GAN-Based Finger Vein (FV) Image Augmentation For Biometric Authentication

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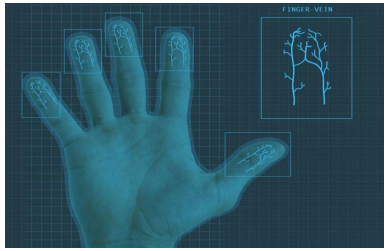
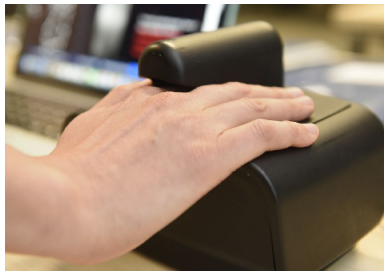
Presentation

- Global ID is a Swiss startup specialized in cyber-security through :
  - High level of security and confidentiality
  - Fighting against identity thief
  - Developing the technology : **Scanner for 3D Finger Vein (FV)**

- Advantages of FV biometrics [1]
  - **Uniqueness** of each person's FVs
  - **Resistant** to forgery and replication
    - FVs are inside the human body and invisible to human eyes
  - **Untraceable** in the future
    - Due to the absence of physical contact between customers and sensor devices.
  - **End-to-end encryption (E2EE)**



Finger vein (FV)
for biometric authentication system



3D FV scanner

[1] AH Mohsin et al., Finger vein biometrics: Taxonomy analysis, open challenges, future directions, and recommended solution for decentralised network architecture, IEEE Access 2020

FV-based Biometric Authentication System

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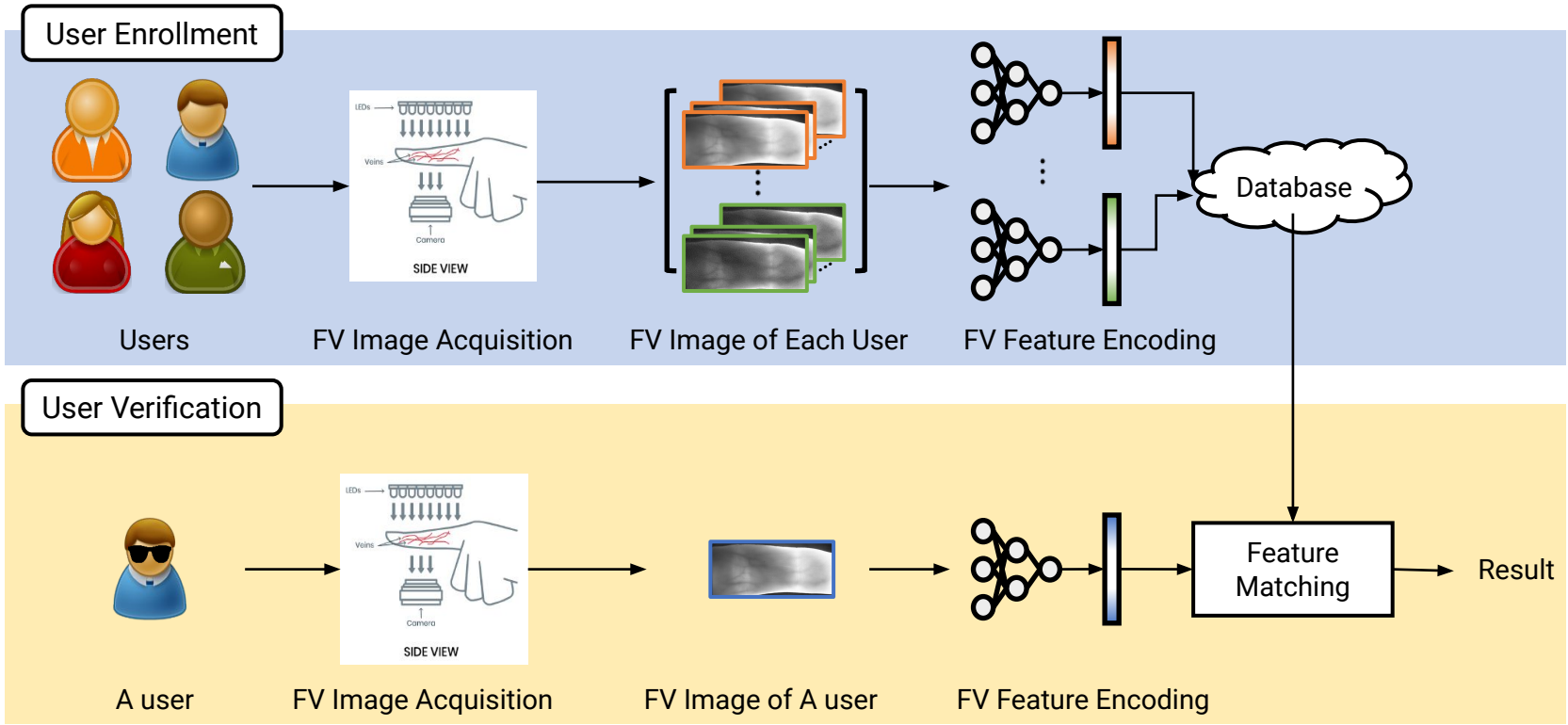


