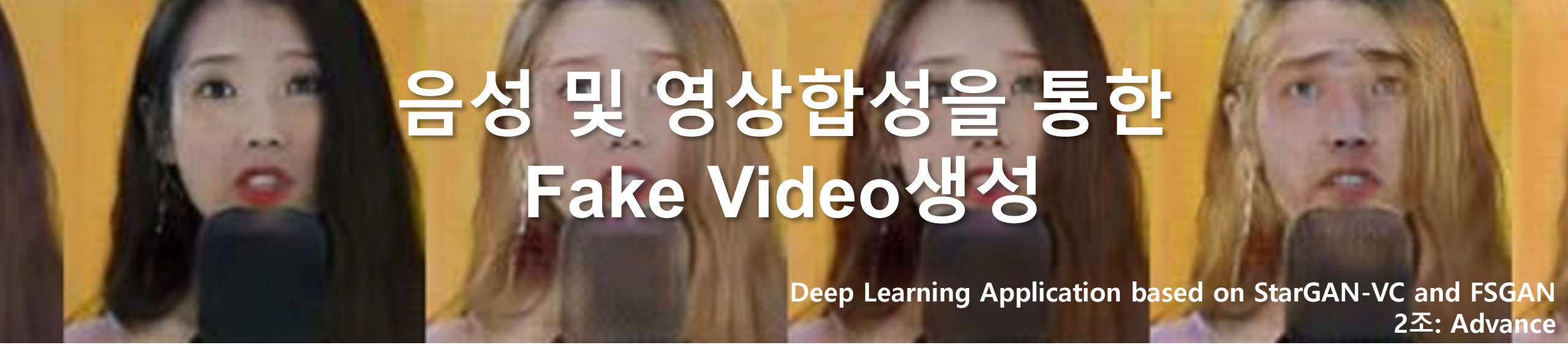


음성 및 영상합성을 통한 Fake Video생성

Deep Learning Application based on StarGAN-VC and FSGAN
2조: Advance

Team Members

2조 - 김정준, 김용신, 김예현, 박승우, 장우원

Schedule

2020.10.02 데이터수집 및 주제선정
2020.10.09 데이터 전처리, 논문리뷰
2020.10.16 모델 생성 및 훈련, 결과도출
2020.10.23 성능향상을 위한 튜닝
2020.10.30 문서작성 및 프로젝트 발표

Preparation

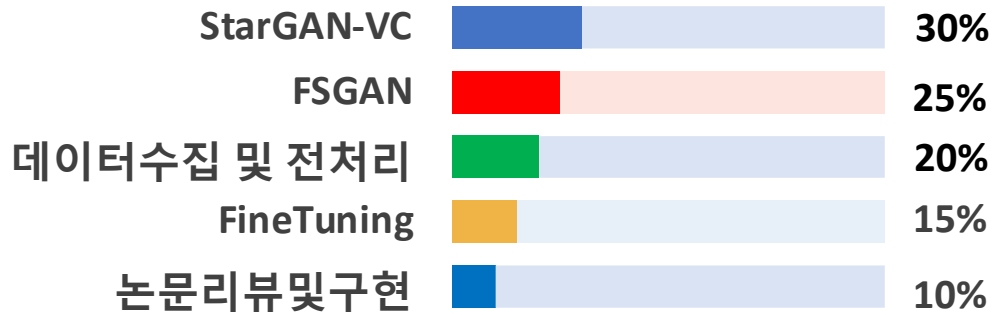
Data Set : 유명인 음성Data
GAN(Generative Adversarial Network) 기반 기술
StarGANVC / FSGAN 모델 적용

GAN을 활용한 음성&영상 합성

Face Swap과 Voice Conversion에 관한 연구

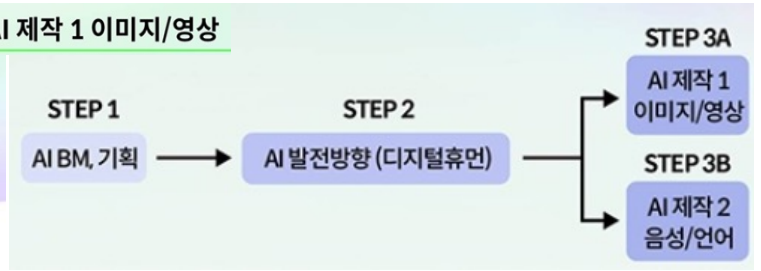
- FSGAN기반 Face Swap
- StarGAN-VC를 이용한 음성 변조

Works



Motivation

DEEPBRAIN 의 AI Human 기술 간략하게 구현해보기
StarGAN을 이용한 음성 변환과 FSGAN을 이용한 영상 합성을 통해 AI Human 영상 제작

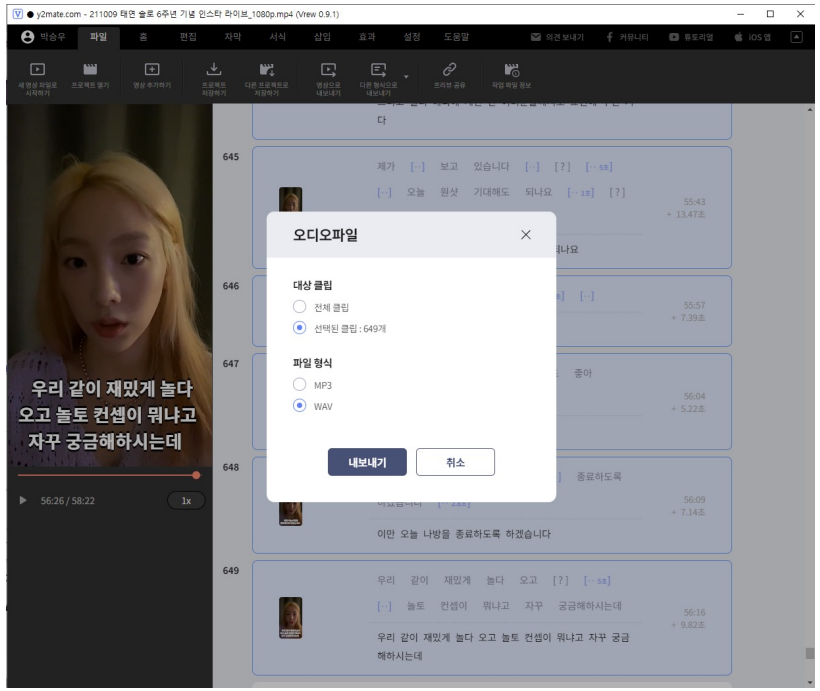


Contents

Introduction

1. Project Goal
   - 음성과 영상 합성을 통한 AI Human 구현하기
2. Overall Process (논문리뷰)
   - 논문리뷰
     - 영상: FSGAN
     - 음성: Cyclegan-vc, Stargan-vc, Stargan-vc2
   - 코드실습
     - GAN, Cyclegan, Stargan, Fsgan
   - 데이터셋 수집
     - 문재인, 김상중, 박근혜, 김주하, 아이유, 유인나
   - 모델학습
     - Training: Cyclegan-vc, Stargan-vc, Stargan2-vc
     - Finetuning: Fsgan
   - 데모영상
     - 문재인->김상중
     - 박근혜->김주하
3. Dataset
   - Description
     - 2 class (문재인, 김상중) – 500개씩
     - 4 class (문재인 김상중 박근혜 김주하) - 200개씩
     - 4 class (김주하, 박근혜, 아이유, 유인나) – 200개씩
     - 4 class(김주하, 박근혜, 아이유, 유인나) – 250개씩
     - 500개 단위가 (음성의 한문장)

