Tugas Besar Bagian B IF3270 Machine Learning
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Implementasi Mini-Batch Gradient Descent

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1. Implementasi

Implementasi yang dilakukan dalam penerapan Mini-Batch Gradient Descent untuk Forward Feeding Neural Network adalah dengan memodifikasi hasil Tugas Besar bagian A dengan menambahkan atribut dan fungsi sebagai berikut.

a. Neuron

Atribut	Deskripsi
errorFactor	Atribut yang melambangkan faktor error dari neuron.
deltaWeight	Atribut yang melambangkan besaran perubahan bobot dari neuron.

Method	Deskripsi
getBobot(self)	Getter untuk memperoleh nilai bobot dari neuron
updateBobot(self, learningRate)	Fungsi untuk mengupdate bobot pada neuron
getError(self)	Getter untuk memperoleh nilai error dari neuron
calculateErrorOut(self,output,activation, prevOutput, target)	Menghitung error dari neuron yang berada pada output layer
calculateHiddenError(self,output,activation, prevOutput, nextWeight, nextError)	Menghitung error dari neuron yang berada pada hidden layer

b. Layer

Atribut	Deskripsi
errorFactor	Atribut yang melambangkan faktor error dari layer
isOutput	Atribut boolean yang melambangkan apakah layer merupakan output layer

Method	Deskripsi

setToOutput(self)	Method untuk set nilai atribut isOutput menjadi True yang menandakan layer adalah output layer
emptyOutput(self)	Method untuk mengosongkan array output dengan clear() pada layer
getError(self)	Getter untuk memperoleh nilai error
getNeuronWeight(self)	Getter untuk memperoleh bobot neuron
updateBobot(self, learningRate)	Method untuk memperbarui nilai bobot berdasarkan nilai learningRate
computeDeltaBobot(self, prevLayer, nextLayer = None, target = None)	Method untuk menghitung delta bobot berdasarkan output dari layer sebelumnya, bobot dari layer berikutnya jika layer bukan output layer, dan nilai target

c. FFNN

Atribut	Deskripsi
learning_rate	Atribut yang melambangkan laju learning
expected_output	Atribut yang melambangkan output yang diharapkan

Method	Deskripsi
setBackwardParameter(self, ex_output, learn_rate)	Method untuk set parameter yang digunakan untuk backward passing
computeCost(self, output, target)	Method untuk menghitung cost dari error margin
adjustWeight(self)	Method untuk menghitung dan update bobot pada model
computeError(self, entryIndex)	Method untuk menghitung faktor error
backward(self, batch_size, error_threshold, max_iteration, input)	Method untuk melakukan backward propagation

2. Hasil Pengujian

Berikut hasil pengujian dari program mini-batch gradient descent dengan maximum iterasi 1000, learning rate 0.1, dan error threshold 0.1.

Model 1
Layer 1:
Fungsi Aktivasi: linear
Neuron 1: [0.1, 0.1, 0.1, 0.1, 0.1]
Neuron 2: [0.1, 0.1, 0.1, 0.1, 0.1]
Layer 2:
Fungsi Aktivasi: sigmoid
Neuron 1: [1.0, 1.0, 1.0]
Neuron 2: [1.0, 1.0, 1.0]
Neuron 3: [1.0, 1.0, 1.0]

Batch size = 1

```
Layer 1:
Fungsi Aktivasi:  linear
Neuron 1: [0.2700713038120438, 0.4952814343367547, 2.647920961805772, -3.6986047757303204, -2.357540868440799]
Neuron 2: [-0.09523199622091194, -0.49325827222825847, 0.28799294220965344, -1.2457358997715682, -0.722304708453058]
Layer 2:
Fungsi Aktivasi:  sigmoid
Neuron 1: [-0.489774174452715, 3.8107641935943457, 1.7430977386619746]
Neuron 2: [-4.421855132195462, 0.17069075596299307, -0.07248903756022965]
Neuron 3: [-12.420574694527364, -5.879424809597369, 5.15238763854651]
iter:  1000
error:  3.2820046906515694
```

