Thickness Estimation from Time-of-Flight Data

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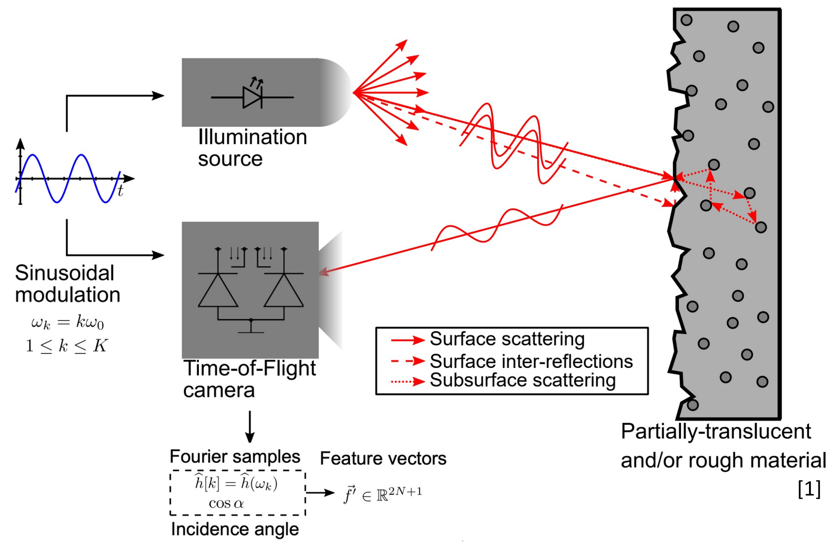
Introduction

- Time-of-flight (ToF) cameras are active imaging sensors.
- When each small particle of light reaches the sensor, it contains data about how far it has traveled.
- The thickness of the material has a strong impact on the MIRF (Material Impulse Response Function).
- Fourier samples of the MIRF are used as features.



Complex Measurements → Tabular Data

```
dataset{1, 1}
 Columns 1 through 5

  0.0068 + 0.0000i   0.0042 + 0.0000i
  0.0062 + 0.0000i   0.0051 + 0.0000i
  0.0042 + 0.0000i   0.0054 + 0.0000i
  0.0030 + 0.0000i   0.0044 + 0.0000i
```

47789x17 double

	1	2	3	4
1	1.0098	0.9691	1.0284	1.0186
2	1.0088	0.9639	1.0242	1.0169
3	1.0111	0.9682	1.0316	1.0206
4	1.0122	0.9716	1.0273	1.0217

Fully Connected Neural Network

Data 42720 x 17 → Train 80% 34176 x 17 (Training 90%, Validation 10%); Test 20% 8544 x 17

Feature of Structure	Mean Absolute Error
Only Dense Layers	1.07306873
Dense Layers and Batch Normalization	0.90540639
Dense Layers, Batch Normalization and Dropout	0.93281695
Dense and Batch Normalization with L1 regularizers	0.93514572
Dense and Batch Normalization with L2 regularizers (MODEL*)	0.90362579
Dense and Batch Normalization with L1+L2 regularizers	0.91598097
(MODEL*) with Selu Activaton Function	0.90889324
(MODEL*) with Elu Activaton Function	0.91530725
(MODEL*) with Sigmoid Activaton Function and RMS Prop optimizer	0.9441277

Started with Basic Fully Connected Neural Network.

New features were added in next steps.

2 Callbacks were used to improve training process

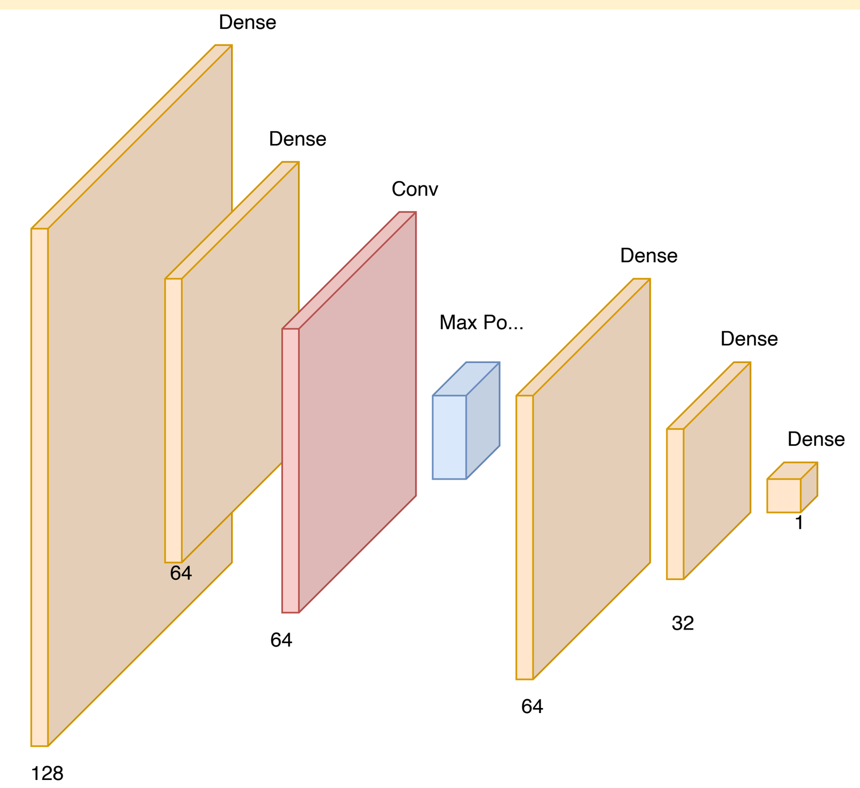
- **EarlyStopping** stops the training if the validation loss does not improve for a certain number of epochs.
- **ReduceLROnPlateau** reduces the learning rate if the validation loss stops improving.