Survey

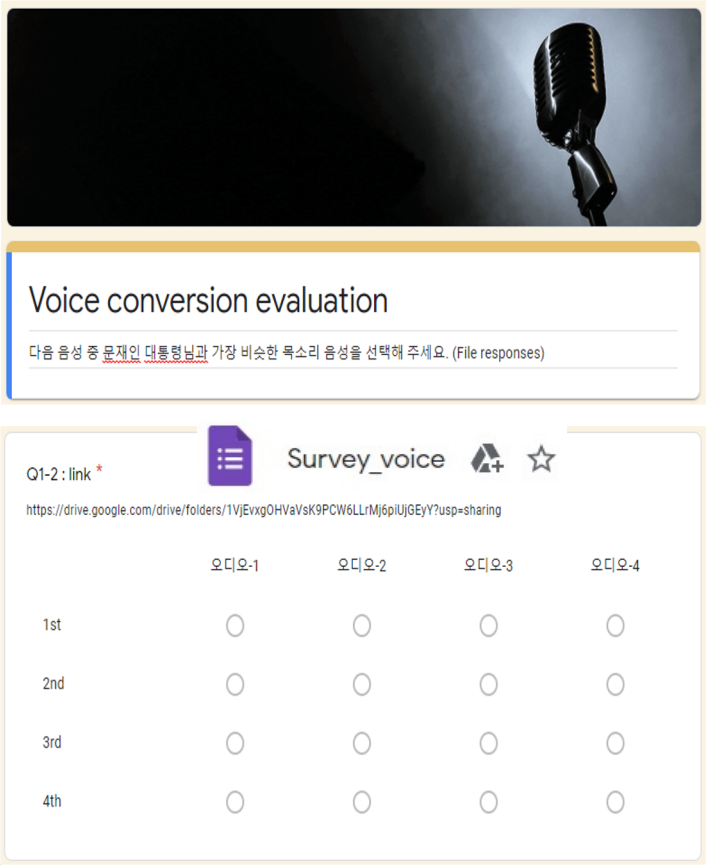


[YouTube to WAV 변환기](#) - Vrew 브루

유인나의 볼륨을 높여요(1).wav
유인나의 볼륨을 높여요(2).wav
유인나의 볼륨을 높여요(3).wav
유인나의 볼륨을 높여요(4).wav
유인나의 볼륨을 높여요(5).wav
유인나의 볼륨을 높여요(6).wav
유인나의 볼륨을 높여요(7).wav
유인나의 볼륨을 높여요(8).wav
유인나의 볼륨을 높여요(9).wav
태연_인스타 라이브_(1).wav
태연_인스타 라이브_(2).wav
태연_인스타 라이브_(3).wav
태연_인스타 라이브_(4).wav
태연_인스타 라이브_(5).wav
태연_인스타 라이브_(6).wav
태연_인스타 라이브_(7).wav
태연_인스타 라이브_(8).wav
태연_인스타 라이브_(9).wav
태연_인스타 라이브_(10).wav
태연_인스타 라이브_(11).wav
태연_인스타 라이브_(12).wav

한문장별로 나눠 음성 데이터 취합

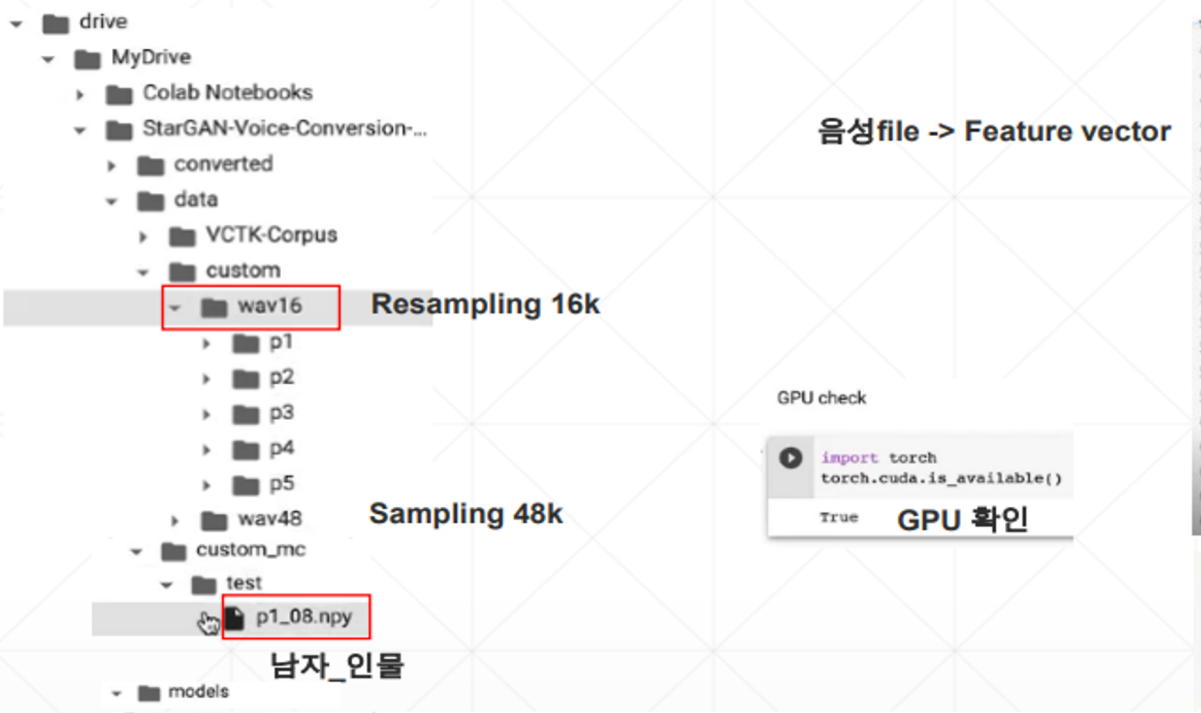
https://forms.gle/ke3b8qgeZACYCJSm6



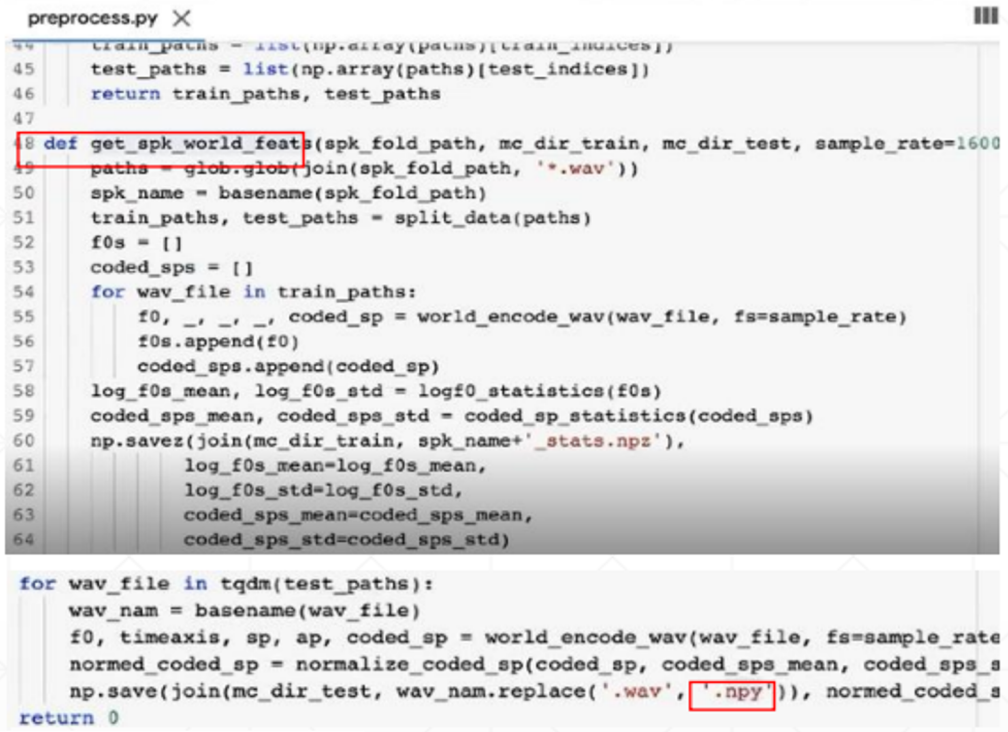
음성 합성된 음성 정성평가분석을 위한 설문조사 진행

StarGAN VC source analysis

StarGan-VC 소스 분석



음성file -> Feature vector

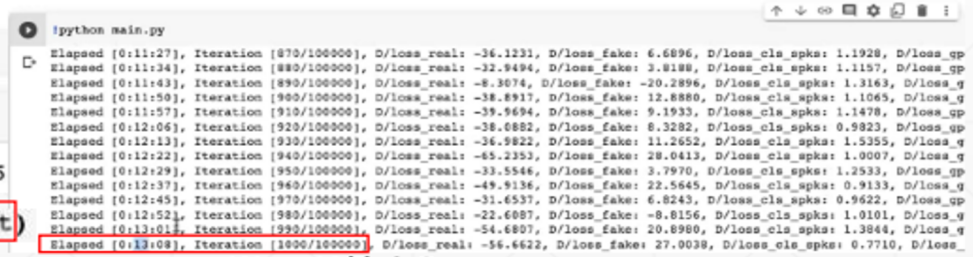


GPU check

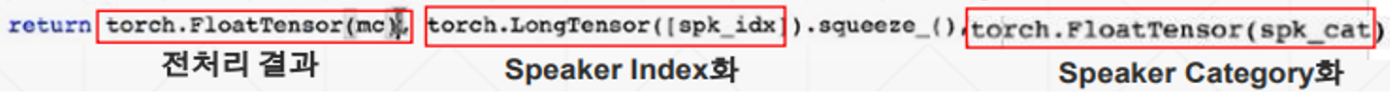
Run Demo

Iteration 확인

Train Model



1% -> 13분 소요



Face Swap

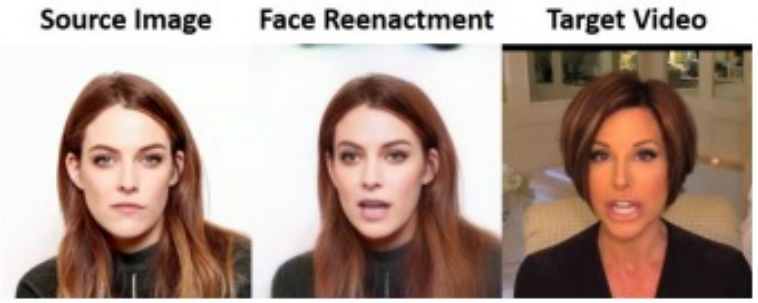
Face Swap 기술이란?

