

LAPORAN TUGAS BESAR 1 IF3270

PEMBELAJARAN MESIN

Feedforward Neural Network



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SEKOLAH TEKNIK ELEKTRO DAN INFORMATIKA
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1. Deskripsi Persoalan

Tugas Besar I dalam mata kuliah IF3270 Pembelajaran Mesin bertujuan untuk memberikan wawasan kepada mahasiswa mengenai implementasi Feedforward Neural Network (FFNN) from scratch. Pada tugas ini, mahasiswa diharapkan untuk membangun modul FFNN tanpa menggunakan library machine learning yang telah tersedia seperti TensorFlow atau PyTorch.

FFNN yang dikembangkan harus memenuhi beberapa spesifikasi utama, antara lain:

1. Arsitektur fleksibel: Model harus dapat menerima jumlah neuron per layer serta jenis fungsi aktivasi yang digunakan. Fungsi aktivasi yang diimplementasikan mencakup Linear, ReLU, Sigmoid, Tanh, dan Softmax.
2. Dukungan berbagai fungsi loss: Model harus mampu menggunakan MSE, Binary Cross-Entropy, dan Categorical Cross-Entropy sebagai fungsi loss.
3. Inisialisasi bobot yang bervariasi: Model harus dapat melakukan inisialisasi bobot menggunakan metode zero initialization, distribusi uniform, dan distribusi normal, serta mendukung pengaturan seed untuk reproducibility.
4. Kemampuan untuk menyimpan dan memvisualisasikan model:
 - Model harus dapat menampilkan struktur jaringan, bobot, dan gradien dalam bentuk graf.
 - Memiliki fitur untuk menampilkan distribusi bobot dan gradien dari beberapa atau semua layer dalam bentuk plot.
5. Forward dan Backward Propagation:
 - Mampu menangani batch input dalam forward propagation.
 - Backward propagation menggunakan chain rule untuk menghitung gradien terhadap loss function.
 - Implementasi weight update menggunakan gradient descent.
6. Mekanisme pelatihan:
 - Menerima parameter batch size, learning rate, jumlah epoch, dan verbose mode.
 - Mengembalikan histori training loss dan validation loss tiap epoch.