Batch size = 10

```
Layer 1:
Fungsi Aktivasi:  linear
Neuron 1: [8.703303047352302, 9.816719462305436, 7.883627163128082, -13.8351113166241, -17.174272241649764]
Neuron 2: [-0.27831038461626034, -1.5401294086352488, -1.216802592655221, 0.11599438617810678, 0.19149263055576973]
Layer 2:
Fungsi Aktivasi:  sigmoid
Neuron 1: [0.5874811991142483, 2.1424912117388963, 5.473359019607706]
Neuron 2: [9.994268785698022, 1.2418549969873187, 0.62581501405573]
Neuron 3: [-4.736727485104996, -1.720148686121544, -0.5938056921662023]
iter:  1000
error:  29.237209324532056
```

Batch size = 50

```
Layer 1:
Fungsi Aktivasi:  linear
Neuron 1: [-20.668441058302328, -135.06257433791052, -61.270803099770255, -113.61721968692966, -41.51617090764308]
Neuron 2: [0.5018619170225147, 2.3845526662055363, 0.9621425029776017, 2.0662960739816794, 0.7406383222980046]
Layer 2:
Fungsi Aktivasi:  sigmoid
Neuron 1: [330.4217070889641, 183.9415701933906, -380.75001141232076]
Neuron 2: [132.17748221637987, 797.4662867842633, -68.90257528627725]
Neuron 3: [-468.61513771684093, -1419.846111961677, 422.8827242725664]
iter:  1000
error:  200.0
```

Model 2

Layer 1:
Fungsi Aktivasi: linear
Neuron 1: [0.1, 0.1, 0.1, 0.1, 0.1]
Neuron 2: [0.1, 0.1, 0.1, 0.1, 0.1]
Layer 2:
Fungsi Aktivasi: linear
Neuron 1: [1.0, 1.0, 1.0]
Neuron 2: [1.0, 1.0, 1.0]
Neuron 3: [1.0, 1.0, 1.0]
Neuron 4: [1.0, 1.0, 1.0]
Neuron 5: [1.0, 1.0, 1.0]
Neuron 6: [1.0, 1.0, 1.0]
Neuron 7: [1.0, 1.0, 1.0]
Neuron 8: [1.0, 1.0, 1.0]
Layer 3:
Fungsi Aktivasi: sigmoid
Neuron 1: [1.0, 1.0, 1.0, 1.0, 1.0, 1.0, 1.0, 1.0, 1.0]
Neuron 2: [1.0, 1.0, 1.0, 1.0, 1.0, 1.0, 1.0, 1.0, 1.0]
Neuron 3: [1.0, 1.0, 1.0, 1.0, 1.0, 1.0, 1.0, 1.0, 1.0]

Batch size = 1

```
Layer 1:
Fungsi Aktivasi:  linear
Neuron 1: [-0.026093598000107493, 0.6603045895533397, 0.867977707463118, -1.3904797317045938, -1.3142373404935406]
Neuron 2: [0.08188632897341183, -0.033512555840127335, 0.6572601724139162, -1.0228892086829584, -0.528194274746598]
Layer 2:
...
Neuron 2: [-4.119207756579966, -6.098547616904043, 0.7716656580301267, -3.696574644094548, -4.184430504153152, -0.26192761261842706, -0.9545676810669436, -0.8536818178281219, -0.8710386762127587]
Neuron 3: [-7.583572576623302, -15.95766794219483, -8.346387737048937, 0.45297236305728655, 0.06756082394824595, 0.10519276562678614, 0.3458463363755486, 0.22798316147947129, 0.2373971353318781]
iter:  1000
error:  2.52156549624378
```