사진 혹은 비디오에 있는 얼굴을 인식하여, 얼굴의 부분을 우리가 원하는 대상의 얼굴 부분으로 바꿔주는 딥러닝 기반의 기술을 의미한다.

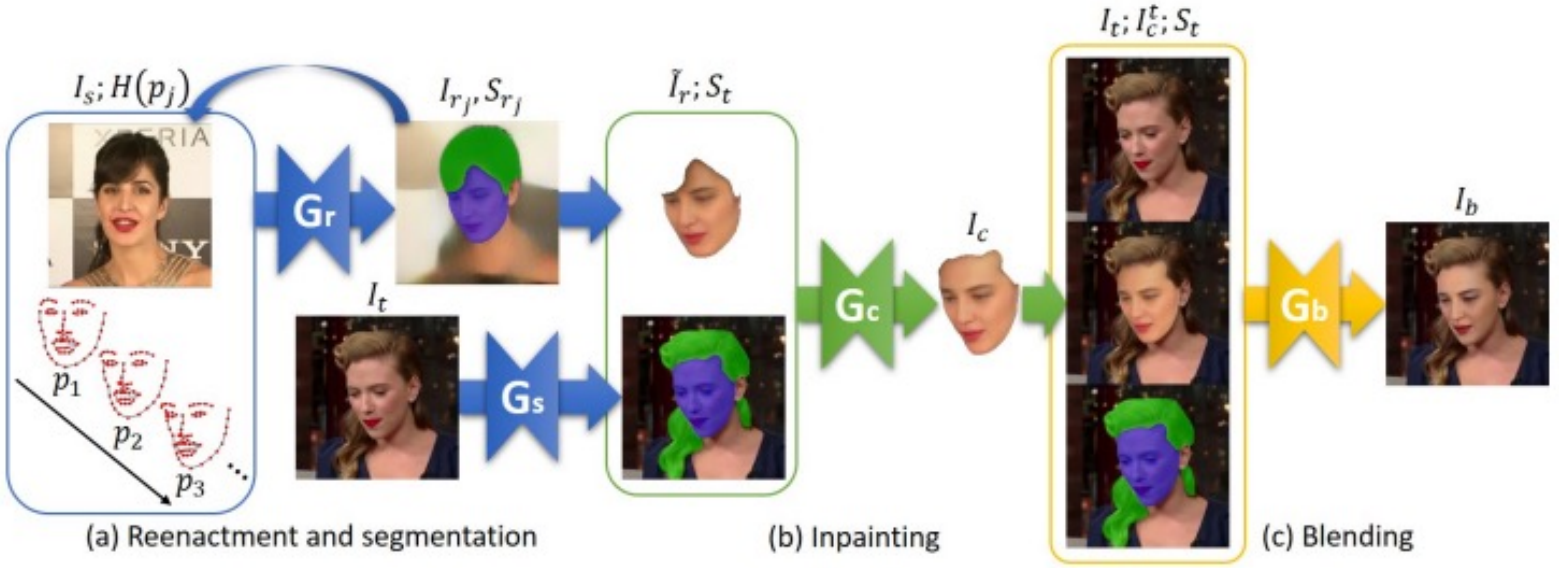
Source + Target → Result

FSGAN (Face-Swapping Generative Adversarial Network)

Goal: Subject-agnostic face swap



FSGAN(Face Swapping Generative Adversarial Network)

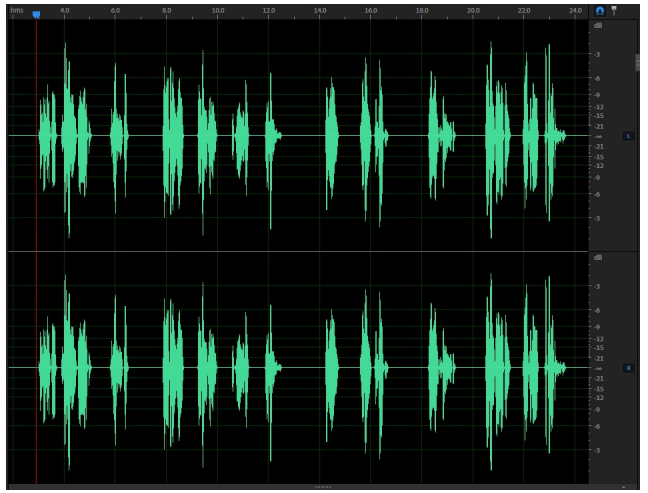


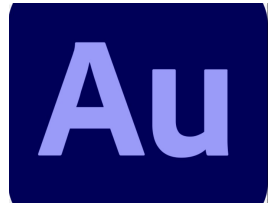
Contribution:

1. RNN기반으로 접근하여 사진 한 장 또는 영상 시퀀스에 적용하여 얼굴 재현을 가능하게 함.
2. Face completion network를 사용하여 얼굴 영역을 생성하고, face blending network를 통해 target의 얼굴색과 조명색을 유지하여 두 얼굴이 매끄럽게 합성되도록 함.
3. 새로운 손실함수인 Poisson blending loss를 사용.

Voice preprocessing

- 고품질의 음성 데이터 수집 및 음성 파일 preprocessing
  - Prototype #1 문재인과 김상중 간 목소리 변환 모델의 데이터 500여개 수집



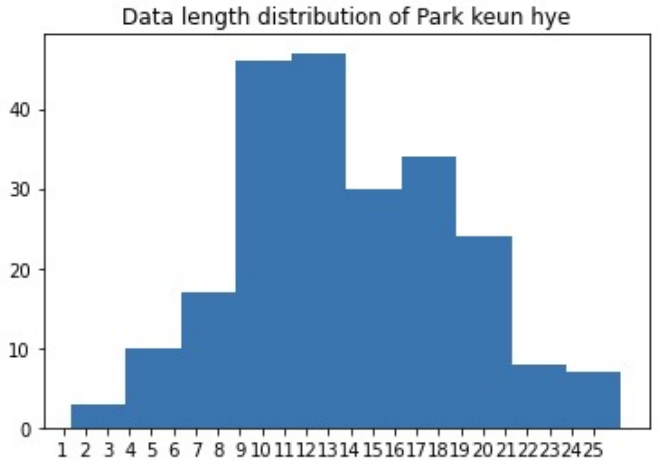


  - Prototype #2 여성 화자 기반의 목소리 데이터 200여개 파일 수집

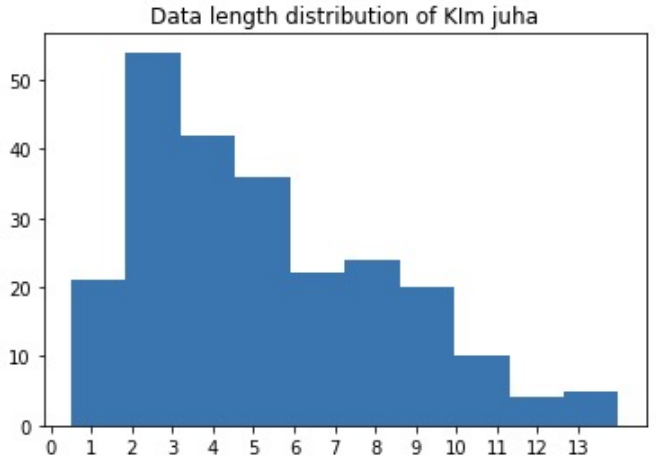
팀 내 역할과 주별 주요 활동

- 음성 데이터 분포 분석

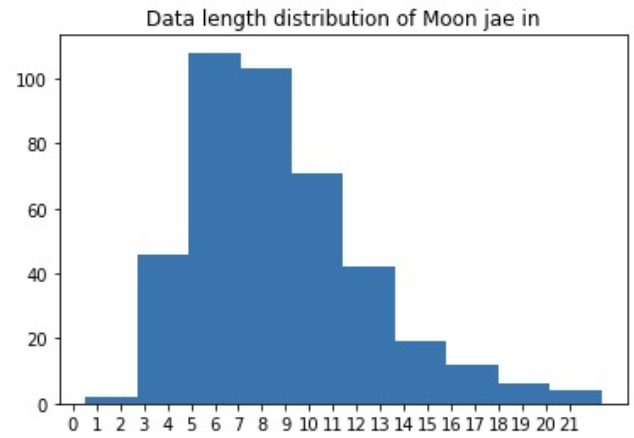
```
mean value:  13.9025958702065
sample_n:  226
```



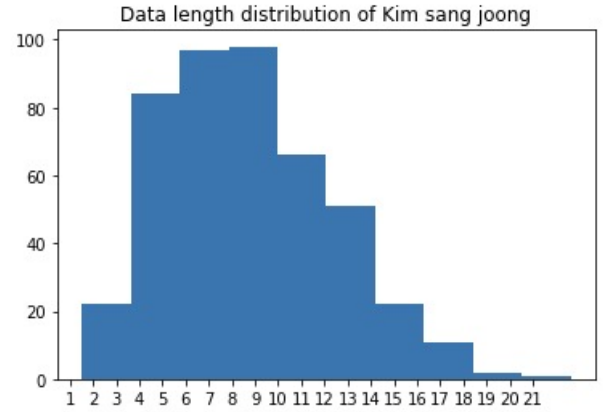

```
mean value:  5.263165266106442
sample_n:  238
```




```
mean value:  8.746853056900717
sample_n:  413
```




```
mean value:  8.778942731277533
sample_n:  454
```