Convolutional Neural Networks

The Fully Connected Network structure with the best results was selected.

It started by adding Convolutional Layers.

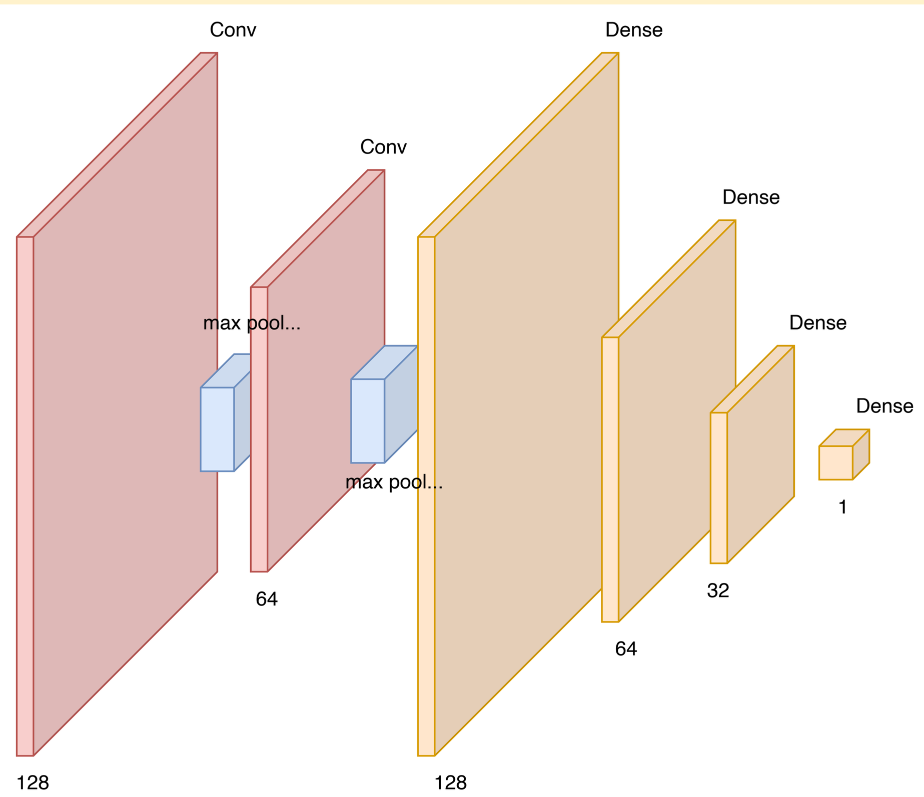
The below structure had "2.055" Mean Absolute Error value.