2. Pembahasan

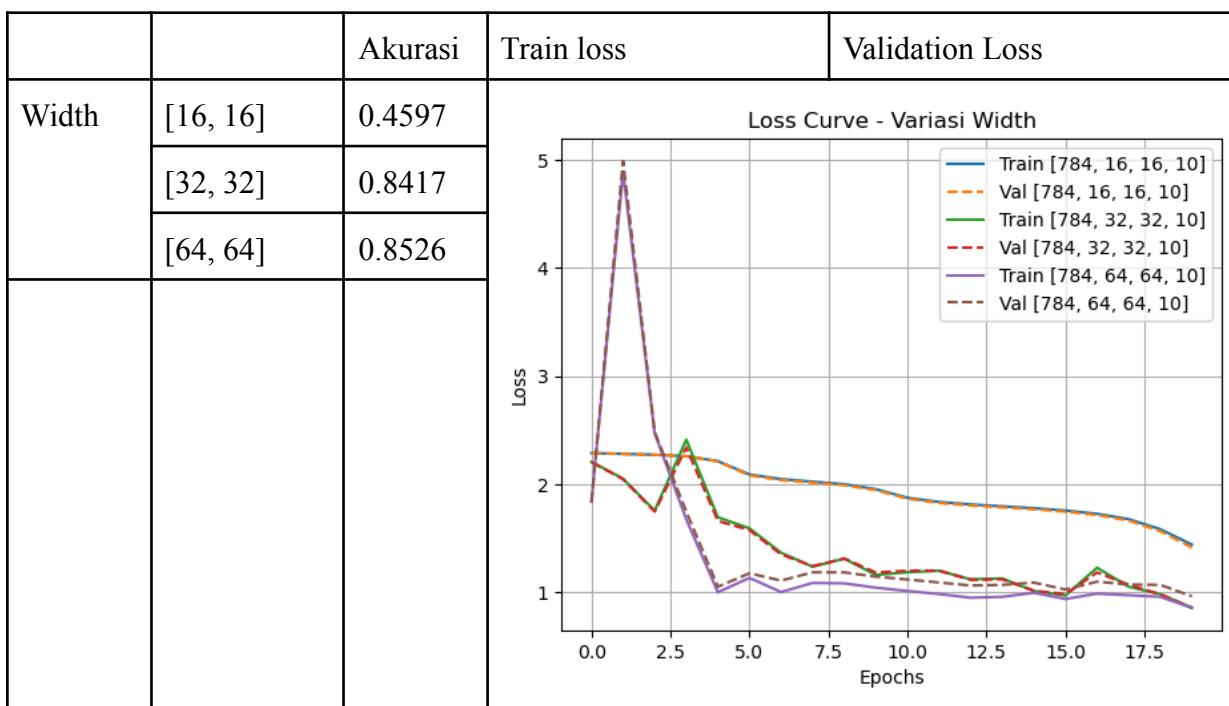
A. Penjelasan Implementasi

Function	Deskripsi
<code>__init__</code>	Inisialisasi arsitektur dari FFNN berupa jumlah layer, jumlah neuron per layer, fungsi aktivasi tiap layer, dan inisialisasi bobot (termasuk bobot bias).
<code>activation</code>	Fungsi yang akan diimplementasikan terhadap matriks input setiap layernya.
<code>forward_propagation</code>	Menambahkan vektor kolom 1 sebagai bias ke matriks input,

	kemudian melakukan perkalian matriks dengan bobot di setiap layer.
loss	Menghitung nilai loss antara prediksi (<code>y_pred</code>) dan label asli (<code>y_true</code>).
backward_propagation	Menghitung gradien error dengan backpropagation dan memperbarui bobot menggunakan gradient descent.
train	Melatih model dengan mini-batch gradient descent, menghitung loss, dan memperbarui bobot dalam epoch.
infer	Melakukan prediksi menggunakan model yang telah dilatih.
plot_network	Memvisualisasikan arsitektur neural network.
plot_weight_distribution	Menampilkan distribusi bobot dalam layer tertentu.
plot_gradient_distribution	Menampilkan distribusi gradien.
save & load	Fungsi save menyimpan model ke file menggunakan pickle dan fungsi load memuat model yang telah disimpan sebelumnya.

B. Hasil Percobaan

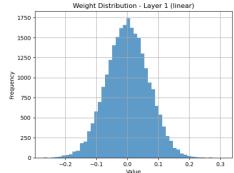
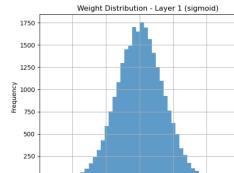
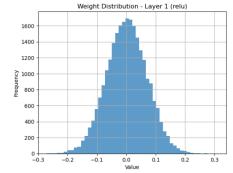
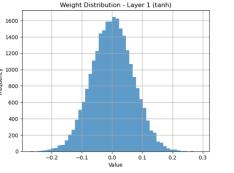
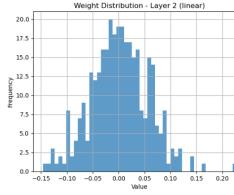
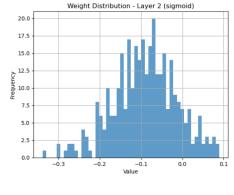
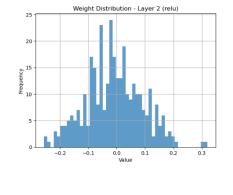
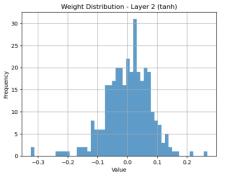
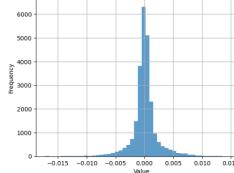
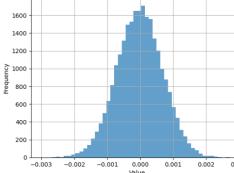
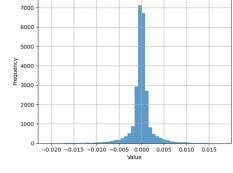
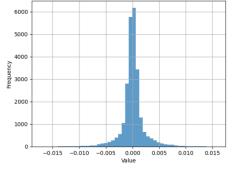
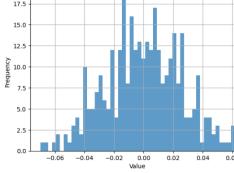
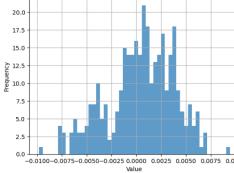
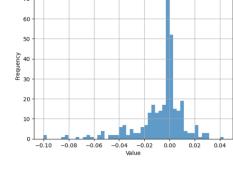
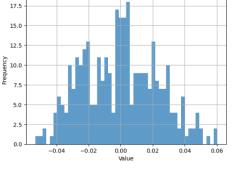
1. Pengaruh Depth dan Width