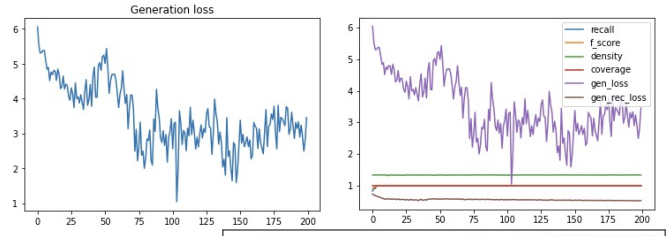


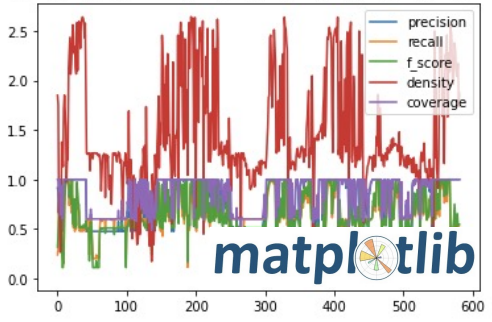

```
import os

DIR = "/content/drive/MyDrive/StarGAN-Voice-Conversion-master/

files = os.listdir(DIR)
files.sort()


lengDict=dict()
for target_id in files[0:]:
  print(target_id)
  subDir=os.listdir(DIR+str(target_id))
  subDir.sort()
  lengDict[target_id]=[]
  for num,file in enumerate(subDir):
    if num%20 ==0:
      print("file :",file)
    f = sf.SoundFile(DIR+str(target_id)+"/"+str(file))

    lengDict[target_id].append(f.frames / f.samplerate)

print("mean value: ",sum(lengDict['p1'])/len(lengDict['p1']))
plt.hist(lengDict['p1'])
print("sample_n: ",len(lengDict['p1']))
x=list(range(int(min(lengDict['p1'])),int(max(lengDict['p1']))
plt.xticks(x)
plt.title("Data length distribution of Kim sang joong")
plt.show()


p1
file : p1_01.wav
file : p1_11.wav
file : p1_128.wav
```

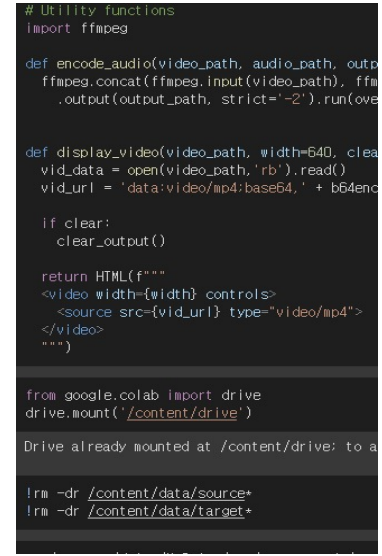
팀 내 역할과 주별 주요 활동

- 학습성능 향상을 위한 영상 편집 및 마스크 처리
- FSGAN
  - 박근혜 김주하 얼굴 합성 및 파라미터 튜닝

- starGAN
  - Model training
  - Loss terms, converge and density 등의
    정량 평가 데이터 분석, 가시화 및 최적 모델 탐색







```
# Utility functions
import ffmpeg

def encode_audio(video_path, audio_path, outp
  ffmpeg.concat(ffmpeg.input(video_path), ffm
    .output(output_path, strict='-2').run(ove


def display_video(video_path, width=640, clea
  vid_data = open(video_path,'rb').read()
  vid_url = 'data:video/mp4;base64,' + b64enc

  if clear:
    clear_output()

  return HTML(f"""
  <video width={width} controls>
    <source src={vid_url} type="video/mp4">
  </video>
  """)
```

```
from google.colab import drive
drive.mount('/content/drive')
```

```
Drive already mounted at /content/drive; to a
```

```
!rm -dr /content/data/source*
!rm -dr /content/data/target*
```

- 데모 시연 영상 편집 및 제작

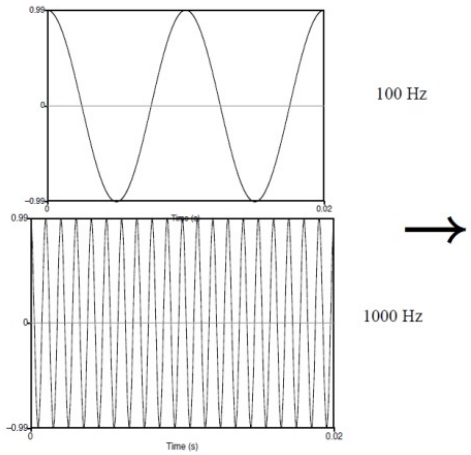
```
Elapsed [0:07:07], Iteration [1000/145000], D/loss_real: -107.6250, D/loss_f
Elapsed [0:14:34], Iteration [2000/145000], D/loss_real: -22.3380, D/loss_fa
Elapsed [0:21:59], Iteration [3000/145000], D/loss_real: -39.7920, D/loss_fa
Elapsed [0:29:25], Iteration [4000/145000], D/loss_real: -54.0177, D/loss_fa
Elapsed [0:36:50], Iteration [5000/145000], D/loss_real: -49.2912, D/loss_fa
Elapsed [0:44:16], Iteration [6000/145000], D/loss_real: -55.7255, D/loss_fa
Elapsed [0:51:42], Iteration [7000/145000], D
Elapsed [0:59:08], Iteration [8000/145000], D
Elapsed [1:06:34], Iteration [9000/145000], D
Elapsed [1:13:59], Iteration [10000/145000]
```

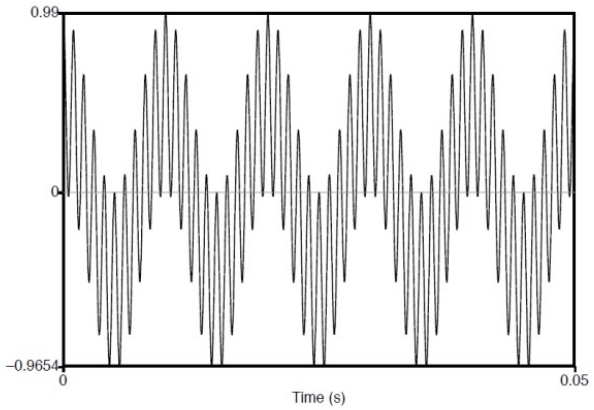
	iter	precision	recall	f_score	density	coverage	gen_loss	gen_rec_loss
197	198000/200000	1.0000	1.0000	1.0000	1.3333	1.0	2.4933	0.5139
190	191000/200000	1.0000	1.0000	1.0000	1.3307	1.0	2.8542	0.5175
194	195000/200000	1.0000	1.0000	1.0000	1.3333	1.0	2.8922	0.5178
196	197000/200000	1.0000	1.0000	1.0000	1.3333	1.0	2.9225	0.5187
189	190000/200000	1.0000	1.0000	1.0000	1.3333	1.0	3.2399	0.5187
...	...	...	...	...	...	...	...	...