Problems & Motivation

- Importance of diverse training dataset in deep learning for biometric authentication
  - DL methods demonstrate state-of-the-art results for biometric authentication
  - However, performance and robustness of DL **depend upon availability of a diverse training dataset to learn different users' attributes and capturing conditions** such as shape or luminance characteristics

- Difficulty of a large scale data collection for biometric authentication
  - Large scale dataset collection is time consuming, complicated and labor intensive
  - It **requires a variety of biometric patterns from each person, also in different conditions**

- Necessity of data augmentation in the domain of finger veins authentication
  - In the FV images field, there are ***uncontrollable factors such as environmental illumination, light scattering or misplaced fingers in the scanner***.
  - ***Augmenting the data by anticipating those parameters*** becomes a necessity to counter them.

Contribution to the project

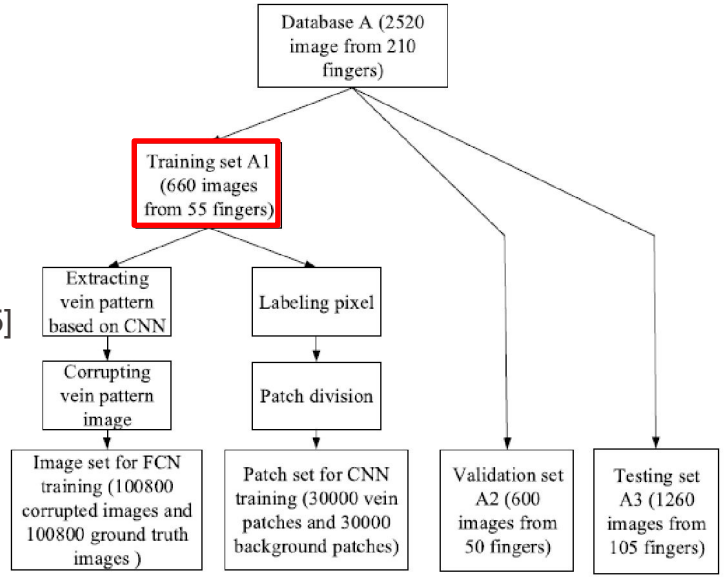
1. Generation of a large number of finger veins images from a small starting dataset using Generative Adversarial Network (GAN)

2. Designing of a GAN-based FV image data augmentation framework, considering spatial variation and illumination variation in FV image acquisition

3. Integration of the algorithm in the Global ID startup pipeline
   a. Create useful images, meaning not only resembling original FV images, but with features able to help the startup to be more efficient and precise

Related Work

- DL-based FV authentication
  - Several existing works on FV image features representation based on DL [2,3]
  - However, **experiments were conducted with a limited number of FV image**
- Data augmentation for FV authentication
  - Simple data augmentation such as pre-defined scale or translation was used to improve authentication [4,5]
  - **No research on data generation to improve the FV authentication**
- Others
  - Global ID paper [6]
  - CycleGAN paper [7]
  - Spatial Transformer Networks paper [8]