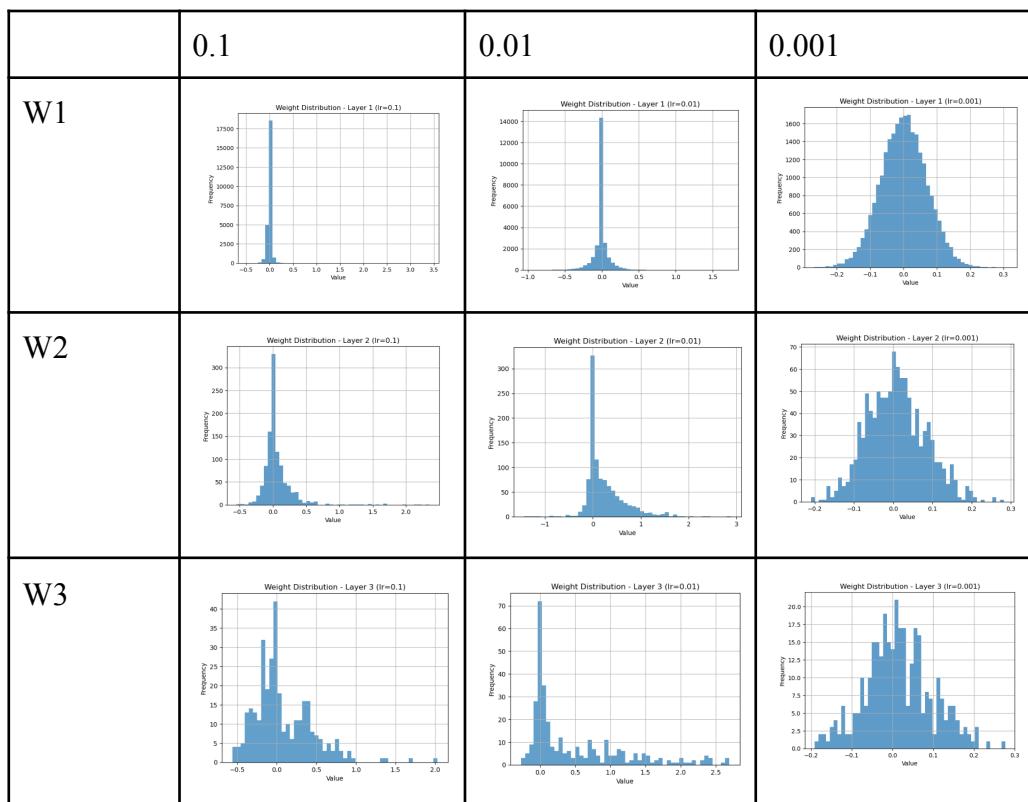
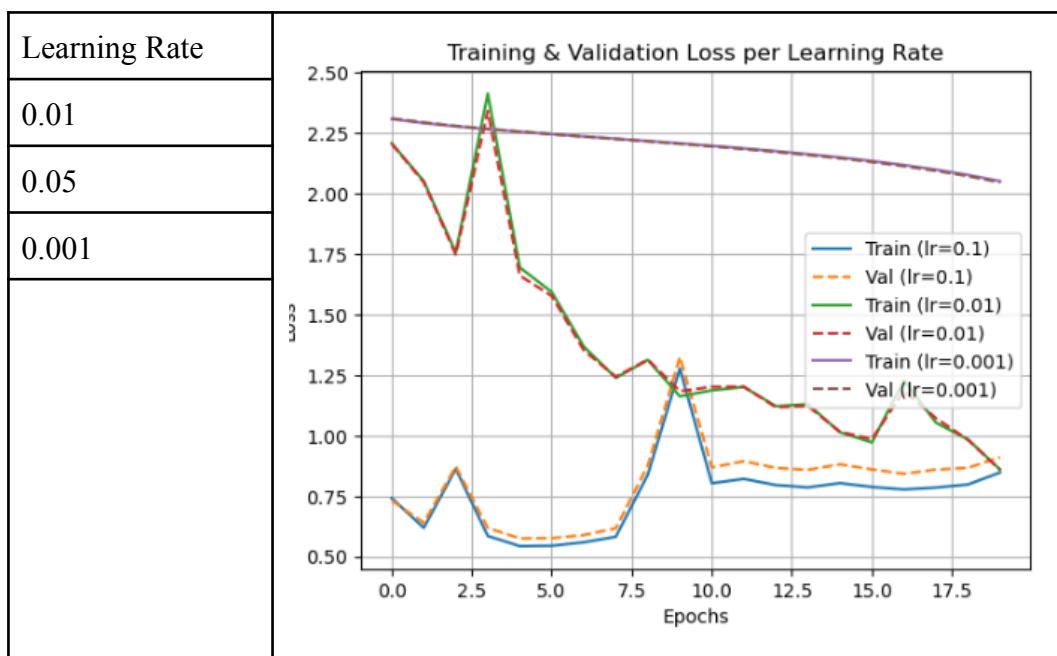
Depth	[32]	0.7680	<p>The plot shows six data series: Train [784, 32, 10] (solid blue), Val [784, 32, 10] (dashed orange), Train [784, 32, 32, 10] (solid green), Val [784, 32, 32, 10] (dashed red), Train [784, 32, 32, 32, 10] (solid purple), and Val [784, 32, 32, 32, 10] (dashed brown). The x-axis is 'Epochs' from 0.0 to 17.5. The y-axis is 'LOSS' from 1.0 to 4.0. All series start at approximately 2.2. The first two series drop sharply to around 1.5 by epoch 5. The third series peaks at ~2.4 around epoch 3 before dropping. The fourth series drops to ~1.5 by epoch 5. The fifth series drops to ~1.2 by epoch 5. The sixth series remains relatively flat around 2.2.</p>
	[32, 32]	0.8417	
	[32, 32, 32]	0.1145	