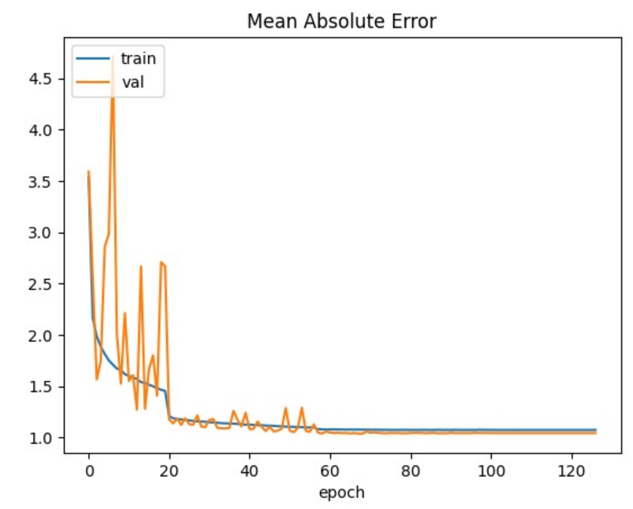


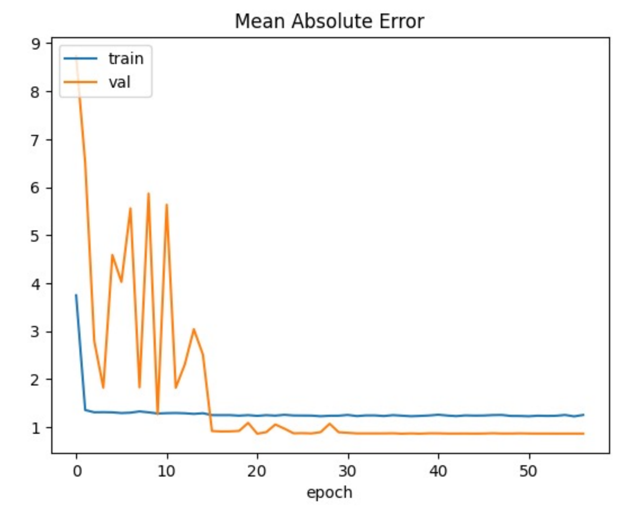
In the next experiment, Convolutional Layers were used in the beginning.

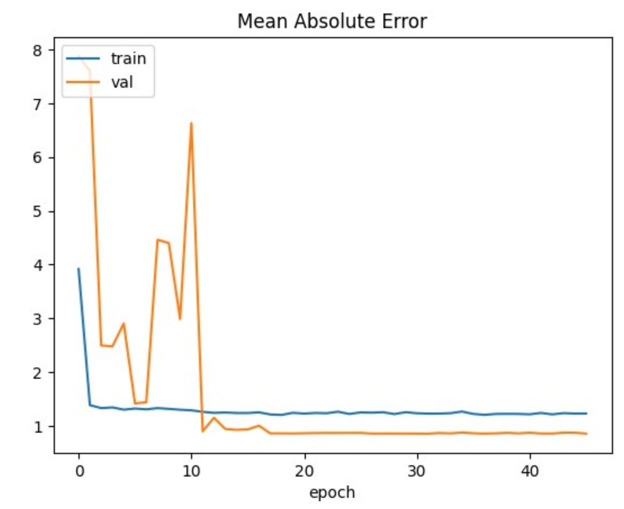
Then they were connected with Fully Connected Networks.

The following structure has "0.947" Mean Absolute Error value.









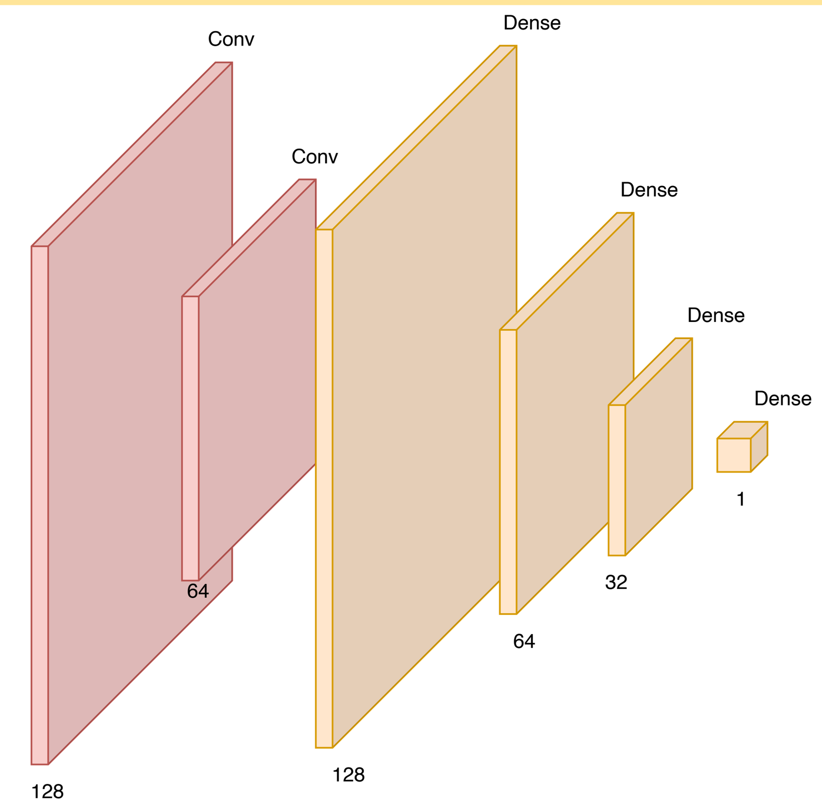
Training Charts for Fully Connected Neural Network

