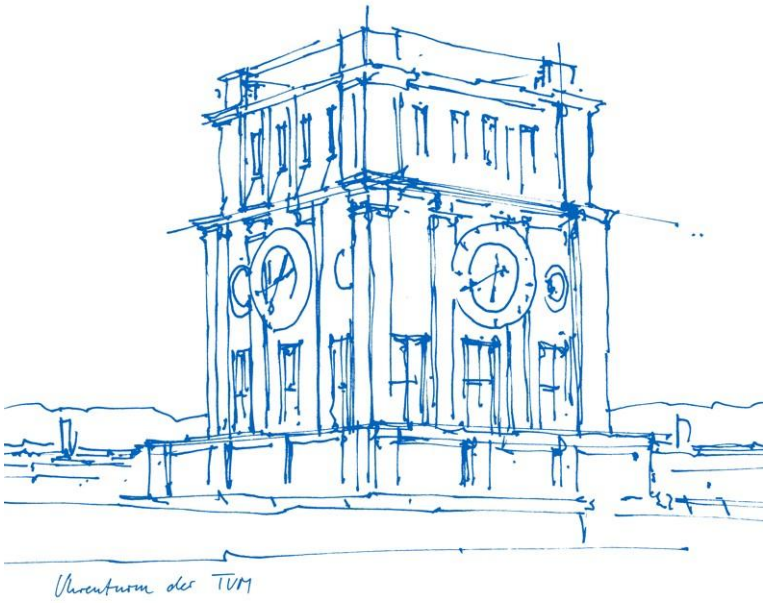
Chair of Computer Vision and Artificial Intelligence
Department of Informatics
Technical University of Munich

Face Recognition with a 3D Camera On an Embedded Processor

Master Thesis Defence



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Outline

1. **Problem Introduction**
2. Methods
3. Results and Analysis
4. List of Contributions
5. Conclusion and Future Work

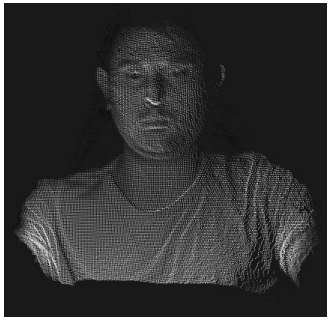
Face Recognition

- Images containing face as an input
- Extraction of face from scene
- Face crop to feature vector
- N + 1 labels as output

2D vs 3D

- Deep Learning performs good for 2D Face Recognition.
- Spoof Detection in 2D is not much reliable.

- Complexity increases when we move from 2D to 3D.
- Increased resource requirement for increased complexity
- Spoof Detection is simple using geometry information in 3D



Problem Statement

- 3D Face Recognition using low resolution depth camera
- Utilizing depth and intensity images only
- Most databases contain high resolution depth and color(not intensity) images
- Solution should run on embedded processor like Raspberry Pi

https://pmdtec.com/picofamily/wp-content/uploads/2018/03/picoflexx-ifm.jpg

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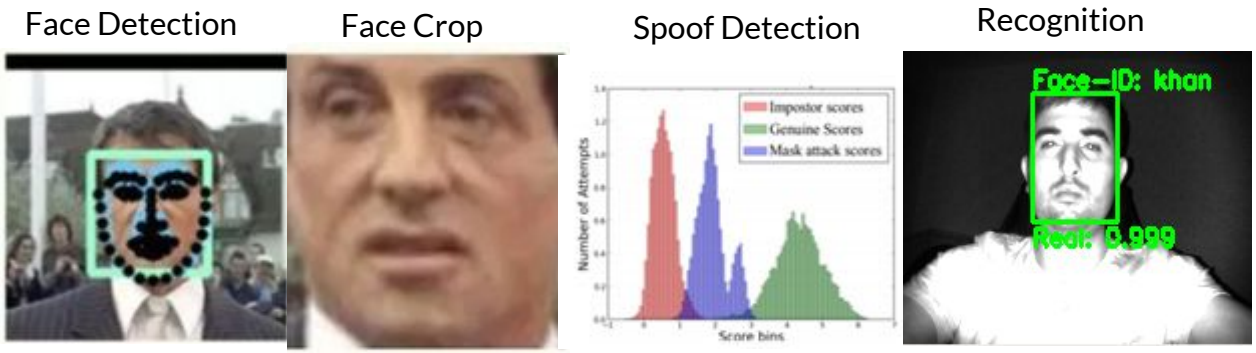
2D Face Recognition with Spoof Detector

