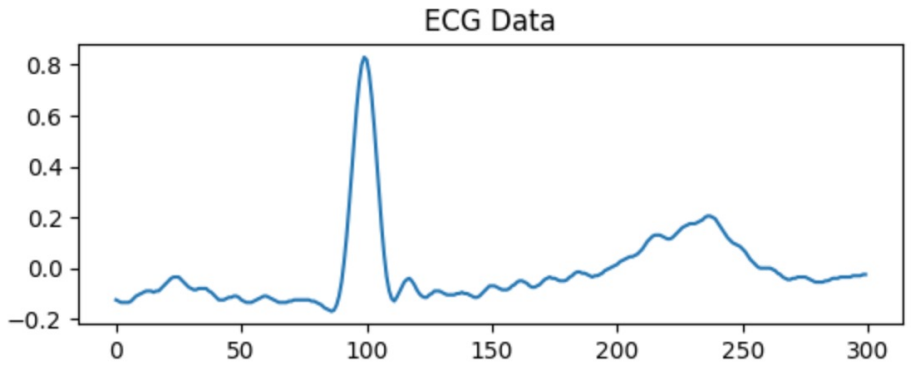
- 각 심장 주기에 대해 PR, QRS 및 QT 간격의 실제 길이와 관계없이
  - R Peak 이전 99개 샘플, 이후 201개 샘플, 총 길이 300개 선택
  - (사용하는 데이터베이스는 R Peak Label을 가지고 있기 때문에 추가 처리는 하지 않다.)

```
record = wfdb.rdrecord('../ECG-ID/Person_'+ person + '/' + data1, sampfrom=0, channels=[1])
data = record.p_signal.flatten()
Rlocation = annotation.sample
print(Rlocation)
```

```
[ 152  288  564  702  978 1105 1394 1529 1824 1952 2241 2376 2661 2799
 3063 3195 3428 3559 3803 3937]
```

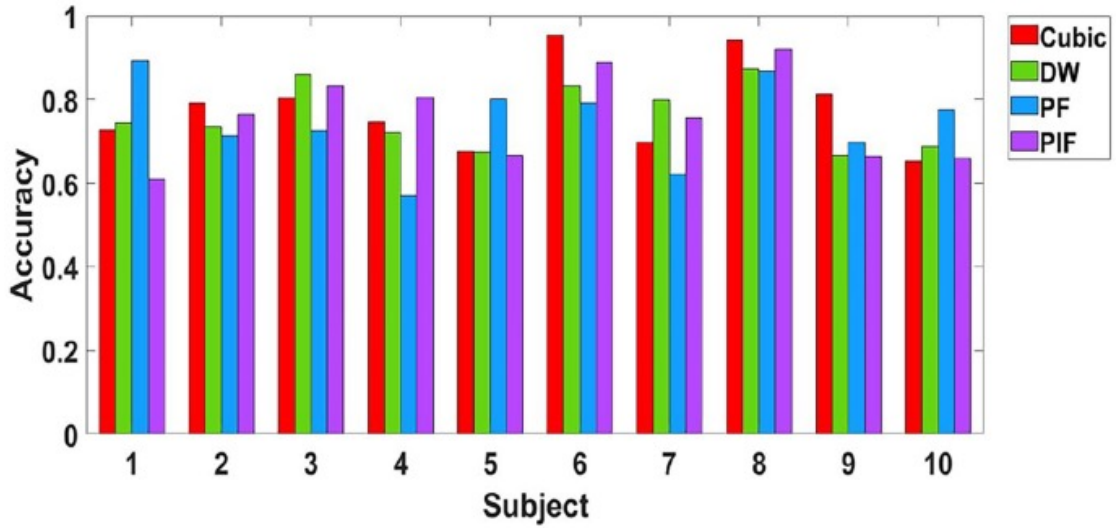



```
300
```



Deep Learning Model(PPG)

- Generate Input Data에 따라 CNN Model 성능도 따른



- 성능 향상을 위해 score fusion methods 사용
  - F(S) : *means the score after each fusion written in lowercase.*
  - S_n : score from a model trained (Cubic, DW, PF, PIF)
  - W_n : weight value assigned in each model

$$F(S)_{min} = min_n(S_n)\ (n = 1...4)$$

$$F(S)_{sum} = \sum_{n=1}^{4} W_n S_n$$

$$F(S)_{product} = \prod_{n=1}^{4} S_n^{W_n}$$

$$F(S)_{median} = median_n(S_n)\ (n = 1...4)$$

Deep Learning Model（PPG）

- Two layers of CNN model have convolutional kernels, Scaled Exponential Linear Unit (SELU) and dropout