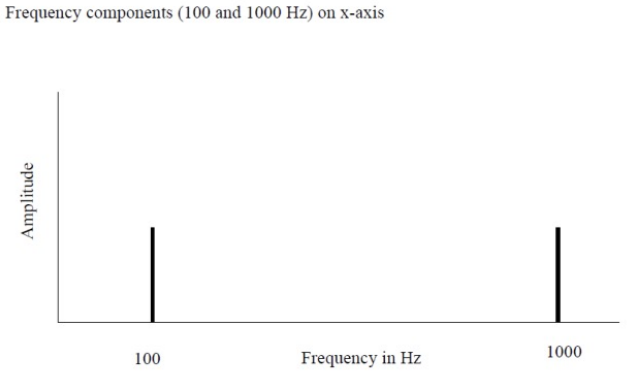
음성 feature 추출 방법

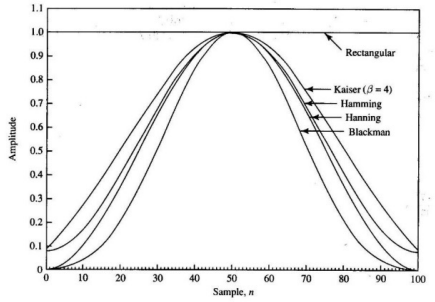
Voice data 분석 및 특징 추출법 연구

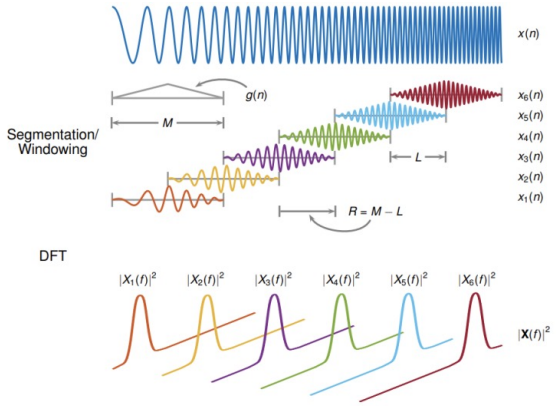
- 음성 파일 추출과 푸리에 변환 코드화











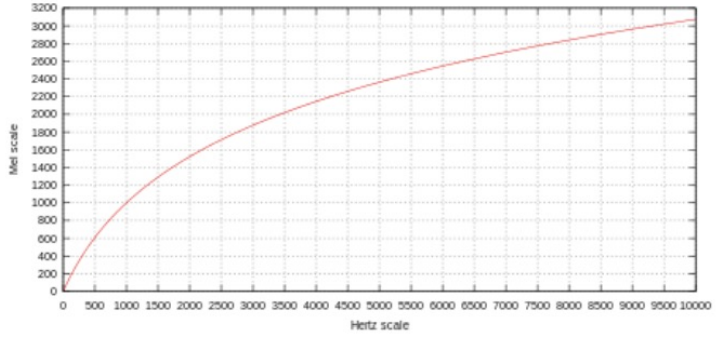

```python
def get_spk_world_feats(spk_fold_path, mc_dir_train, mc_
    paths = glob.glob(join(spk_fold_path, '*.wav'))
    spk_name = basename(spk_fold_path)
    train_paths, test_paths = split_data(paths)
    f0s = []
    coded_sps = []
    for wav_file in train_paths:
        f0, _, _, _, coded_sp = world_encode_wav(wav_fil
        f0s.append(f0)
        coded_sps.append(coded_sp)
    log_f0s_mean, log_f0s_std = logf0_statistics(f0s)
    coded_sps_mean, coded_sps_std = coded_sp_statistics(
    np.savez(join(mc_dir_train, spk_name+'_stats.npz'),
             log_f0s_mean=log_f0s_mean,
             log_f0s_std=log_f0s_std,
             coded_sps_mean=coded_sps_mean,
             coded_sps_std=coded_sps_std)

    for wav_file in tqdm(train_paths):
        wav_nam = basename(wav_file)
        f0, timeaxis, sp, ap, coded_sp = world_encode_wa
        normed_coded_sp = normalize_coded_sp(coded_sp, c
        np.save(join(mc_dir_train, wav_nam.replace('.wav

def world_decompose(wav, fs, frame_period = 5.0):
    # Decompose speech signal into f0, spectral e
    wav = wav.astype(np.float64)
    f0, timeaxis = pyworld.harvest(wav, fs, frame
    sp = pyworld.cheaptrick(wav, f0, timeaxis, fs
    ap = pyworld.d4c(wav, f0, timeaxis, fs)
    return f0, timeaxis, sp, ap

def world_encode_spectral_envelop(sp, fs, dim=36):
    # Get Mel-cepstral coefficients (MCEPs)
    #sp = sp.astype(np.float64)
    coded_sp = pyworld.code_spectral_envelope(sp,
    return coded_sp

def world_decode_spectral_envelop(coded_sp, fs):
    # Decode Mel-cepstral to sp
    fftlen = pyworld.get_cheaptrick_fft_size(fs)
    decoded_sp = pyworld.decode_spectral_envelope
    return decoded_sp

def world_encode_wav(wav_file, fs, frame_period=5
    wav = load_wav(wav_file, sr=fs)
    f0, timeaxis, sp, ap = world_decompose(wav=wa
    coded_sp = world_encode_spectral_envelop(sp =
    return f0, timeaxis, sp, ap, coded_sp
```

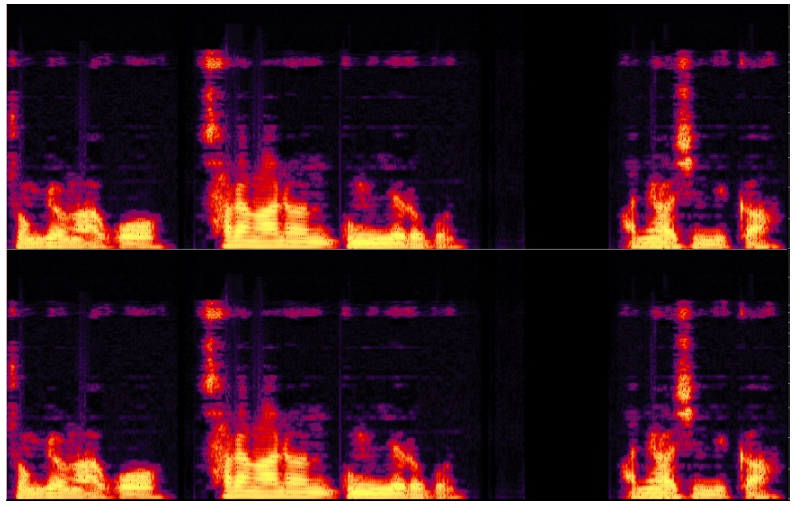
출처: SK t아카데미/ 스마트 ICT 전문가 양성/ 딥러닝 기반 음성학습 강의 자료

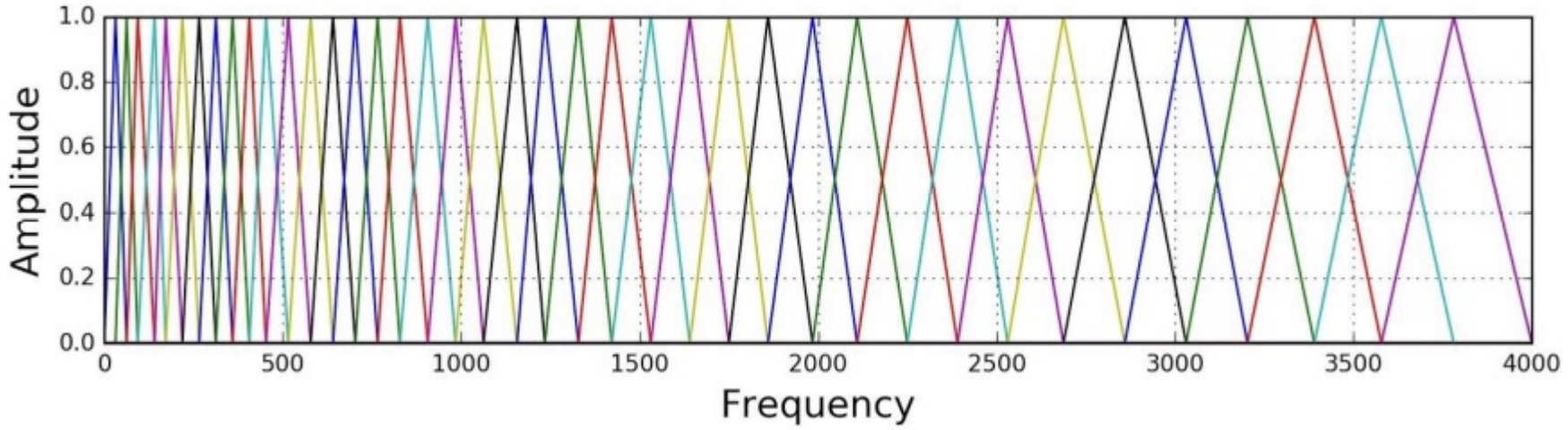
음성 feature 추출 방법

Voice data 분석 및 특징 추출법 연구

- **MCEP 채택**








```
    return wav_padded

def logf0_statistics(f0s):
    log_f0s_concatenated = np
    log_f0s_mean = log_f0s_co
    log_f0s_std = log_f0s_con

    return log_f0s_mean, log_

def pitch_conversion(f0, mean

    # Logarithm Gaussian norm
    f0_converted = np.exp((np

    return f0_converted

def wavs_to_specs(wavs, n_fft

    stfts = list()
    for wav in wavs:
        stft = librosa.stft(w
        stfts.append(stft)

    return stfts
```

출처: SK t아카데미/ 스마트 ICT 전문가 양성/ 딥러닝 기반 음성학습 강의 자료

FSGAN

얼굴 합성 데모 영상 생성 (박근혜 < - > 김주하)