- FaceNet Encodings + SVM for Identity, DCNN for Spoof

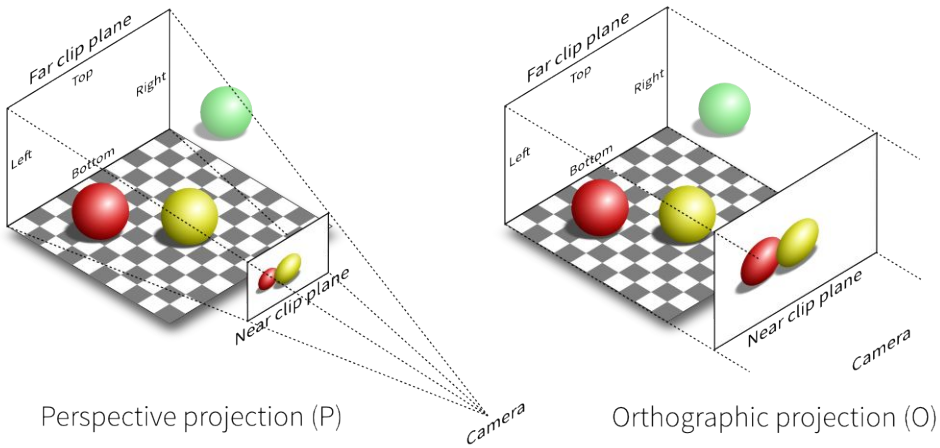


Preprocessing for 3D

- Face and landmark detection
- Face cut using fixed sphere with radius around nose
- Scale and mean normalization
- Rotation normalization
- Voxel based downsampling
- Around 500 points good enough to establish identity