Batch size = 10

```
Layer 1:
Fungsi Aktivasi:  linear
Neuron 1: [0.18594307892838563, 0.5514912287047528, 0.37786471688270196, 0.33131543618917725, 0.15907803455633893]
Neuron 2: [0.19101427648308295, 0.4862226456830101, 0.385827409850328, 0.16986776534127898, 0.08379339817320132]
Layer 2:
Fungsi Aktivasi:  linear
Neuron 1: [0.8075908657677455, 0.30885510176668984, 2.7221894731258267]
Neuron 2: [0.006602532088940016, -11.512284948973948, -9.263276306730758]
Neuron 3: [0.8903428079231993, 0.1985190977464086, 2.7252817187407827]
Neuron 4: [1.7153989952500066, 1.8792290298461758, 1.0498807495170568]
Neuron 5: [0.895146251232821 8, 0.3663400778037661 5, 2.606170836322853 3]
Neuron 6: [1.6311615240671302, 1.838781147936739, 1.069418232040672 4]
Neuron 7: [-0.6689339410090491, -9.922490290999049, -5.381544460831 76]
Neuron 8: [1.5342642469078176, 1.6797126056255944, 1.216198507270449 3]
Layer 3:
Fungsi Aktivasi:  sigmoid
Neuron 1: [8.340302766656011, 25.01513408417115, 1.4288630461530332, 27.82832548128271, 6.021428222553653, 21.308797717323305, 6.189568683135846, 16.35019762638704, 8.422598460044671]
Neuron 2: [23.09413981269165, 58.25629585114366, 25.522646814877476, 63.533809148088714, 25.619288319108875, 57.32795074675133, 24.597720584302397, 40.69747375517761, 27.363553411149855]
Neuron 3: [-95.05189404556036, -293.8195590379697, -53.453774788352135, -317.28857069155305, -100.08688079253085, -271.287742169820 4, -98.07016227792464, -206.72843252323892, -116.07529500158016]
iter:  1000
error:  20.000000057300234
```

Batch size = 50

```
Layer 1:
Fungsi Aktivasi:  linear
Neuron 1: [0.32784207469891813, 1.6737700441944727, 0.7545399216459433, 1.3153915525116382, 0.48949239362218655]
Neuron 2: [0.12337131906744334, 0.40557544032781156, 0.1273156585869345, 0.5577439538539251, 0.27691896355377 48]
Layer 2:
...
Neuron 2: [134.40645432939243, -39.91839714949926, 292.6820579642389, 152.68889607219205, 2860.426894367316, 26.50265862281435, 130.7967287827616, 239.22377636140806, 9138.208691440637]
Neuron 3: [-501.02969311392144, 290.34056068018674, -934.5479793158147, -324.17123003583 09, -16652.466983092512, -51.01794610031368, -339.77160659919133, -1688.525167654283, -34240.689311523034]
iter:  1000
error:  175.0
```

Model 3

Layer 1:
Fungsi Aktivasi: linear
Neuron 1: [0.1, 0.1, 0.1, 0.1, 0.1]
Neuron 2: [0.1, 0.1, 0.1, 0.1, 0.1]
Layer 2:
Fungsi Aktivasi: linear
Neuron 1: [1.0, 1.0, 1.0]
Neuron 2: [1.0, 1.0, 1.0]
Neuron 3: [1.0, 1.0, 1.0]
Layer 3:
Fungsi Aktivasi: linear
Neuron 1: [1.0, 1.0, 1.0, 1.0]
Neuron 2: [1.0, 1.0, 1.0, 1.0]
Neuron 3: [1.0, 1.0, 1.0, 1.0]
Layer 4:
Fungsi Aktivasi: linear
Neuron 1: [1.0, 1.0, 1.0, 1.0]
Neuron 2: [1.0, 1.0, 1.0, 1.0]
Neuron 3: [1.0, 1.0, 1.0, 1.0]
Layer 5:
Fungsi Aktivasi: RELU
Neuron 1: [1.0, 1.0, 1.0, 1.0]
Neuron 2: [1.0, 1.0, 1.0, 1.0]