->결과가 좋지 않아 fsGAN으로 모델 변경

- fsGAN 코드 실행 및 데모 생성

->결과 확인을 반복하여 가용 resource내에서

파라미터 튜닝

Iteration 800 > 1000, batch size 8 > 30

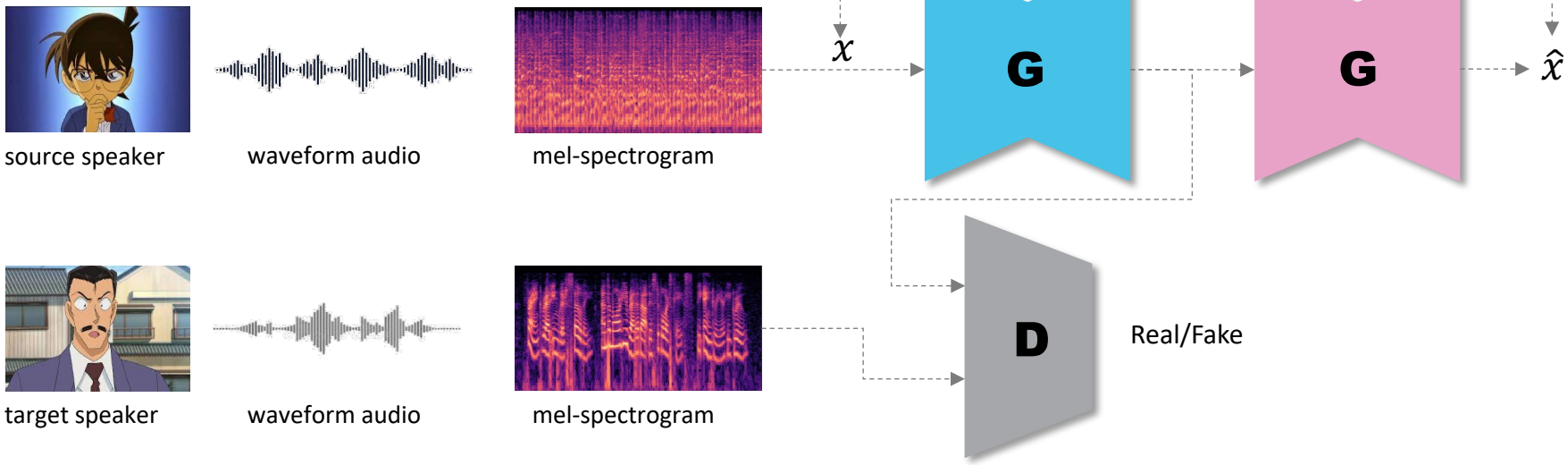

```
import os
from fsgan.inference.swap import FaceSwapping
from fsgan.criterions.vgg_loss import VGGLoss

#@markdown This step should only be done once unless one of the
#@markdown following parameters is changed:

#@markdown ---
#@markdown Path to the weights directory (make sure it is corr
weights_dir = '/content/drive/My Drive/fsgan/weights' #@param
#@markdown Number of finetune iterations on the source subject
finetune_iterations = 1000 #@param {type:"slider", min:100, ma
#@markdown If True, the inner part of the mouth will be remove
seg_remove_mouth = True #@param {type:"boolean"}
#@markdown Segmentation batch size
seg_batch_size = 30 #@param {type:"slider", min:1, max:64, ste
#@markdown Inference batch size
batch_size = 30 #@param {type:"slider", min:1, max:64, step:1}
#@markdown ---


detection_model = os.path.join(weights_dir, 'v2/WIDERFace_DSFD_
pose_model = os.path.join(weights_dir, 'shared/hopenet_robust_
lms_model = os.path.join(weights_dir, 'v2/hr18_wflw_landmarks.
seg_model = os.path.join(weights_dir, 'v2/celeba_unet_256_1_2_
reenactment_model = os.path.join(weights_dir, 'v2/nfv_msrunet_
completion_model = os.path.join(weights_dir, 'v2/ijbc_msrunet_
blending_model = os.path.join(weights_dir, 'v2/ijbc_msrunet_25
criterion_id_path = os.path.join(weights_dir, 'v2/vggface2_vgg
criterion_id = VGGLoss(criterion_id_path)
```

Voice Conversion

: 화자가 전달하려는 내용 (linguistic content)은 유지하고 우리가 원하는 대상화자의 말하기 특징 (acoustic feature)을 합성하여 목소리 스타일을 변환하는 기술을 의미한다.

발화 내용
- 동일한 발화 데이터를 사용하는지 여부 – Parallel vs Non-Parallel
- 발화된 언어가 동일한지 여부 – Mono-lingual vs Cross-lingual

발화자 구성
- 여러 명의 화자를 사용하는지 여부 – (one-to-one) vs (many-to-many)
- 동일한 성별의 화자를 사용하는지 여부 – (same gender) vs (different gender)



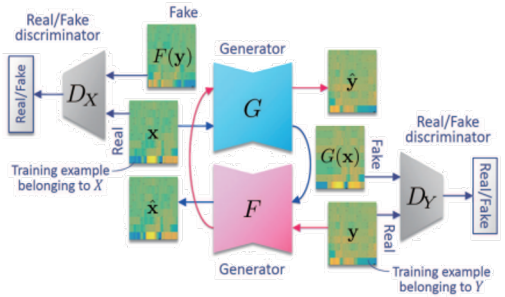
Voice Conversion Models

모델 선택

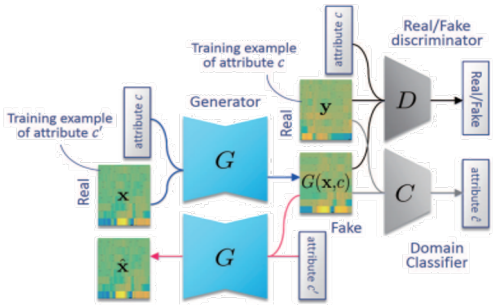
: CycleGAN-VC, StarGAN-VC

목적

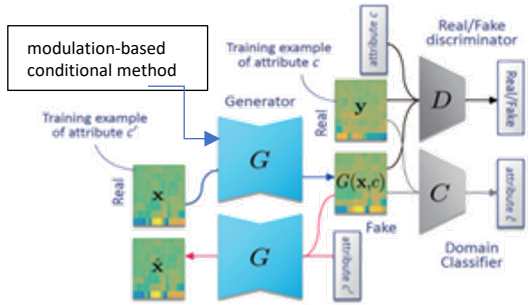
: 각 모델이 갖는 특성에 따라 합성된 음성의 퀄리티가 어떻게 달라지는지 살펴보고 음성 함성 도메인에서 개선의 여지가 있는 기능들을 살펴보고자 한다.



CycleGAN-VC



StarGAN-VC



StarGAN-VC2

선행 분석

- 다양한 sampling rate 설정 : 16K, 22K, 32K
- 배치사이즈 변경 : 16, 128, 256
- 학습 iteration : 50K, 100K, 200K
- 다양한 목소리 특징을 갖는 화자를 구성하여 학습
  : 박근혜, 유인나, 아이유, 김주하

분석 결과

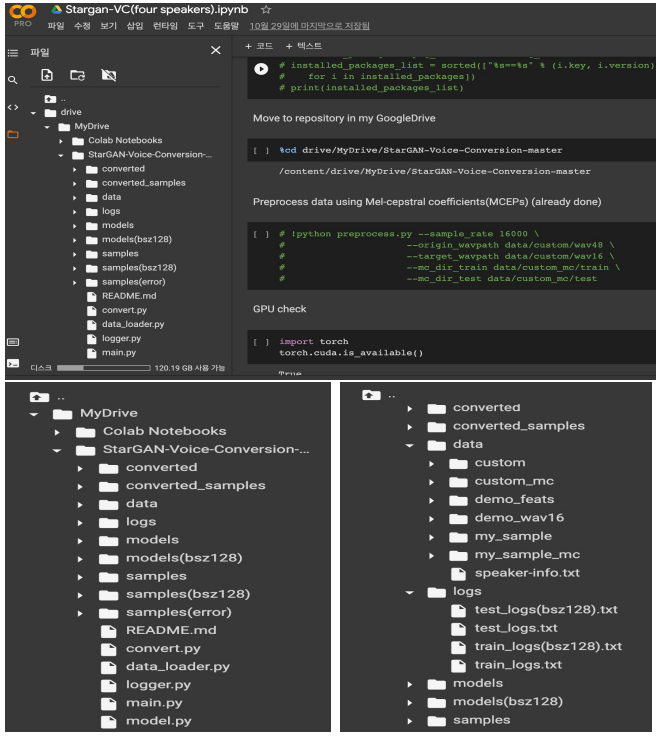
- 기존 연구에서 사용되는 16K로 resampling하는 결과가 제일 좋음
- 배치사이즈가 적을 수록 미세하게 좋은 합성 결과를 얻음
- 배치사이즈를 작게 설정하고 iteration을 많게 설정하면 비교적 안정적인 음성 합성 결과를 얻음
- 목소리의 높낮이나 말의 빠르기가 많이 차이나는 화자 간의 음성합성은 잘 되지 않는 결과를 얻음