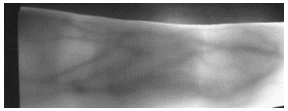


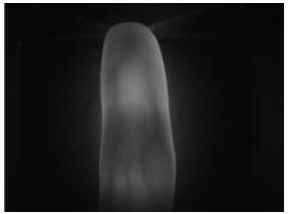
Data petitioning and training data construction in [2]

[2] H Qin and MA El-Yacoubi, Deep representation-based feature extraction and recovering for FV verification, IEEE TIFS 2017
[3] W Yang et al., FV-GAN: Finger vein representation using GANs, IEEE TIFS 2019
[4] KJ Noh et al., Finger-vein recognition based on densely connected CNN using score-level fusion with shape and texture images, IEEE Access 2020
[5] J Choi et al., Modified conditional GAN-based optical blur restoration for FV recognition, IEEE Access 2020
[6] Durak et al., BioLocker: A Practical Biometric Authentication Mechanism based on 3D Fingervein, IACR Cryptol. ePrint Arch., vol. 2020
[7] Zhu et al., Unpaired image-to-image translation using cycle-consistent adversarial networks, arXiv 2017
[8] Jaderberg et al., Spatial transformer networks, arXiv 2016

Database survey & Collection

- VERA Finger Vein Database for Finger Veins recognition
  - Produced by IDIAP Research Institute, used by the Global ID startup
  - Total of 440 images from 110 subjects (4 FV images for each subject)
- Finger Vein USM (FV-USM) Database
  - Produced by Universiti Sains Malaysia for FV recognition
  - 2 sessions, 123 subjects, 4 fingers and 6 pictures taken
  - **Total of 5,904 images from 123 subjects (48 FV images for each subject)**
- Tsinghua University Finger Vein and Finger Dorsal Texture Database (THU-FVFDT)
  - Produced by Tsinghua Univ. for FV representation and authentication
  - 3 databases but only 1 of interest
  - Total of 1,220 images from 610 subjects (2 FV images for each subject)