Neuron 3: [1.0, 1.0, 1.0, 1.0]

Batch size = 1

```
    ffnn.setBackwardParameter(target, 0.1)
    ffnn.backward(1, 0.1, 1000, x)
 ✓ 26.6s

Layer 1:
Fungsi Aktivasi:  linear
Neuron 1: [0.09999999999987913, 0.0999999999993399, 0.09999999999959586, 0.09999999999983761, 0.09999999999998402]
Neuron 2: [0.09999999999987913, 0.0999999999993399, 0.09999999999959586, 0.09999999999983761, 0.09999999999998402]
Layer 2:
Fungsi Aktivasi:  linear
Neuron 1: [0.9999999999998662, 0.9999999999998744, 0.9999999999998744]
Neuron 2: [0.9999999999998662, 0.9999999999998744, 0.9999999999998744]
Neuron 3: [0.9999999999998662, 0.9999999999998744, 0.9999999999998744]
Layer 3:
Fungsi Aktivasi:  linear
Neuron 1: [0.9999999999984117, 0.9999999999946797, 0.9999999999946797, 0.9999999999946797]
Neuron 2: [0.9999999999984117, 0.9999999999946797, 0.9999999999946797, 0.9999999999946797]
Neuron 3: [0.9999999999984117, 0.9999999999946797, 0.9999999999946797, 0.9999999999946797]
Layer 4:
Fungsi Aktivasi:  linear
Neuron 1: [0.9999999996872654, 0.999999996742756, 0.999999996742756, 0.999999996742756]
Neuron 2: [0.9999999787697286, 0.9999997855933341, 0.9999997855933341, 0.9999997855933341]
Neuron 3: [0.9999999787697299, 0.9999997855933541, 0.9999997855933541, 0.9999997855933541]
Layer 5:
Fungsi Aktivasi:  RELU
Neuron 1: [59.9297806959599, -341.46259661270835, -341.4626346846121, -341.46263468460626]
Neuron 2: [15.837196458781328, -120.39190935076877, -120.39203111451947, -120.39203111451874]
Neuron 3: [41.91718082937687, -14.158796157287206, -14.158980774022524, -14.158980773999021]
iter:  1000
error:  12397.692298619111
```

Batch size = 10

```
ffnn.setBackwardParameter(target, 0.1)
ffnn.backward(10, 0.1, 1000, x)
```

✓ 24.7s

```
Layer 1:
Fungsi Aktivasi:  linear
Neuron 1: [0.09999999998132764, 0.09999999991565667, 0.09999999994674877, 0.09999999997589509, 0.09999999999613259]
Neuron 2: [0.09999999998132764, 0.09999999991565667, 0.09999999994674877, 0.09999999997589509, 0.09999999999613259]
Layer 2:
Fungsi Aktivasi:  linear
Neuron 1: [0.9999999999685236, 0.9999999999689142, 0.9999999999689142]
Neuron 2: [0.9999999999685236, 0.9999999999689142, 0.9999999999689142]
Neuron 3: [0.9999999999685236, 0.9999999999689142, 0.9999999999689142]
Layer 3:
Fungsi Aktivasi:  linear
Neuron 1: [0.9999999997713883, 0.9999999993171392, 0.9999999993171392, 0.9999999993171392]
Neuron 2: [0.9999999997713913, 0.9999999993171472, 0.9999999993171472, 0.9999999993171472]
Neuron 3: [0.9999999997713913, 0.9999999993171472, 0.9999999993171472, 0.9999999993171472]
Layer 4:
Fungsi Aktivasi:  linear
Neuron 1: [0.9999999235385412, 0.9999992277848176, 0.9999992277848176, 0.9999992277848176]
Neuron 2: [0.9999974504798521, 0.9999742458475338, 0.9999742458475338, 0.9999742458475338]
Neuron 3: [0.9999974504624936, 0.9999742456765723, 0.9999742456765723, 0.9999742456765723]
Layer 5:
Fungsi Aktivasi:  RELU
Neuron 1: [-422.9040801611179, -14687.743019813894, -14688.96767826285, -14688.967677050534]
Neuron 2: [45.649788822386654, -24851.10685440419, -24854.24291930311, -24854.242933592872]
Neuron 3: [-993.1923288841147, -44777.8210806147, -44780.07144406462, -44780.071452532175]
iter:  1000
error:  75.0
```