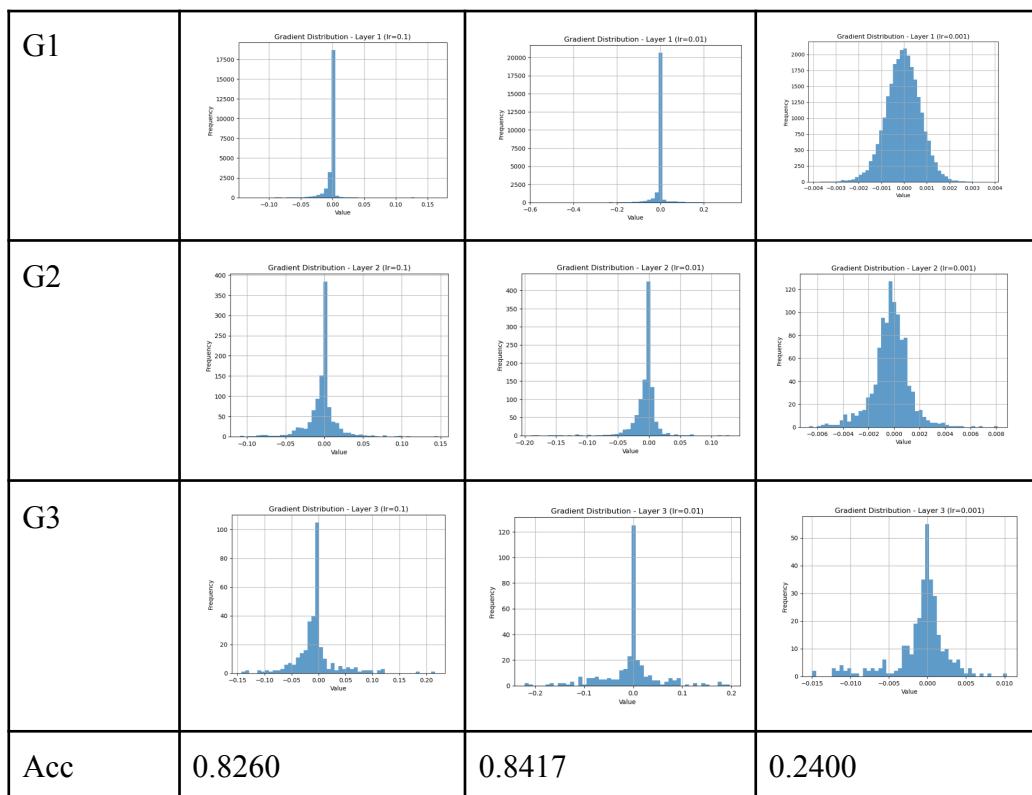
2. Pengaruh Fungsi Aktivasi Hidden Layer