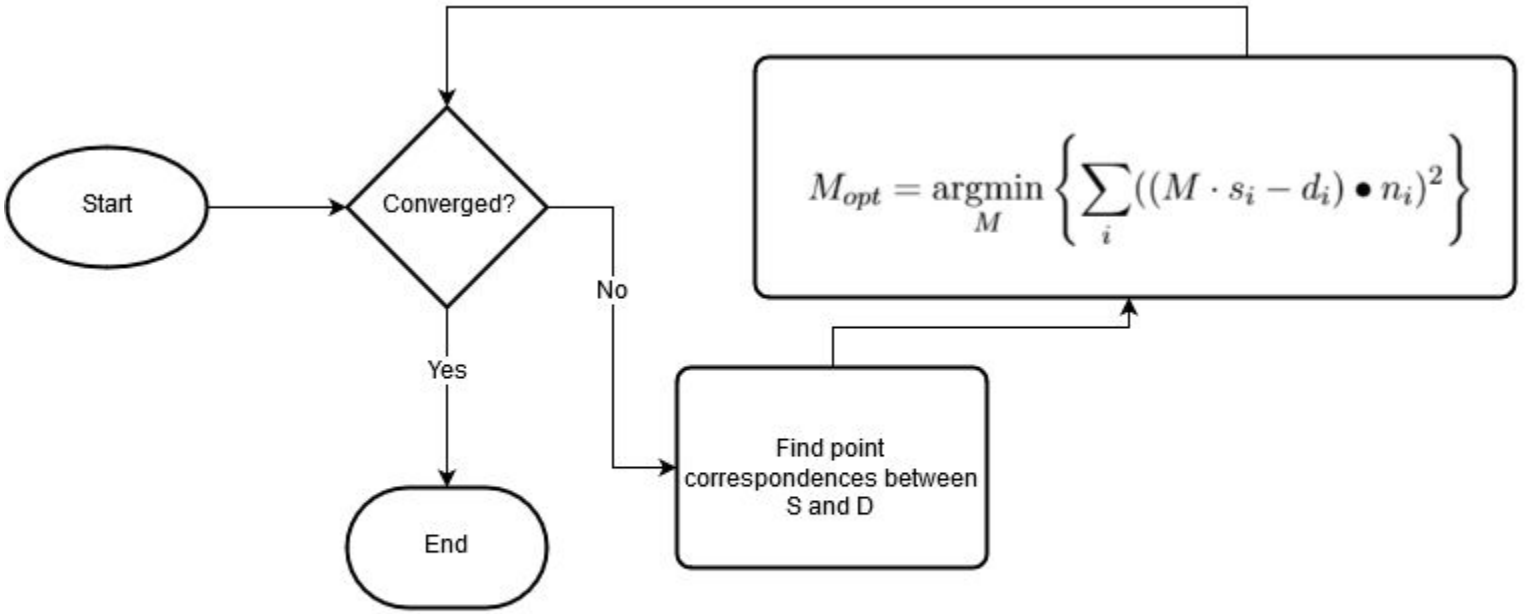
ICP with 2.5D Projection

- Point-to-Plane ICP
- Fitness and RMSE as output of ICP
- Orthographic Projection after ICP
- Establish canonical faces with correlation score



https://i.stack.imgur.com/q1SNB.png

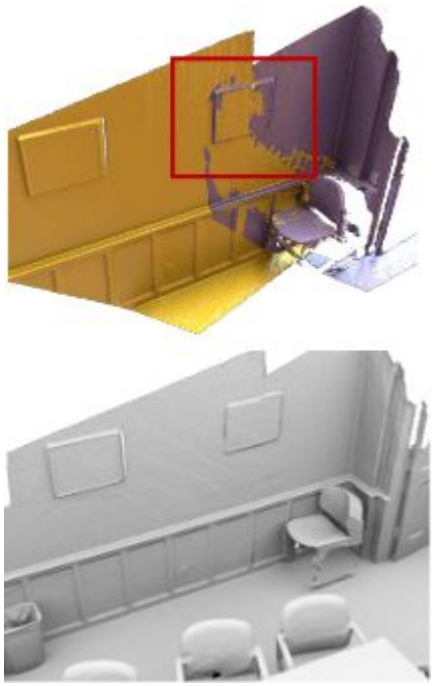
Iterative Closest Point (ICP)



Where:
s, d are corresponding points in point clouds S and D.
n is normal vector of point di.
M is Transformation from s to d