Batch size = 50

```
ffnn.setBackwardParameter(target, 0.1)
ffnn.backward(50, 0.1, 1000, x)
```

✓ 23.1s

```
Layer 1:
Fungsi Aktivasi:  linear
Neuron 1: [0.09999999900806307, 0.09999999552084389, 0.09999999717111592, 0.09999999872099379, 0.0999999997947913]
Neuron 2: [0.09999999900806307, 0.09999999552084389, 0.09999999717111592, 0.09999999872099379, 0.0999999997947913]
Layer 2:
Fungsi Aktivasi:  linear
Neuron 1: [0.9999999998327334, 0.999999998347865, 0.999999998347865]
Neuron 2: [0.9999999998327334, 0.999999998347865, 0.999999998347865]
Neuron 3: [0.9999999998327334, 0.999999998347865, 0.999999998347865]
Layer 3:
Fungsi Aktivasi:  linear
Neuron 1: [0.9999999987857962, 0.9999999637368364, 0.9999999637368364, 0.9999999637368364]
Neuron 2: [0.999999987865347, 0.9999999637588936, 0.9999999637588936, 0.9999999637588936]
Neuron 3: [0.999999987865347, 0.9999999637588936, 0.9999999637588936, 0.9999999637588936]
Layer 4:
Fungsi Aktivasi:  linear
Neuron 1: [0.9999968123521099, 0.9999678224292062, 0.9999678224292061, 0.9999678224292061]
Neuron 2: [0.999864539214063, 0.9986324035423736, 0.9986324035423653, 0.9986324035423653]
Neuron 3: [0.9998645377199105, 0.9986323884512859, 0.9986323884512761, 0.9986323884512761]
Layer 5:
Fungsi Aktivasi:  RELU
Neuron 1: [-62033.17816397236, -2556296.882287305, -2556389.96436373, -2556389.9648791626]
Neuron 2: [-16844.95173869919, -791614.3742679608, -791732.5108309791, -791732.5114309561]
Neuron 3: [-34150.73286904623, -1068279.1657977493, -1068413.497704182, -1068413.4983637272]
iter:  1000
error:  75.0
```

Model 4

Layer 1:
Fungsi Aktivasi: linear
Neuron 1: [0.1, 0.1, 0.1, 0.1, 0.1]
Neuron 2: [0.1, 0.1, 0.1, 0.1, 0.1]
Layer 2:
Fungsi Aktivasi: linear
Neuron 1: [1.0, 1.0, 1.0]
Neuron 2: [1.0, 1.0, 1.0]
Neuron 3: [1.0, 1.0, 1.0]
Layer 3:
Fungsi Aktivasi: softmax
Neuron 1: [1.0, 1.0, 1.0, 0.5]
Neuron 2: [1.0, 0.5, 0.5, 0.5]
Neuron 3: [1.0, 0.5, 0.5, 1.0]

Batch size = 1

```
Layer 1:
Fungsi Aktivasi:  linear
Neuron 1: [0.02286998804827396, -0.21073758365443765, -0.01462371097485473, -1.1986688520280382, -0.6007971767590292]
Neuron 2: [0.20580870268621562, 0.9966961622915502, 0.5768351874302214, -0.30990620905985766, -0.34795633920263863]
Layer 2:
Fungsi Aktivasi:  linear
Neuron 1: [1.5893870929800378, 2.7080349248252755, 2.606901446097535]
Neuron 2: [-1.3366036960903271, -2.418283870044538, 0.3762439128185482]
Neuron 3: [-0.08960274400814736, 0.7770331242184626, -3.452091833742927]
Layer 3:
...
Neuron 2: [4.704182969160311, 25.47726696696934, -32.330697274536526, -30.62360343881536]
Neuron 3: [-3.9439084407783276, -81.1813422291427, 55.52316424802533, 52.085498665152805]
iter:  1000
error:  404.3623646617326
```