	PRRB	TROIKA	Biosec1, Biosec2
The length of Input data	450	190	150
Kernel Size (W x H x D) in 1st Convolution Layer	180x1x50	75x1x50	60x1x50
Kernel Size (W x H x D) in 2nd Convolution Layer	210x50x70	90x50x70	70x50x70
Dropout (50%), SELU	All of them are applied in each layer		
FC Layer with Sigmoid	Give binary classification result		

	PRRB	TROIKA	Biosec1	Biosec2
Number of Subjects	42	20	31	100
Sampling Frequency	300 Hz	125 Hz	100 Hz	100 Hz
Single or Two?	Single-session	Single-session	Two-sessions	Two-sessions
Environment for Collection	Elective surgery	Running on a treadmill	Office environment and could talk	Office environment and could talk
Measuring Device	Pulse oximetry	Wrist-worn	Fingertip	Fingertip
Dominant Noise	Respiration	Exercise	Usual activity	Usual activity

Deep Learning Model（ECG）

- Data
  - ECG lead I, recorded for **20 seconds**, digitized at **500 Hz**
  - **10 annotated beats** (unaudited R- and T-wave peaks annotations from an automated detector)
  - The database contains **310 ECG recordings**, obtained from 90 persons. The number of records for each person varies from **2** (collected during one day) to **20** (collected periodically over 6 months).

- Model：
  - Convolutional layers: 4
  - pooling layer：4
  - fully connected layer

Layer (type)	Output Shape	Param #
conv1d_4 (Conv1D)	(None, 300, 4)	88
max_pooling1d_2 (MaxPooling 1D)	(None, 150, 4)	0
conv1d_5 (Conv1D)	(None, 150, 16)	1488
max_pooling1d_3 (MaxPooling 1D)	(None, 75, 16)	0
conv1d_6 (Conv1D)	(None, 75, 32)	12832
average_pooling1d_1 (Averag ePooling1D)	(None, 38, 32)	0
conv1d_7 (Conv1D)	(None, 38, 64)	55360
flatten_1 (Flatten)	(None, 2432)	0
dense_2 (Dense)	(None, 190)	462270
dropout_1 (Dropout)	(None, 190)	0
dense_3 (Dense)	(None, 90)	17190

Total params: 549,228
Trainable params: 549,228
Non-trainable params: 0

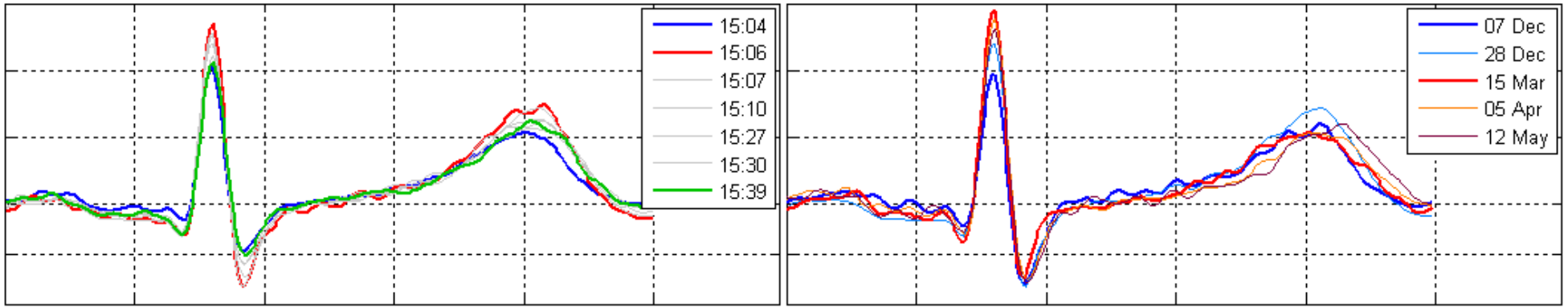
Result

- accuracy %-(EER (%)) –training time (sec)