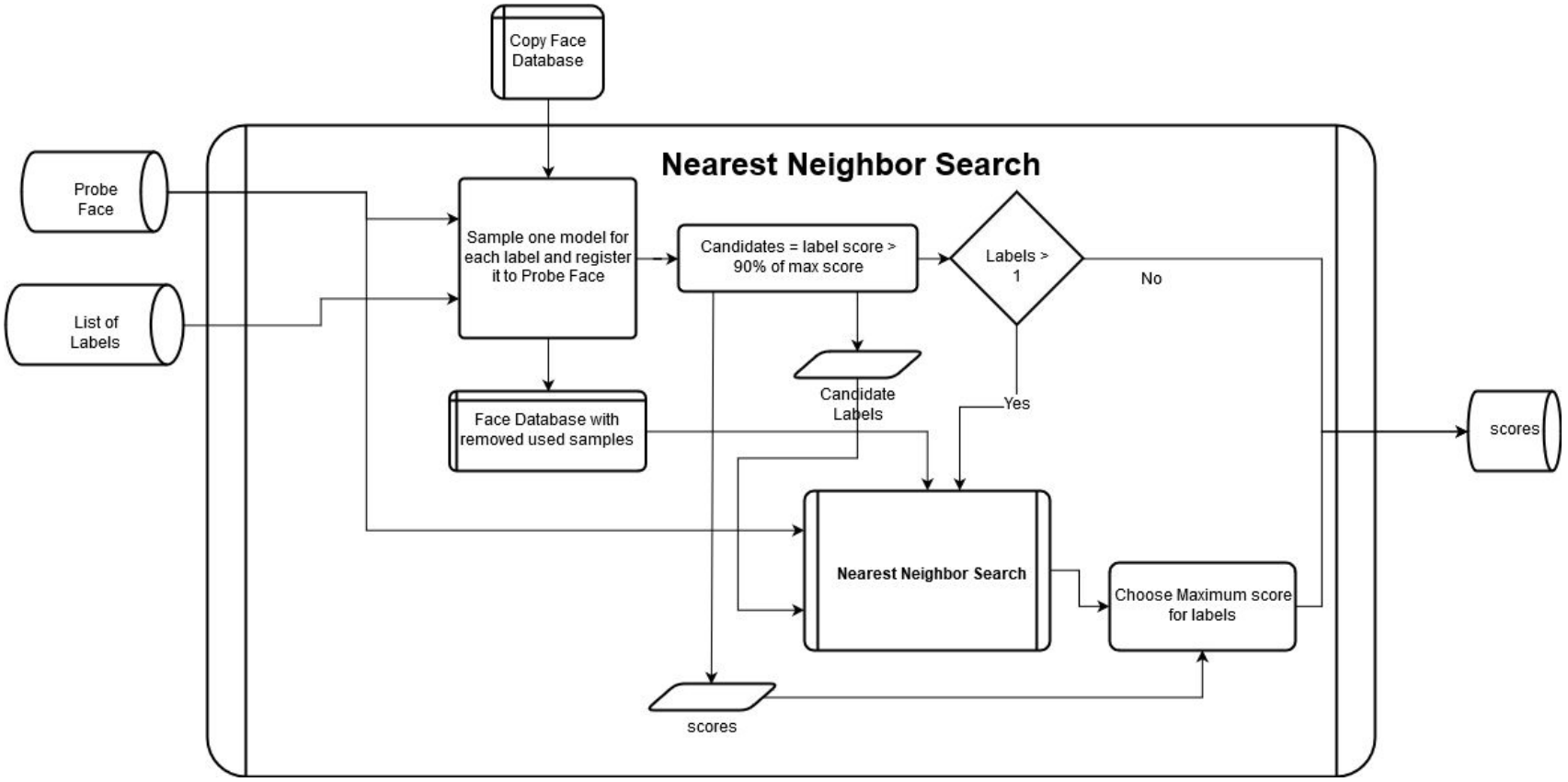
Colored ICP

- Uses ideas from RGB-D Image Alignment
- Gradient information in point cloud using virtual images
- Joint photometric and geometric objective
- Coarse to fine approach for good initialization
- Nearest neighbour search for query