	Akurasi	Grafik Train Loss	Validation Loss
Linear	0.8412	<p>The plot shows eight data series: Train (sigmoid) (solid blue), Val (sigmoid) (dashed orange), Train (tanh) (solid green), Val (tanh) (dashed red), Train (relu) (solid purple), Val (relu) (dashed brown), Train (linear) (solid pink), and Val (linear) (dashed grey). The x-axis is 'Epochs' from 0.0 to 17.5. The y-axis is 'LOSS' from 0 to 12. The sigmoid and tanh series drop quickly from ~12 to ~2. The ReLU and linear series drop more slowly from ~12 to ~4. The validation losses follow a similar downward trend but remain slightly higher than the training losses.</p>	<p>The plot shows eight data series: Train (sigmoid) (solid blue), Val (sigmoid) (dashed orange), Train (tanh) (solid green), Val (tanh) (dashed red), Train (relu) (solid purple), Val (relu) (dashed brown), Train (linear) (solid pink), and Val (linear) (dashed grey). The x-axis is 'Epochs' from 0.0 to 17.5. The y-axis is 'LOSS' from 0 to 12. The sigmoid and tanh series drop quickly from ~12 to ~2. The ReLU and linear series drop more slowly from ~12 to ~4. The validation losses follow a similar downward trend but remain slightly higher than the training losses.</p>
ReLU	0.8060		
Sigmoid	0.2450		
Tanh	0.8482		