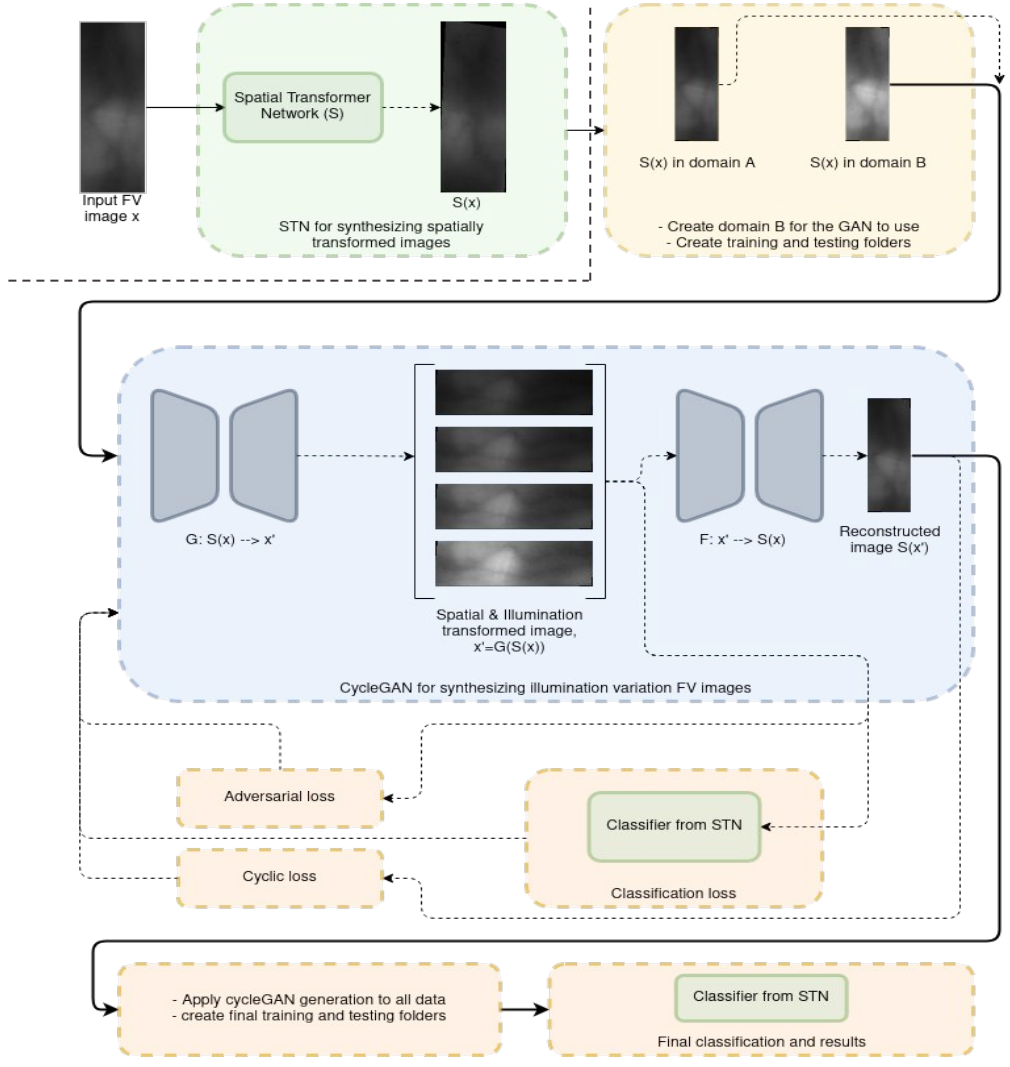




Examples of FV image in each database

Full framework

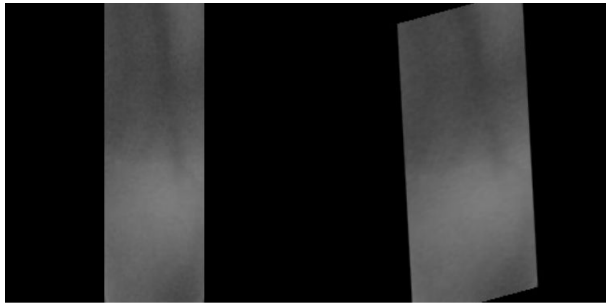
1. FV Spatial Transformer
2. Illumination variation
3. FV Illumination Transformer
   a. Adversarial loss
   b. Cyclic loss
   c. Classification loss
4. Data augmentation
5. Reclassification

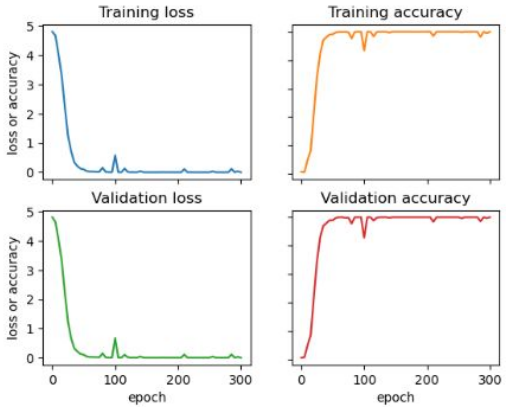


FV Spatial Transformer Network

- Help to spatially place and transform FV images, based on scale, location and orientation

1. Localisation network
2. Spatial Transformer module
3. Classifier





Batch size	Learning rate							
	0.0001		0.001		0.01		0.0005	
1	4.812	0.008	4.812	0.008	4.824	0.008	4.812	0.008
4	4.444	0.637	10.430	0.009	4.816	0.008	4.812	0.008
16	2.085	0.720	4.812	0.008	4.814	0.008	12.221	0.203
32	**1.770**	**0.765**	4.812	0.008	4.813	0.008	8.723	0.380
64	1.784	0.737	4.813	0.007	4.813	0.007	4.579	0.586

Table 3.5 – Epoch 300 (test loss & test accuracy)

