15-821 Course Project

Cloudlet-based Real-Time Deep Face Swap on Mobile Devices

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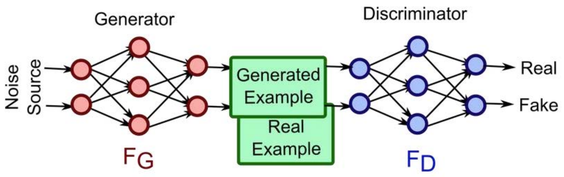
Background

Face reenactment is a fairly interesting research topic in the field of computer vision. In general, it takes images or live video feed as input, detect faces in them, and superimposes these faces, including facial movements, to another person in a natural-looking way.

Traditional 3D model based approach[1] requires massive computational resources, and no open source solution is available online. However, recent appearance of GAN (Generative Adversarial Networks) made it possible to do image translation with deep learning. Our project is based on Pix2Pix[2], an open source image translation framework using GAN, and Face2Face[3], an open source face reenactment application.

A **GAN** consists of two neural networks, one learns to generate fake samples that are close to target, the other learns to discriminate the generated fakes and the authentic targets.

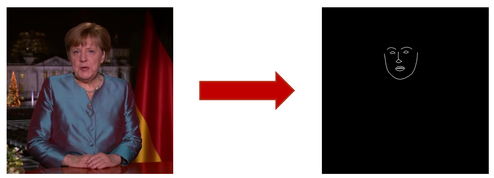


Pix2Pix aims to solve the image translation problem. The training data contains a source and a target, and Pix2Pix trains a GAN on such data. The trained generator can then construct pictures given an input image. The input image must have similar context with the source images in the training dataset to get satisfactory results.

Methodology

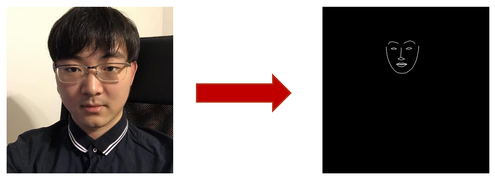
We used the method introduced in Face2Face to train the GAN model for face reenactment and translate input images using the trained models.

First, we preprocess frames captured from a video, selecting frames that have a face in it, and generate abstracts of facial landmarks.



Second, we train the GAN that is used in Pix2Pix, with the source being the facial landmarks, and the target being the video capture.

Third, we get the testing image from camera stream and generate its corresponding facial landmark. The facial landmarks are transformed to match the characteristics of facial landmarks in the training data.

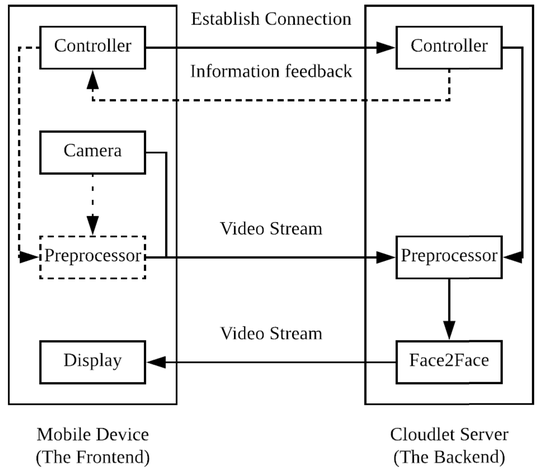


Last, we use the transformed facial landmarks as input to the trained GAN generator, and get our facial reenactment result

We run the whole application logic on **cloudlets**, because the mobile devices lacks the processing power to run a deep neural network and stream transformed video with reasonable framerate, resolution and latency. In fact, the performance for the model on a powerful GPU is barely just acceptable, with an average framerate of 12.6 FPS

System Design

Below is the design diagram for our system.



Our design is based on **Gabriel**, a cloudlet-based computation platform that supports offloading of mobile workloads. More specific, the frontend and the backend are modifications of Gabriel's frontend and backend.

Elements in solid lines represents the major workflow of our system and are all implemented. Elements in dashed lines represents the alternate workflow and are potential future improvements on the system. Detailed workflow is listed below.

1.The frontend controller establishes connection to the controller on the backend.

2.Upon successful connection, the camera on the frontend streams video to the preprocessor on the backend.

3.The preprocessor on the backend preprocesses the input video and send result to the Face2Face algorithm implementation on the backend.

4.The Face2Face algorithm implementation on the backend processes the video and streams back the output to display on the frontend.

5.The backend controller gathers performance data and dynamically adjusts the fidelity of the output video stream.

Lessons Learned

1. We found that the quality of training data is extremely important. We've trained over 20 models using 5 different input datasets and tested various pre-processing techniques, but only 2 of the input datasets yield good results.
2. Proper pre-processing of input data and post-processing of output video is vital for the final quality of face reenactment. Figures below shows outputs of the model with inadequate pre-processing, where facial landmarks are not properly transformed to match the training targets.

Head too close | Head close and low | Preprocessed

3. Latency is very important in live video based applications. For an app like real time face reenactment, it's more acceptable to have low resolution and low frame rate than to have high latency. High latency will make the output and input totally unsynchronized, which eventually confuses the user.
4. For an mobile application, if the performance is largely dependent on network conditions, it's essential to make the application adaptive to network changes, and one effective method is to alter the fidelity of the app's content.

References

[1] Thies, Justus, et al. "Face2face: Real-time face capture and reenactment of rgb videos." *Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition*. 2016.

[2] Isola, Phillip, et al. "Image-to-Image Translation with Conditional Adversarial Networks." *2017 IEEE Conference on Computer Vision and Pattern Recognition (CVPR)*. IEEE, 2017.

[3] Tran, Face2Face-demo, Github Repository, https://github.com/datitran/face2face-demo