	PRRB	TROIKA	Biosec1 1st session	Biosec1 2nd session	Biosec2 1st session	Biosec2 2nd session
Min	100 (0.1)- 356	85.1 (14.7)- 96	97.7 (2.1)- 108	94.8 (5.2)- 108	97.1 (2.9)- 337	96.3 (3.7)- 337
Sum	100 (0.1)- 356	91.7 (8.2)- 96	99.3 (0.5)- 108	97.9 (1.9)- 108	98.7 (1.2)- 337	98.2 (1.6)-337
Product	100 (0.1)- 356	89.8 (10.1)- 96	99.3 (0.5)- 108	97.4 (2.5)- 108	98.5 (1.3)- 337	98 (1.9)-337
Median	100 (0.1)- 356	87.6 (12.4)- 96	97.8 (2.1)- 108	95.9 (4)- 108	98.1 (1.8)-337	97.5 (2.5)- 337
Variation - Min	100 (0.1)- 363	85.3 (14.5)- 100	97.7 (2.1)- 113	94.8 (5.2)- 113	97.1 (2.9)- 364	96.3 (3.7)-364
Variation - Sum	100 (0.1)- 362	91.7 (8.2)- 99	99.3 (0.5)- 112	97.9 (1.9)- 112	98.7 (1.2)- 359	98.2 (1.6)- 359
Variation - Product	100 (0.1)- 362	89.7 (10.1)- 99	99.3 (0.5)- 112	97.4 (2.5)- 112	98.5 (1.3)- 359	98.1 (1.8)- 359
Variation - Median	100 (0.1)- 363	87.6 (12.3)- 100	98 (1.9)- 113	96.1 (3.9)- 113	98.1 (1.8)- 364	97.6 (2.5)- 364

Result

- PPG 신호의 시간에 따라서 변화 하는 가능성도 있음



A. within one hour　　B. within six months

	Biosec1 Train from 1st	Biosec1 Train from 2nd	Biosec2 Train from 1st	Biosec2 Train from 2nd
Min	81.5 (18.5)- 125	72.2 (27.9)- 125	83.3 (16.7)- 434	78.5 (21.5)- 434
Sum	84.6 (15.4)- 125	79.8 (20.1)- 125	85.6 (14.4)- 434	84.2 (15.8)- 434
Product	84 (15.9)- 125	77.4 (22.6)- 125	85.8 (14.1)- 434	83.7 (16.3)- 434
Median	82.6 (17.5)- 125	77.1 (22.8)- 125	85.3 (14.7)- 434	82.5 (17.6)- 434
Variation - Min	83.5 (16.5)- 130	74.4 (25.6)- 130	85.3 (14.8)- 460	80.7 (19.3)- 460
Variation - Sum	**86.1 (14)- 126**	**80.6 (19.6)- 126**	**87.3 (12.6)- 435**	**84.9 (15)- 435**
Variation - Product	84.6 (15.5)- 126	78.2 (21.9)- 126	86.6 (13.5)- 435	83.9 (16)- 435
Variation - Median	83.7 (16.3)- 130	78 (22.1)- 130	86 (14.2)- 460	83.2 (16.8)- 460

Result

- 각 사람에 대해 측정된 단일 ECG 조각(심장박동 10회) 사용

분류 정확도: 0.725925925925926

예측 결과:

```
[ 5 61 76 16 57 61  8 82 42 14 62  0 41 67 33 63 41 74 55 62  6 16  8  6
  5 17 32 83  9 50 68 68 83 26  8 19 56 50 62 26  4 80 27 56 37 40 83 71
 49 60 27 82 45 30 16 10 55 23 13 32 21 29 66 81 40 45 71 45 24 58 85 12
 65 28 47 50  9 22 56  6 42 18 26 75 64 32 26 15 74 70 38 63 86 84 12 45
 33 15 56 16 82 69 48 77 35 19 60 62 27 74 59 49 40 85 35 24 11 34 79 48
 32 28 21 19 62 18 52 78 55 71 54 40  9 21 23 55 16 87  1 74 50 15 35 67
 67 35  9 15 63 26 55 45 43 63 21 75 32 28  5 46 65 19 10 19 23 60 89 31
  8  5 71 10 86 76 74 12 55 11 58 67 87 82 73 65 35 10 48  7 28 57 78 54
 69 52 48  6 88 83 68 86 15 14 16 59 75 64 56 87 50  5 16 10 29 18  6 75
  7 62 77 63 69 74 24 16 68 24 34 76 30 58 18 37 68 62  1 58 67 54 67 57
  5 80 36 69 50  1 11 55 63 24 15 30 87 49 31 42 78  3  2 35 40 40 32 89
 41 84 68  8 88  3]
```

실제 결과:

```
[72. 61. 76.  0. 53. 61.  8. 82. 42. 14. 62.  0. 41. 67. 33. 63. 41. 74.
 84. 62.  6. 16.  8.  6.  5. 17. 87. 30. 45. 50. 68. 68. 83. 26. 48. 57.
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 23.  2.  9. 15. 63. 26. 28. 45. 43. 63. 21. 75. 85. 28.  5. 46. 65. 19.
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```