RGB-D Image Alignment

Nearest Neighbor Search



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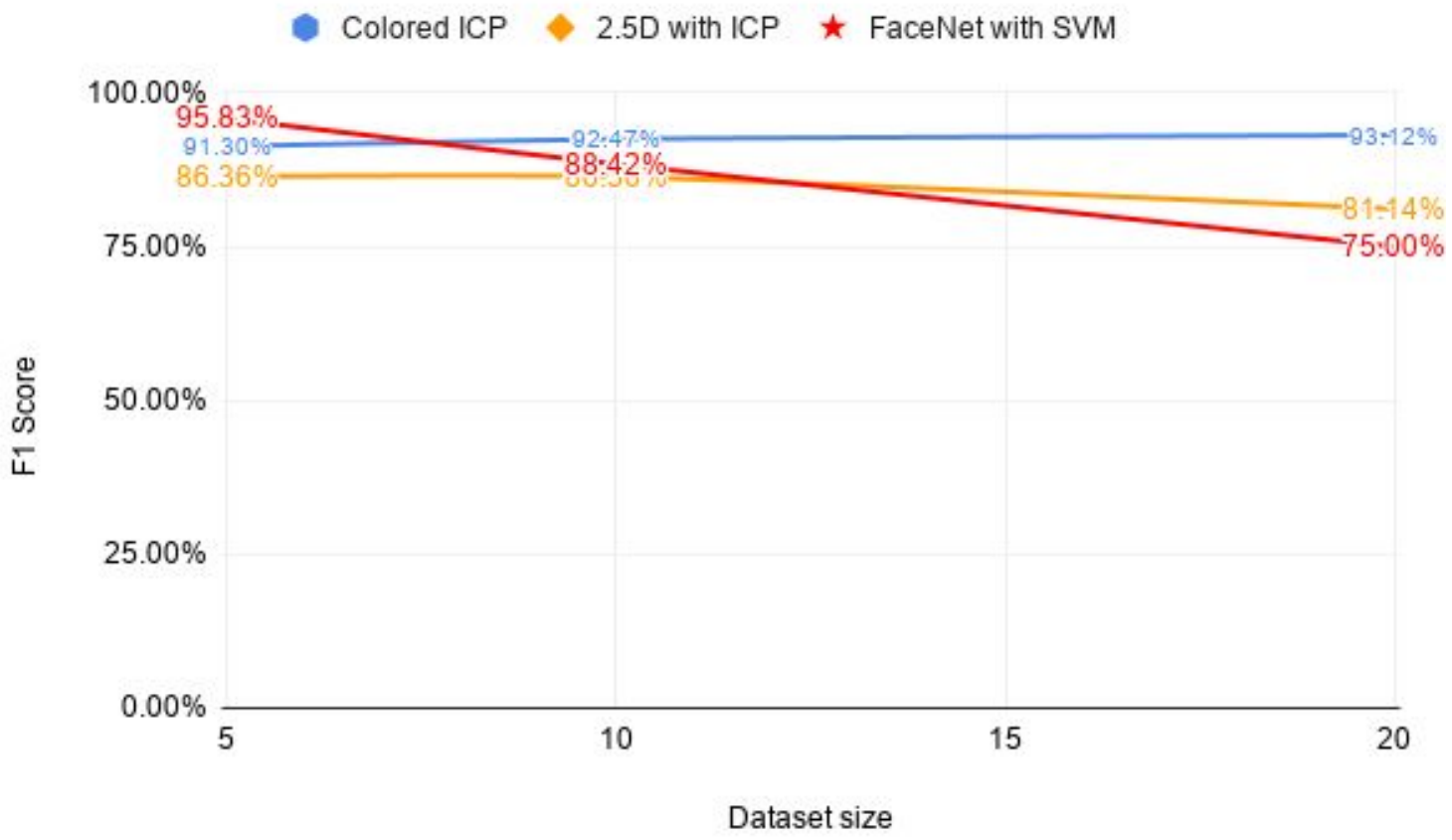
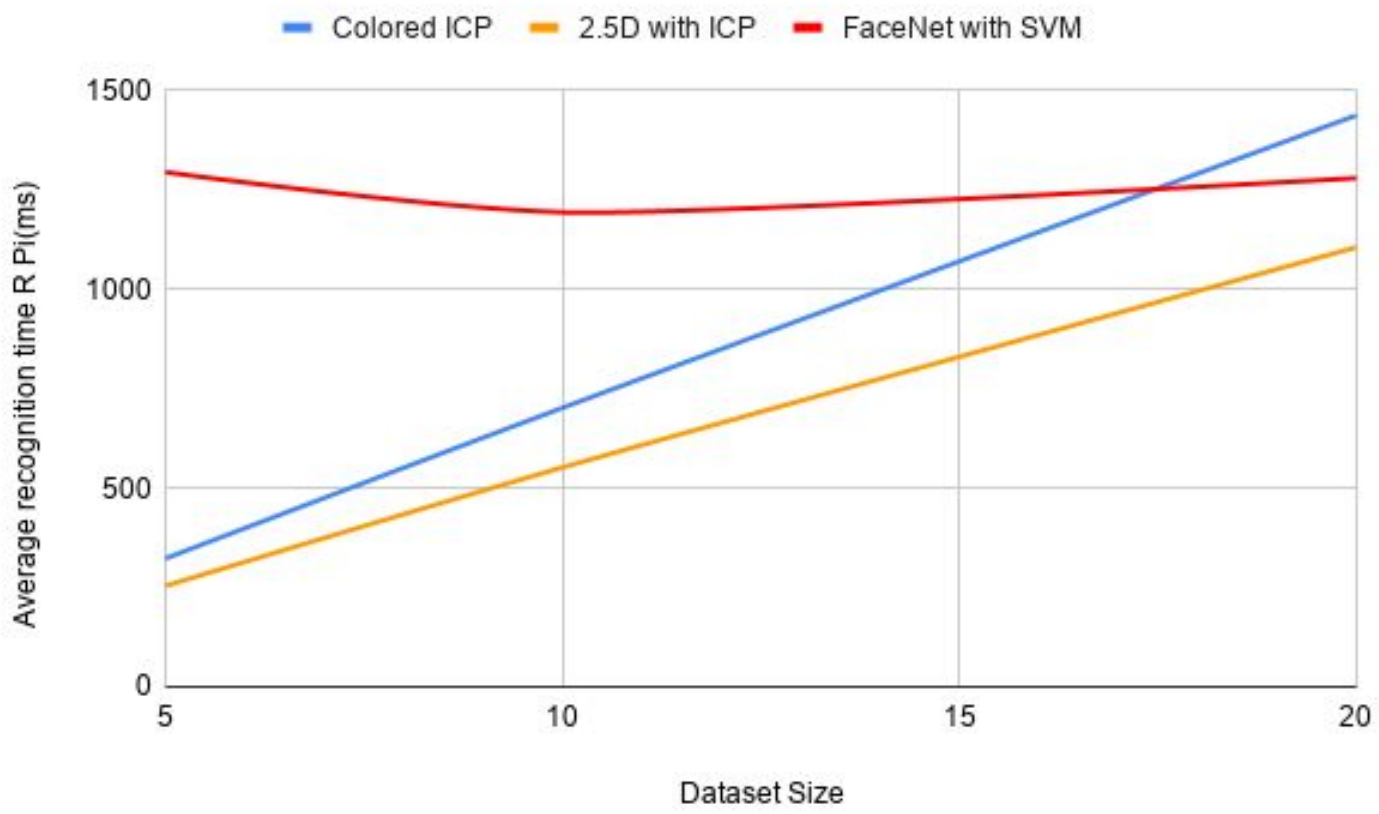
F1 Score