Batch size = 10

```
Layer 1:
Fungsi Aktivasi:  linear
Neuron 1: [0.5770379230091658, 3.1822964911633096, 1.4712751091065936, 2.693157111139464, 1.0753944958105532]
Neuron 2: [0.5552420979032299, 3.0422614190177484, 1.4089173709049618, 2.575134428554738, 1.0310395911816288]
Layer 2:
Fungsi Aktivasi:  linear
Neuron 1: [1.2813405481480904, 0.6365261608265319, 0.6435245727248734]
Neuron 2: [2.241383175476275, -0.6070312897053035, -0.5761021273726191]
Neuron 3: [2.2320772475886335, -0.5978772956233159, -0.5671541631036194]
Layer 3:
Fungsi Aktivasi:  softmax
Neuron 1: [357.71766989449986, 787.90383342022, 496.5275390932874, 497.3589068003466]
Neuron 2: [167.03842170861518, 364.71645494838054, 233.06228495993992, 233.65662738428034]
Neuron 3: [-521.7560916031135, -1150.6202883686012, -727.5898240532267, -729.0155341846274]
iter:  1000
error:  inf
```

Batch size = 50

```
Layer 1:
Fungsi Aktivasi:  linear
Neuron 1: [3.887708020241794, 24.571459912951898, 11.260661019823061, 20.757577060063188, 7.740502105180645]
Neuron 2: [3.265788684520724, 20.555479374043173, 9.430320338077403, 17.371172443665685, 6.490093656153428]
Layer 2:
Fungsi Aktivasi:  linear
Neuron 1: [2.8596699406110795, -1.997896900001603, -2.008423709787321]
Neuron 2: [15.142143234795261, -21.15075287573384, -21.229939773882514]
Neuron 3: [15.520301868631421, -21.728353793537153, -21.809634163900657]
Layer 3:
Fungsi Aktivasi:  softmax
Neuron 1: [1511.965697110522, 6155.574527735296, 42245.3576656886, 43345.11733135401]
Neuron 2: [755.8386589104155, 1580.0110960299644, 5158.21464111346, 5271.920624652084]
Neuron 3: [-2264.8043560209376, -7733.585623765201, -47401.57230680244, -48615.03795600621]
iter:  1000
error:  inf
```

3. Perbandingan dengan MLP sklearn

Konfigurasi MLP yang digunakan adalah sebagai berikut:

```
clf = MLPClassifier(solver='adam', alpha=1e-5,hidden_layer_sizes=(5, ), random_state=1,
max_iter=1000, batch_size= 1, learning_rate_init=0.1)

Keterangan:
solver "adam" untuk gradient descent
hidden layer sizes sebesar 5
max_iter, iterasi maksimum 1000
batch_size, besar batch 10
learning_rate_init, learning rate
```

Berikut hasil eksekusi dengan MLP sklearn:

IrisModel merupakan Model 4 Mini-Batch Gradient Descent dibandingkan dengan model Sklearn. Dari 150 data prediksi, sklearn memiliki ketepatan 100% sedangkan model 4 memiliki ketepatan 97%.

```
IrisModel:  [1.0, 0.0, 0.0] Sklearn:  [1 0 0] target:  [1, 0, 0]
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IrisModel Correct count 145
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4. Pembagian Tugas

Nama	NIM	Tugas
Syihabuddin Yahya Muhammad	13519149	FFNN
Rolland Steven Supardi	13519173	Layer + aktivasi

Muhammad Furqon	13519184	Neuron
Ahmad Saladin	13519187	Neuron, Host Liveshare