FV Illumination Transformer

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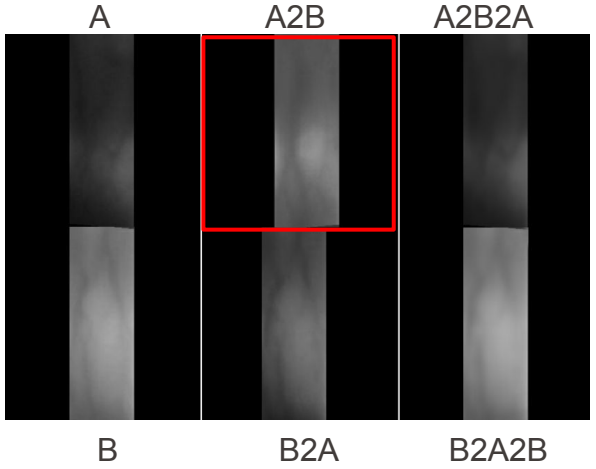
- Generative aspect of the framework was based on the cycleGAN
- Two losses : Adversarial loss & Cyclic loss

- FV images had to be resized to 256x256
- To avoid losing information, use of **zero-padding** so ratio of FV images remains the same

- Our contribution :
  - Add a **new classification loss** with the use of the FV Classifier
  - Remove the zero-padding → classify
  - Difference between true label and classified label is classification loss



- When the generator works well, we can have the whole dataset be the first domain from which the second domain will be generated

Results

- Important results that we achieved :

Baseline (FV Classifier)	0.612	
FV Classifier + FV Spatial Transformer	0.765	
FV Classifier + FV Spatial Transformer + FV Illumination Transformer	0.625 → 0.714 0.640 → 0.704 0.681 → 0.715 **0.576 → 0.736**	14% 10% 5% **27%**

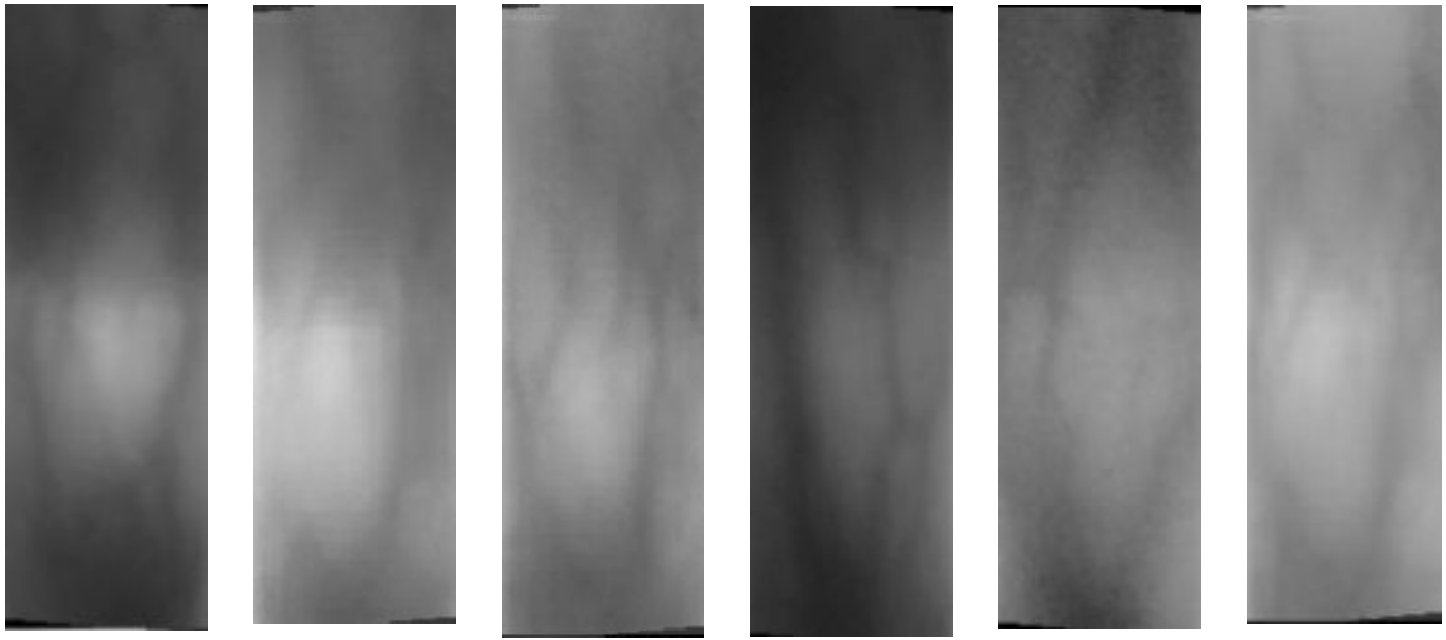
1. Fully functional code, GAN implementation, useful to the startup
2. Double the size of database by modifying the FV illumination
   a. Different values of illumination could be applied to further augment
   b. Basic transformation, without knowledge could also be applied