Left : Only Dense Layers

Middle : Dense Layers and Batch Normalization

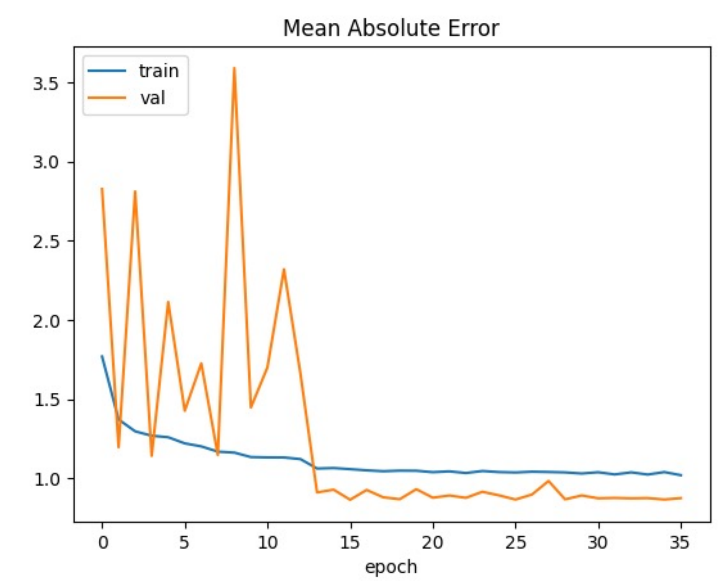
Right : Dense Layers, Batch Normalization and L2 regularization

When Max pooling Layers removed, this structure type gave the best results with "0.897" Mean Absolute Error.

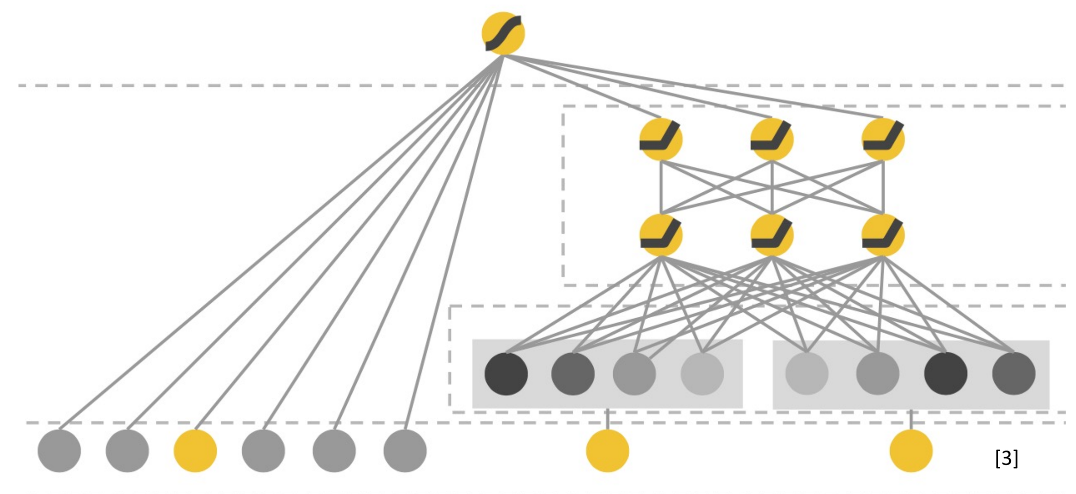


Different Structures From Literature

- TabNet [2]
  - Applying deep neural networks on tabular data effectively.
  - It contains different parts :
    - Feature Transformer
    - Attentive Transformer
    - Attention Mask
  - This structure got "0.913" Mean Absolute Error.



- Wide & Deep Framework [3]
  - Hybrid architecture that consists of linear and deep neural network models.
  - Linear models are good at capturing memorization.
  - Deep Learning Models are good at capturing generalization.
  - Mean Absolute Error of this structure was "1.081"



References

[1] M. H. Conde, T. Kerstein, B. Buxbaum and O. Loffeld, "Near-Infrared, Depth, Material: Towards a Trimodal Time-of-Flight Camera".

[2] S. O. Arik and T. Pfister, "TabNet: Attentive interpretable tabular learning," 2019, arXiv:1908.07442.

[3] H.-T. Cheng et al., "Wide & deep learning for recommender systems," in Proc. 1st Workshop Deep Learn. Recommender Syst., 2016, pp. 7–10.