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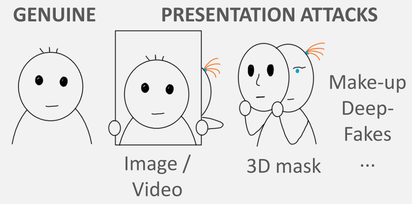
Closing the gap: An Annotated Synthetic Large-Scale 3D Dataset with Low-Cost Time-of-Flight Data and High-Quality Ground Truth

Motivation

Although face recognition has become part of our everyday lives, 2D face recognition still faces several challenges. While 3D face recognition can overcome most of these challenges, acquiring high-quality 3D data is costly. To ensure a high level of security and meet the increasing demand for face recognition applications, affordable 3D face recognition solutions are needed.
While low-cost Time-of-Flight (ToF) cameras could reduce hardware costs, they currently lack accuracy. To bridge the quality gap and develop reliable face recognition algorithms, a large-scale dataset with ToF data and high-quality ground truth is required. As the available datasets do not meet these requirements, we develop an annotated large-scale datasets with low-quality ToF data and high-quality ground truth.

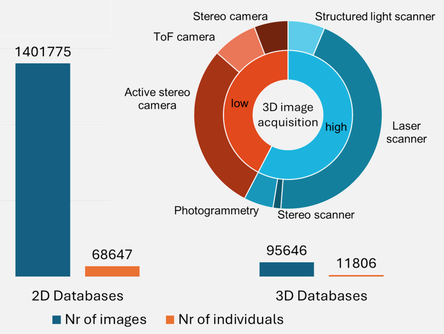
3D Face Recognition compared with 2D Face Recognition [1,2]

Advantages	Disadvantages



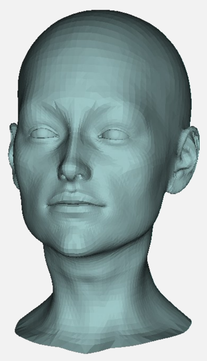
- More secure against presentation attacks
- Stable illumination variation
- Pose independent

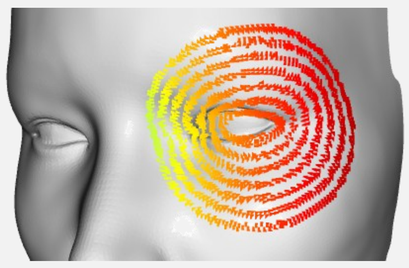
- High hardware costs
- Few algorithms
- Large databases missing



Methods

Synthetic high-quality dataset
1. Dataset creation: The synthetic characters are created with the Open-Source 3D graphics software tool Blender using the Human Generator Plugin.
2. Face Recognition Analysis: We evaluate the realism of the synthetic data by comparing its recognition rates to the recognition rates of real-life face data captured at the H-BRS's biometric evaluation center (BEZ). As deep-learning algorithms can be biased due to the limited annotated datasets and their decisions are not always explainable, we use conventional 3D face recognition algorithms instead. To reduce bias and offer a better comparison we evaluate both synthetic and real datasets using multiple algorithms.