Colored ICP
2.5D with ICP
FaceNet with SVM
100.00%
75.00%
50.00%
25.00%
0.00%
F1 Score
95.83%
91.30%
92.47%
93.12%
88.42%
86.36%
81.14%
75.00%
5
10
15
20
Dataset size

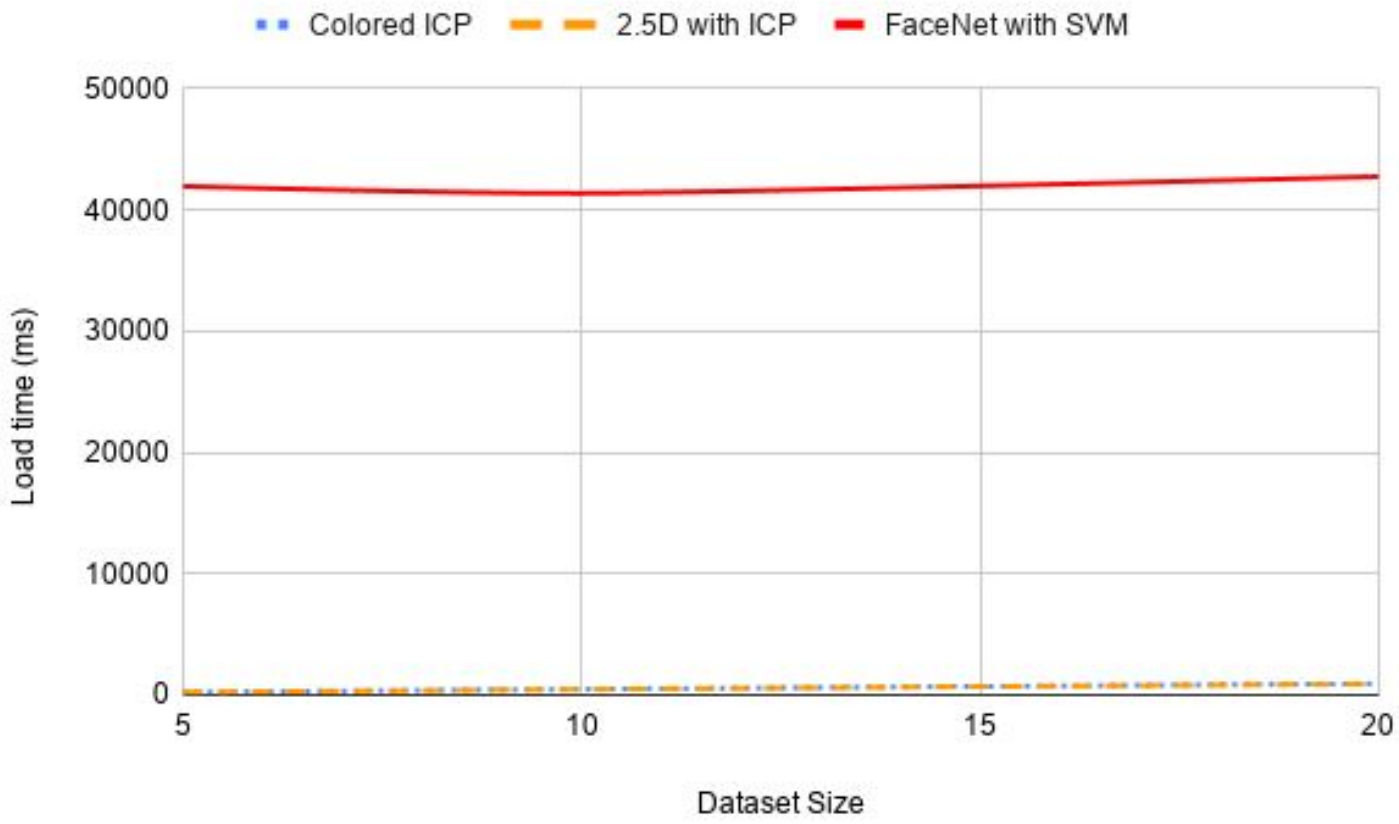
Training Time

- 2D Face Recognition training exhausts raspberry pi and it runs out of system memory.
- Adding or removing an Identity requires retraining.
- For ICP based techniques training step is as simple as adding models to database

Inference Time on Raspberry Pi



Model Loading Time on Raspberry Pi



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Contributions

- Search for suitable face recognition algorithms.
- Training SVM for face recognition using FaceNet embeddings.
- Search for multiple preprocessing steps for 3D point cloud.
- 3D face recognition algorithm by combining Face Detector, Facial Landmark Detector and ICP.
- Comparison of algorithms.

Contributions Continued...

- Development of nearest neighbour search algorithm to improve search time.
- Optimization of algorithms to run them on almost real-time on Raspberry Pi.
- Compilation of python and system libraries for Raspberry Pi.
- Deployment and testing of algorithms on Raspberry Pi.
- Collection of small dataset of low resolution depth and intensity images.

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Conclusion and Future work

- Conclusion
  - Deep Neural Networks for face recognition are more of a brute force way and ICP is an intelligent way.
  - Using RGB-D Image Alignment in ICP allows better convergence.
- Future Work
  - Adaptive radius of sphere for face cutout.
  - Using quicker alternatives of face detection and landmark detection.
  - Add weights for different facial regions in Colored ICP.
  - Eigenvalue based clustering for better scaling.

Major References

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Questions?

ToF Depth Camera