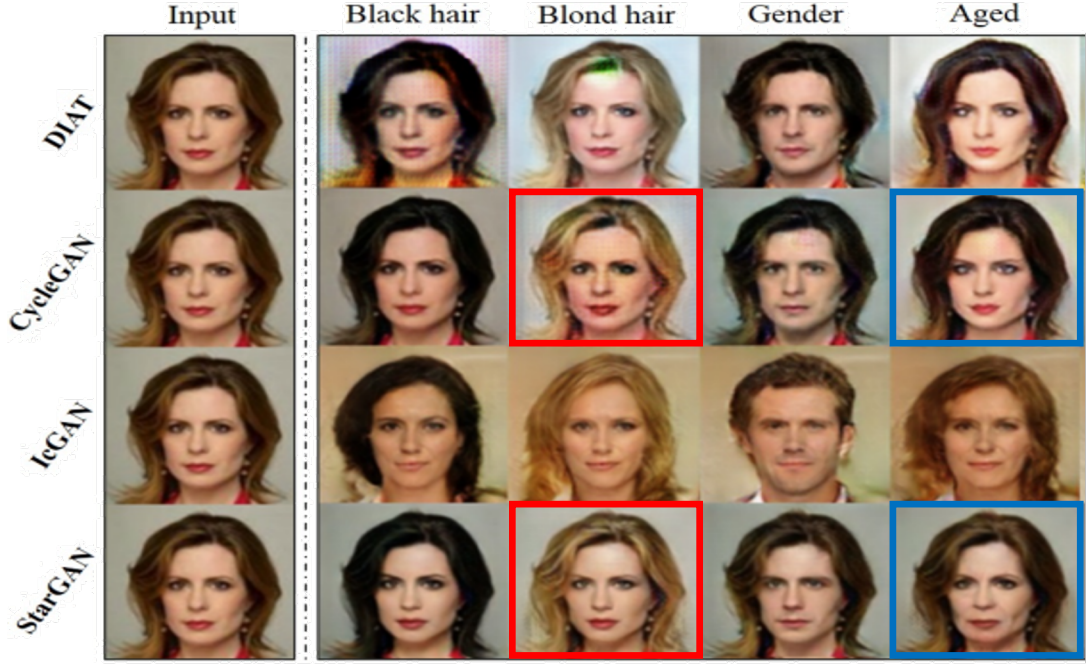
Model Comparison (1)

	CycleGAN-VC	StarGAN-VC	StarGAN-VC	StarGAN-VC2
Classification Loss (discriminator)	×	O	O	O
Domain code modulation (Generator)	×	Depth-wise modulation	Depth-wise modulation	Conditional instance normalization
Reconstruction Loss	O	O	O	O
Domain A-Domain B	One-to-One	One-to-One	Many-to-Many	Many-to-Many

CycleGAN-VC (one-to-one)
vs
StarGAN-VC (one-to-one)

StarGAN-VC (one-to-one)
vs
StarGAN-VC (Many-to-Many)





Facial attribute transfer results on StarGAN

Model Comparison (2)

	CycleGAN-VC	StarGAN-VC	StarGAN-VC	StarGAN-VC2
Classification Loss (discriminator)	×	O	O	O
Domain code modulation (Generator)	×	Depth-wise modulation	Depth-wise modulation	Conditional instance normalization
Reconstruction Loss	O	O	O	O
Domain A-Domain B	One-to-One	One-to-One	Many-to-Many	Many-to-Many

StarGAN-VC (Many-to-Many) vs StarGAN-VC2 (Many-to-Many)

sample 1

sample 2

Run Demo

```
!python convert.py --resume_iters 100000 --src_spk p1 --trg_spk p2

Namespace(convert_dir='./converted', log_dir='./logs', model_save_dir='./models', num_converted_wav
Loading the trained models from step 100000...
131120
Before being fed into G:  (1640, 36)
After being fed into G:  (1640, 36)
112560
Before being fed into G:  (1408, 36)
After being fed into G:  (1408, 36)
67760
Before being fed into G:  (848, 36)
After being fed into G:  (848, 36)
65840
Before being fed into G:  (824, 36)
After being fed into G:  (824, 36)
177200
Before being fed into G:  (2216, 36)
After being fed into G:  (2216, 36)
159920
Before being fed into G:  (2000, 36)
After being fed into G:  (2000, 36)
193200
Before being fed into G:  (2416, 36)
After being fed into G:  (2416, 36)
140720
Before being fed into G:  (1760, 36)
```

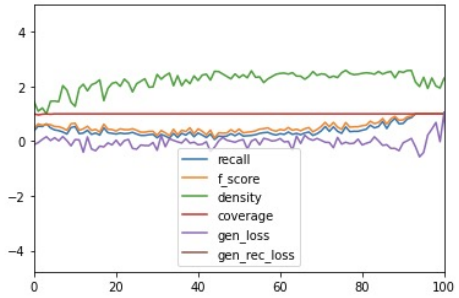
Limitation on previous methods

: Source speaker의 음성 길이에 맞춰 target 스피커의 말 하기 특징 (acoustic feature)을 합성하다 보니 여전히 source speaker의 음성 특징 정보가 남아 음성합성 결과에 안 좋은 영향을 미침

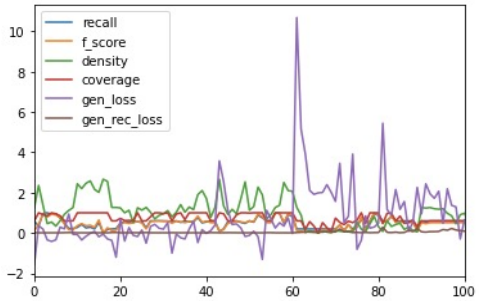
Experimental Results (1)

정량적 결과 (Quantitative Results)

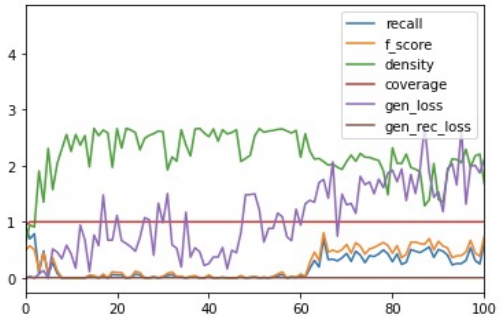
Evaluation metrics: precision, recall, density, coverage



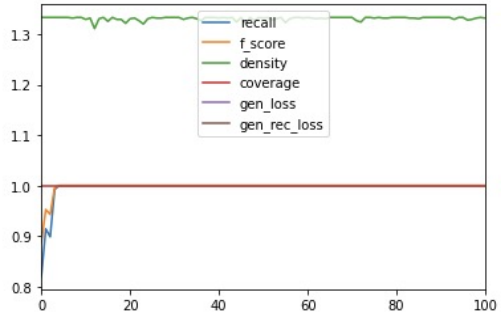
CycleGAN-VC



StarGAN-VC (2p)



StarGAN-VC (4p)



StarGAN-VC 2 (4p)

정성적 결과 (Qualitative Results)

평가 방법: 구글 설문조사를 통해 음성파일을 듣고 좀 더 문재인 (target speaker)의 목소리와 비슷한 샘플에 순위를 매기도록 함

음성 합성 샘플 : 김상중 → 문재인

설문조사자 수: 25명

질문 목록

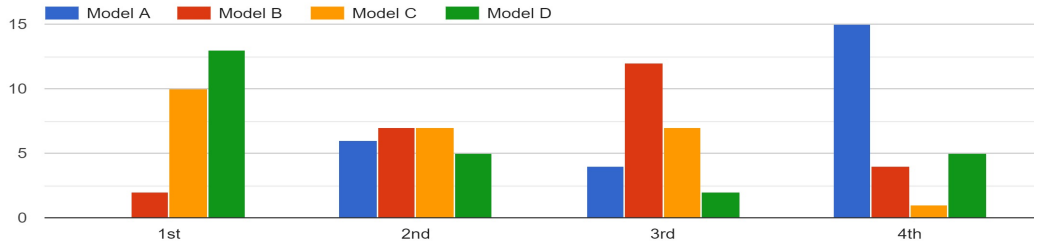
- 각 모델이 합성한 음성 샘플을 비교하여 어떤 모델이 정성적으로 좋은 결과 가지는가?
- 정량지표 (Density, Reconstruction Loss, Generation Loss) 의 min, max, median 값을 시점 (iteration)의 모델의 정성평가 (StarGAN-VC 2 모델로 고정)

Experimental Results (2)

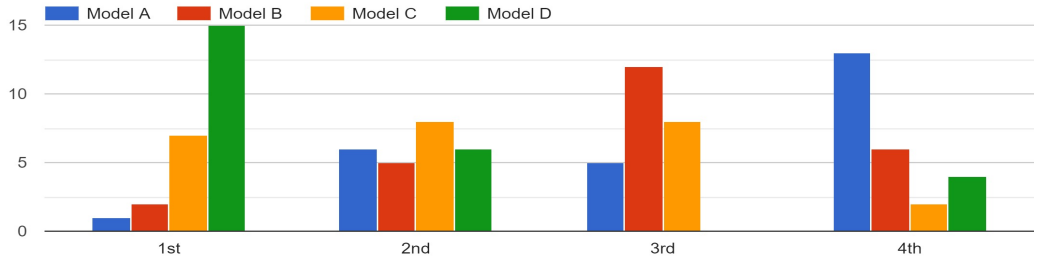
Model A : CycleGAN-VC
Model B : StarGAN-VC (2p)
Model C : StarGAN-VC (4p)
Model D : StarGAN-VC 2 (4p)