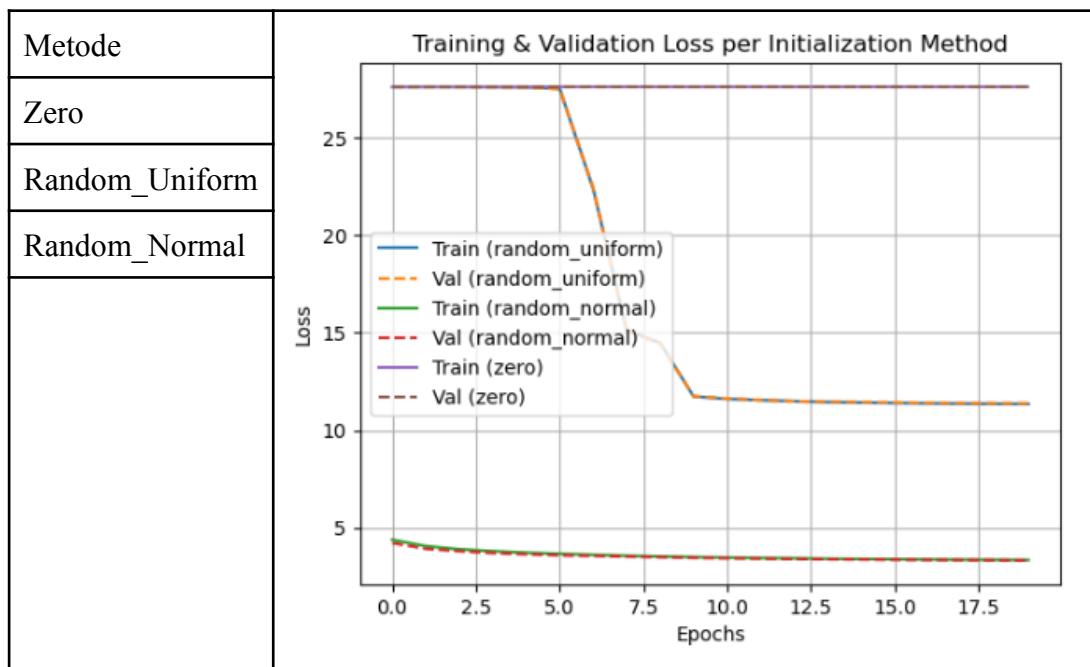
	Linear	Sigmoid	ReLU	Tanh
W1				
W2				
G1				
G2				
Acc	0.8412	0.2450	0.8060	0.8482

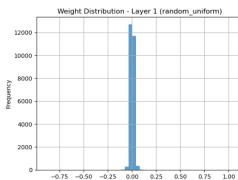
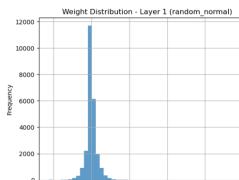
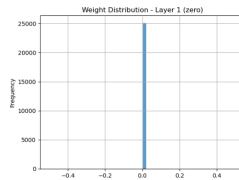
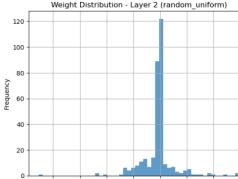
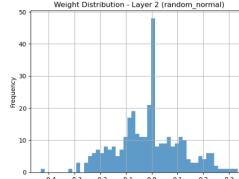
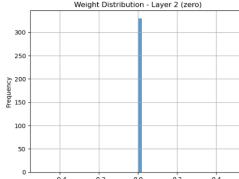
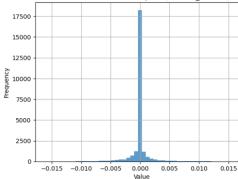
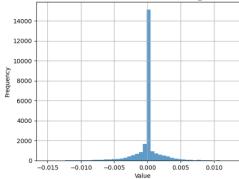
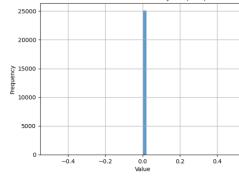
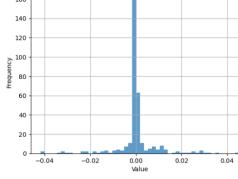
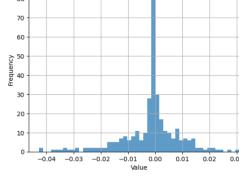
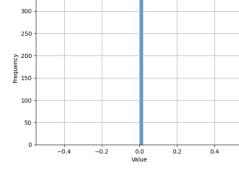
3. Pengaruh learning rate