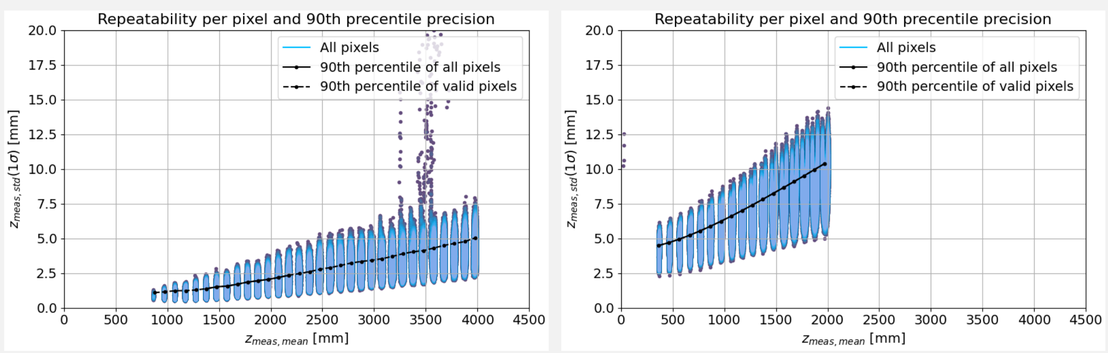




Visualization of the curve-based face recognition algorithm proposed in [3] for the eye-region. Two faces are compared by correlating the curvature on equi-distant points on several geodesic level curves in the eye and nose region.

Simulation of sensor characteristics

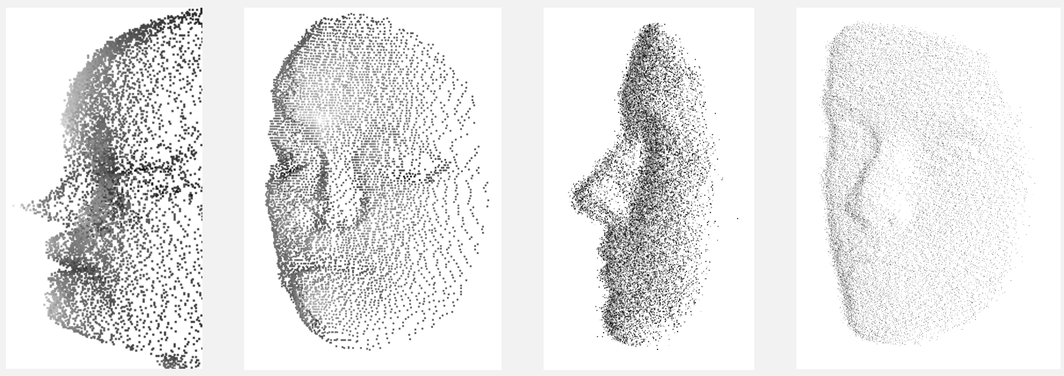
To generate the sensor data, the high-quality ground truth data is used as the scene and rendered with a ToF camera simulation. The simulation is based on Uni Siegen's CamSim simulation [4]. Additionally, we enhance the CamSim application with the simulation of wiggling, multi-frequency phase unwrapping and subsurface scattering for skin. To ensure realistic behavior, simulated output is compared to real-life data.



Comparison between real (left, Basler blaze101) and simulated (right) ToF-camera's statistical measurement error. For each distance 100 frames are captured / computed.

Preliminary results

Status:
- 16,000 characters created
- 1 of 3 face recognition algorithms implemented [5]
- Enhanced simulation including wiggling error and multi-frequency phase unwrapping



real data (Basler blaze-101) simulated data

Comparison of real and simulated ToF-camera face data. While the noise looks realistic, systematic artefacts are not yet simulated correctly.

Bibliography:
[1] Guo, Y., Wang, H., Longguang, W., Lei, Y., Liu, L., Bennamoun, M. (2023). 3D Face Recognition: Two Decades of Progress and Prospects. In ACM Comput. Surv. 56, 3, Article 54.
[2] Grgic, M., Delac, K. (2020). Databases. Face Recognition Homepage. face-rec.org/databases/.
[3] Jribi, M., Mathalouthi, S., Ghorbel, F. (2021). A geodesic multipolar parametrization-based representation for 3D face recognition. In Signal Processing: Image Communication, 99.
[4] Lambers, M., Hoberg, S., A. Kolb (2015). Simulation of Time-of-Flight Sensors for Evaluation of Chip Layout Variants. In IEEE Sensors Journal, 15(7), pages 4019-4026.
[5] Mielke, A. (2025). 3D Face Recognition: Implementation of Jribi's geodesic multipolar parameterization-based representation (2021) (Version 0.1.0-beta) [Computer software]

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