Recon_loss: reconstruction loss
Gen_loss : generation loss

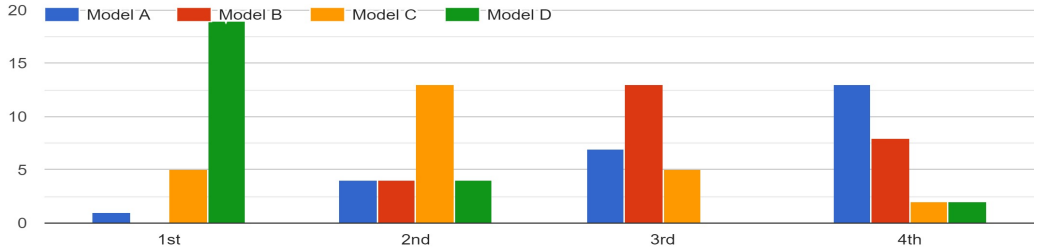
Q1-1



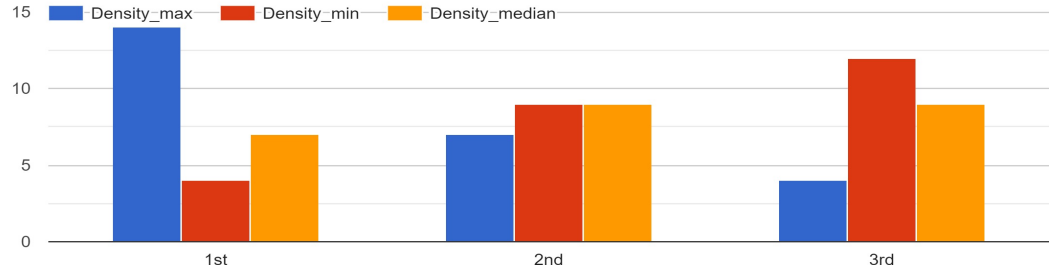
Q1-2 : link



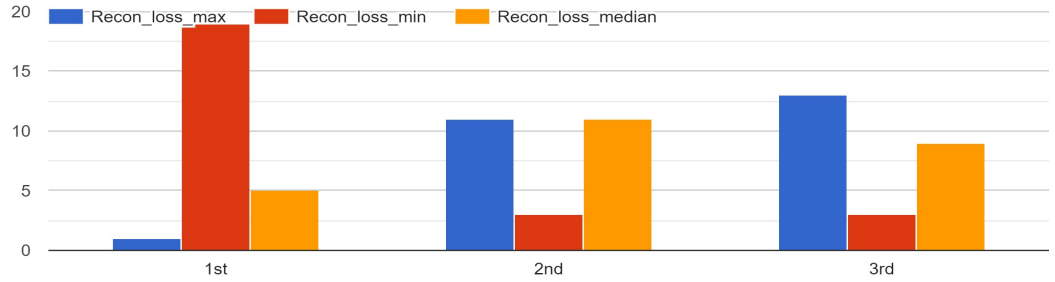
Q1-3 : link



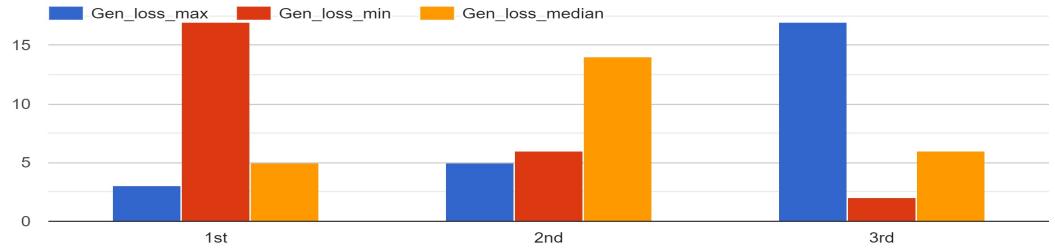
Q2-1 : link



Q2-2 : link



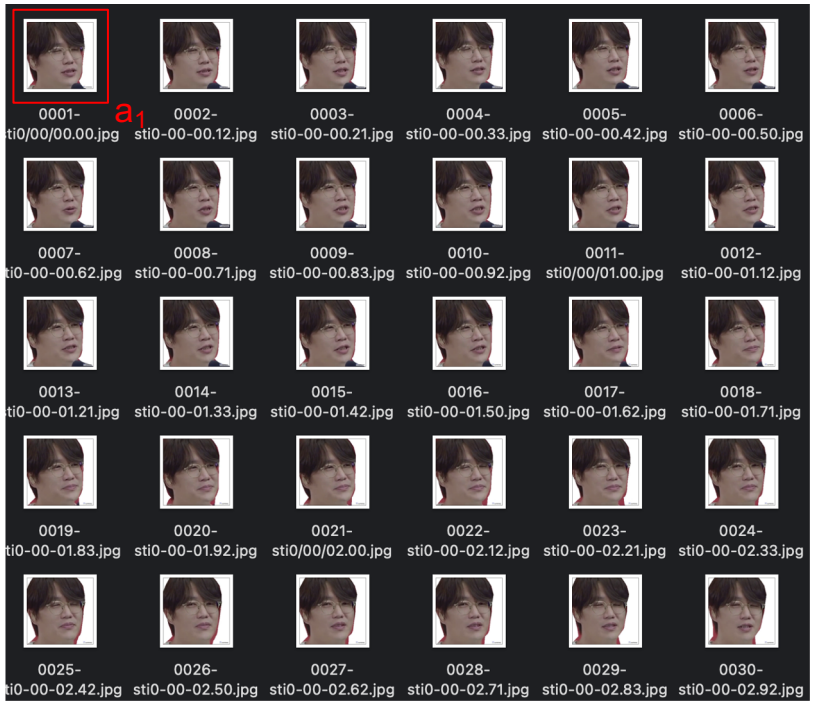
Q2-3 : link



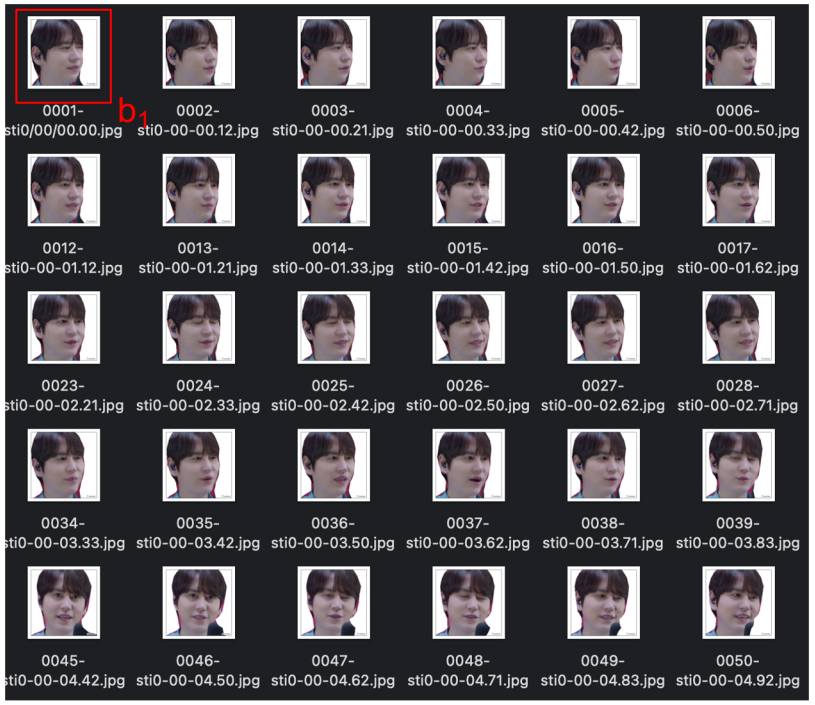
Average similarity

- Problem
  - The more movement on the face, the lower the performance
  - It takes about an hour to synthesize the two videos.
- Average similarity between the two videos
  - Feature types: Pixel vs. Face embedding(FaceNet) vs. PCA
  - Metrics: Cosine similarity, MSE, SSIM(Structural Similarity Index Measure)
  - $$\frac{\Sigma[Cosine\,sim,\ MSE,\ SSIM](a_n,\ b_n)}{n}$$

A



B



Average similarity

Cosine sim: 0.7563 | 비 → 김종국

Cosine sim: 0.8391 | 성시경 → 비

Cosine sim: 0.9358 | 김종국 → 성시경

Cosine sim: 0.9437 | 규현 → 성시경

Demo video

김상중 → 문재인

박근혜 → 김주하

Conclusion

- Experience in synthesizing videos from data collection to demo video
  - 논문리뷰 → 코드실습 → 데이터셋 수집 → 모델학습 → 데모영상
- Voice
  - Sampling rate, batch size, iteration, …
  - 정량 및 정성평가
- Video
  - Average similarity between the two videos
- Future work
  - 음성) Source speaker의 음성내용에 Target speaker 목소리 톤을 입히는 경우 Source speaker의 음성 길이에 맞춰 Target speaker의 목소리 톤을 합성하다 보니 자연스러운 음성 변환이 힘든 경우가 있다.
    - Target speaker의 corpus당 음성 길이를 유지하기 위한 loss term을 학습과정에 추가하여 Target speaker의 자연스러운 음성 변환
  - 클래스당 데이터의 개수를 늘리고 좀 더 다양한 클래스를 구성하여 모델을 학습하도록 한다
  - Voice conversion에서 feature를 추출한 방법 상 고주파수 영역의 소리, phase 정보 손실
    - MFCC로 feature 추출 방법을 변경
    - wav 파일 자체를 feature로 사용(학습 시간이 오래 걸리기 때문에 추후 예정)

Q & A