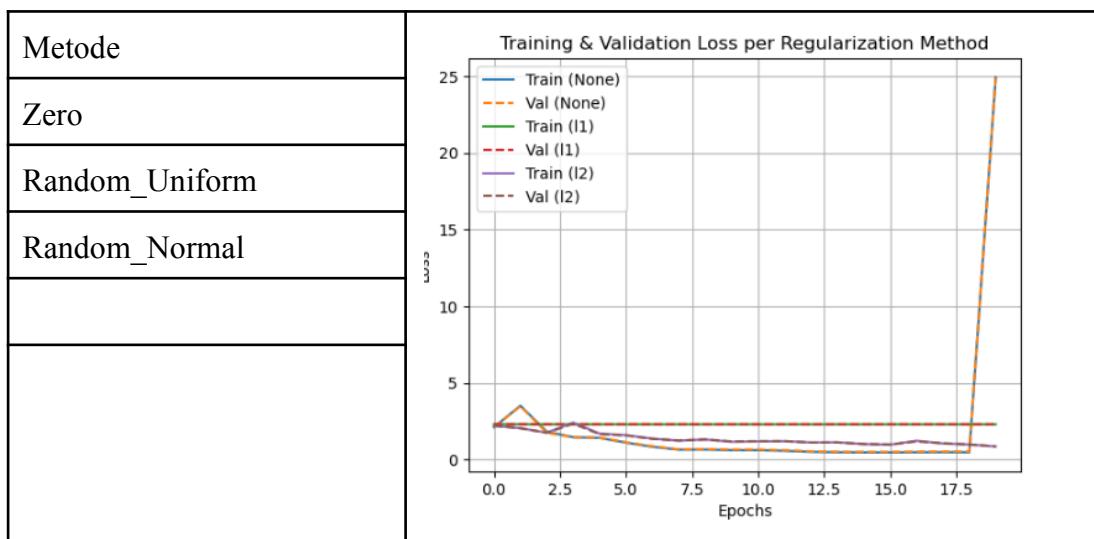


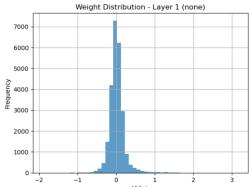
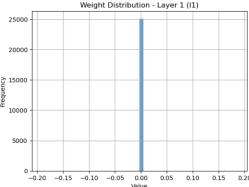
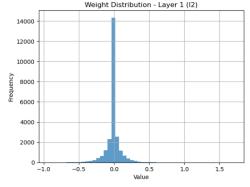
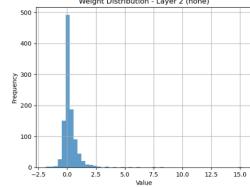
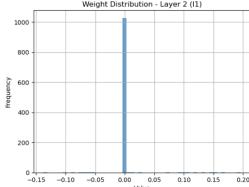
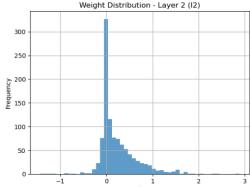
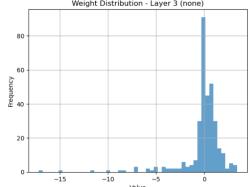
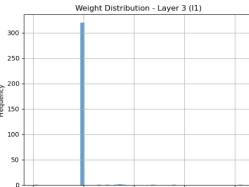
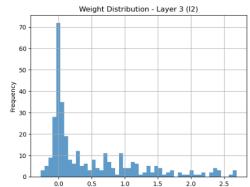
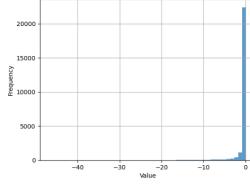
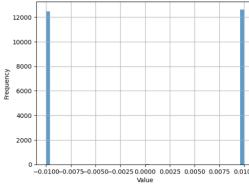
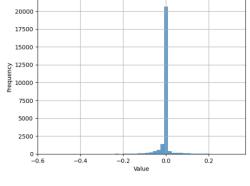
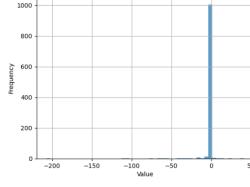
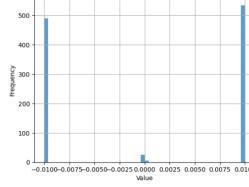
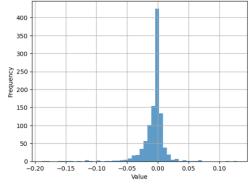
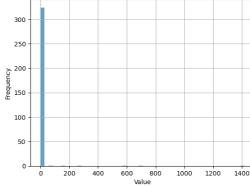
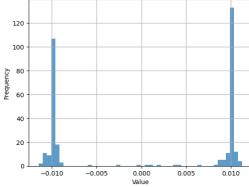
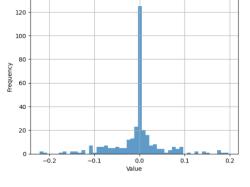
4. Pengaruh inisialisasi bobot