Conclusion

- The possibility for FV image augmentation to improve authentication is real
  - We achieved an accuracy improvement in a just a few months of at least 10%

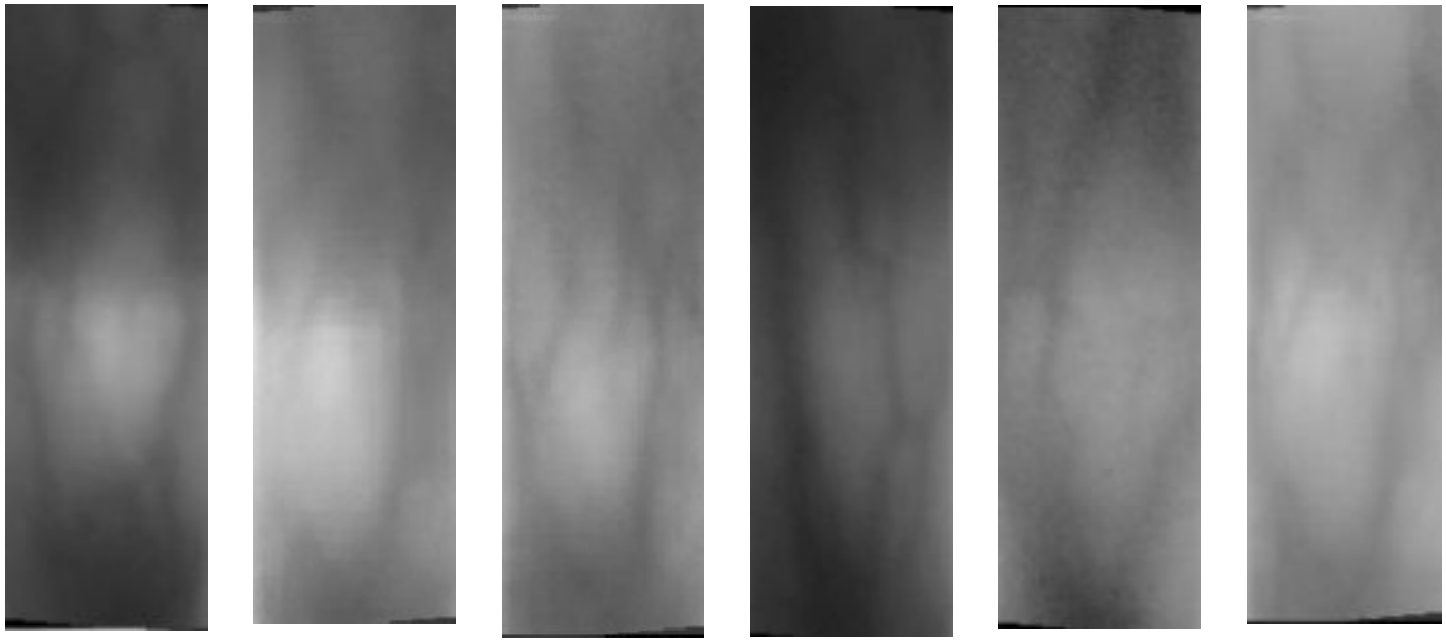
- Potential ideas and openings for the future:
  - Addition of another loss based on the FV extractor of the startup Global ID
  - Implement another type of GAN like the StarGAN for augmenting the database on a bigger scale at once
  - Use of multiple databases at once as seen in the Related Work

Quiz time !



- Which are real, which are fake ?

Quiz time !



REAL FAKE FAKE REAL REAL FAKE

Questions ?

Thank you for your attention !