	random_uniform	random_normal	zero
W1			
W2			
G1			
G2			
Acc	0.6207	0.8797	0.0980

5. Pengaruh Regularisasi



	none	L1	L2
W1	 <p>Weight Distribution - Layer 1 (none)</p>	 <p>Weight Distribution - Layer 1 (I1)</p>	 <p>Weight Distribution - Layer 1 (I2)</p>
W2	 <p>Weight Distribution - Layer 2 (none)</p>	 <p>Weight Distribution - Layer 2 (I1)</p>	 <p>Weight Distribution - Layer 2 (I2)</p>
W3	 <p>Weight Distribution - Layer 3 (none)</p>	 <p>Weight Distribution - Layer 3 (I1)</p>	 <p>Weight Distribution - Layer 3 (I2)</p>
G1	 <p>Gradient Distribution - Layer 1 (none)</p>	 <p>Gradient Distribution - Layer 1 (I1)</p>	 <p>Gradient Distribution - Layer 1 (I2)</p>
G2	 <p>Gradient Distribution - Layer 2 (none)</p>	 <p>Gradient Distribution - Layer 2 (I1)</p>	 <p>Gradient Distribution - Layer 2 (I2)</p>
G3	 <p>Gradient Distribution - Layer 3 (none)</p>	 <p>Gradient Distribution - Layer 3 (I1)</p>	 <p>Gradient Distribution - Layer 3 (I2)</p>
Acc	0.0982	0.1135	0.8417

6. Perbandingan dengan MLPClassifier Sklearn

Akurasi Model FFNN Scratch : 0.9225

Akurasi Model MLPClassifier sklearn : 0.9803

DAFTAR PUSTAKA

F. Pedregosa *et al.*, "Scikit-learn: Machine learning in Python," *Journal of Machine Learning Research*, vol. 12, pp. 2825–2830, 2011. [Online]. Available: https://scikit-learn.org/stable/modules/generated/sklearn.neural_network.MLPClassifier.html

DeepAI, "Feed-forward neural network." [Online]. Available: <https://deeppai.org/machine-learning-glossary-and-terms/feed-forward-neural-network> [Accessed: Apr. 11, 2025].

S. Cota, "Deep learning basics — Part 7 — Feed Forward Neural Networks (FFNN)," *Medium*, Dec. 7, 2023. [Online]. Available: <https://medium.com/@sasirekharameshkumar/deep-learning-basics-part-10-feed-forward-neural-networks-ffnn-93a708f84a31>

LAMPIRAN

Pengecekan Program

Poin	Ya	Tidak
1. Pengaruh Depth dan Width	✓	
2. Pengaruh Fungsi Aktivasi	✓	
3. Pengaruh learning rate	✓	
4. Pengaruh inisialisasi bobot	✓	
5. Pengaruh regularisasi	✓	
6. Perbandingan Model Scratch dgn MLPClassifier	✓	

Tabel 3. Tabel Pengecekan Program

Lembar Kontribusi

Nama (NIM)	Kontribusi
Konstan Aftop Anewata Ndruru (12822058)	Forward propagation & Backward propagation
Ryan Kurnia Hidayatullah (13519212)	Backward propagation

Tabel 4. Lembar Kontribusi

Repository

Link Repository dari Tugas Besar 1 Pembelajaran Mesin adalah sebagai berikut.

[Github](#)