Results report: Feed forward back propagation neural network

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Abstract

Analysis on the neural network was completed to observe its performance on datasets: `run_iris()`, `run_sin()`, and `run_xor()`. In general, this neural network was built to accomplish the training of models, enabling parameter adjustments, and improving performance metrics (i.e., RMSE, accuracy, etc.).

1 Training

A variety of training can be done using this neural network.

- For instance, `run_iris()` completes a classification task, and more specifically in this case, it predicts a species. When reviewing the 'samplerun' file, note that a single line is conceptualized as one data point from the dataset. Each output is a vector, indicating the probability (%) to its corresponding class. For further illustration, refer to the first input for `run_iris()`: [4.9, 3.0, 1.4, 0.2]. The expected output is [1.0, 0.0, 0.0]. The output [0.9904199514567914, 0.9965739475659805, 0.9890647732172095] provides high confidence in predicting class 0 (setosa, versus versicolor and virginica).
- Separately, `run_sin()` performs a regression task, where the model approximates sine values. The accuracy can be assessed where the model compares the outputs against the expected values.
- Finally, `run_xor()` is designed to train for 'exclusive or' problems, specifically testing for the neural network's capacity to learn complex relationships. As seen in the 'samplerun', the model runs input vectors that represent truth table pairs ([1. 0.], [1. 1.], [0. 0.], [0. 1.]) for corresponding expected values ([1.] = true, [0.] = false).

2 Performance

RMSE values provide indication of performance during training. In general, a negative correlation between epochs and RMSE over time signifies model improvement. In other words, "as epochs increase, RMSE decreases". Epochs refer to the number of times an entire dataset is forward passed and backward passed through a neural network during training, where each pass counts as one epoch. As the neural network goes through more training and iterations, it becomes more accurate in predicting values. When looking at each model in the

'samplerun', the training method of gradient descent can also be observed, such that there is iteration through multiple epochs, adjusting parameters based on the gradient of loss function, minimizing errors.

2.1 Performance, as is:

- In `run_iris()`, Epoch 0-900, a small average growth can be seen, indicating learning over time and prediction improvement. In addition, high confidence in its predictions in the entry range of epochs can be observed. However, more broadly, the performance of `run_iris()` plateaus and does not show great improvement beyond that. Nonetheless, performance is still reasonable in this classification task.
- In `run_sin()`, similar to `run_iris()`, multiple epoch iterations can be observed upon run, with the parameters of `run_sin()` minimizing RMSE between predicted and expected outputs.
- In `run_xor()`, RMSE also decreases during progressive training. This may indicate attempts of `run_xor()` to meet better approximation rates, however even through reduction of RMSE, predictions appear to be inaccurate. Specifically, output values sit at 0.5 and plateaus. The expected 1 or 0 is not obtained. There is suggestion that, despite ongoing training, the unsuccessful attempts to learn complex relationships, as seen in `run_xor()`, point to the limited capacity to capture nonlinear relationships between input and output.

2.2 Performance, post-alteration:

- In alterations to `run_iris()`, topology (i.e., hidden layers) was doubled, from 3 to 6, and learning rate (i.e., epochs) was halved, from 10001 to 5000. Comparatively, the original settings produced a lower 'Final RMSE', indicating better performance in prediction accuracy. The original settings also produced slightly better performance in terms of the predicted values being closer to the expected values. For the classification task, this suggests lower topology and/or higher learning rate is most optimal. To test this, in the second alterations to `run_iris()`, topology was set back to its original value, from 6 to 3, and learning rate was raised by one order of magnitude, from 5000 to 50005. This resulted in lower RMSE, which could suggest a few factors: better generalization capabilities, less prone to overfitting, and/or increased capacity for better discrimination between classes. This second alteration was successful in showing that a higher learning rate is more optimal for this task and model.
- In alterations to `run_sin()`, topology was raised by one order of magnitude, from 3 to 30, and learning rate was doubled, from 10001 to 20002. Comparatively, both the original settings and the post-alteration settings produced similar 'Final RMSE' values, being 0.2309 versus 0.2350. Both runs vary slightly in terms of producing input-output pairs, but the error is similar. This suggests `run_sin()` is a robust model capable of producing consistent results.
- In alterations to `run_xor()`, topology was raised by three orders of magnitude, from 3 to 3000, and learning rate was raised to the approximate power of $\frac{1}{4}$, from 40001 to 10001. Even with these alterations, the binary

classification task yields similar results, where the output lands 0.5, not much different from random guess. Since the model remains stable over both runs, there is no reason to believe it is learning effectively. This is likely because the `run_xor()` dataset is lacking in complexity.

Overall, runtime was notably faster when `run_iris()` learning rate was lower, showing improved efficiency as the alterations reduced the time complexity, leading to more rapid execution. Time complexity increased when `run_iris()` learning rate was higher, due to longer runtimes. `run_iris()` performed slightly better in its original version compared to its post-altered version, but `run_sin()` and `run_xor()` performed more or less the same.

samplerun

FFBPNetwork (Complete Neural Network) samplerun

run_iris()

```
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4

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Input: [5.1 3.5 1.4 0.3], Expected: [1. 0. 0.], Output: [0.9972709587432589, 0.02764788009
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Epoch 2000: RMSE: 0.4296005342850072
Epoch 2100: RMSE: 0.4368180851764391
Epoch 2200: RMSE: 0.43414193270887536
Epoch 2300: RMSE: 0.43155003243732276
Epoch 2400: RMSE: 0.43380285005027625
Epoch 2500: RMSE: 0.4322689730561826
Epoch 2600: RMSE: 0.42717624737249155
Epoch 2700: RMSE: 0.43650691987415285
Epoch 2800: RMSE: 0.4304239332717642
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Epoch 2900: RMSE: 0.42549383581302963
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Epoch 3000: RMSE: 0.43166975409162495
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Epoch 3200: RMSE: 0.43200506149935414
Epoch 3300: RMSE: 0.4384114971233271
Epoch 3400: RMSE: 0.42737519108241306
Epoch 3500: RMSE: 0.4322228019859184
Epoch 3600: RMSE: 0.4210555133149086
Epoch 3700: RMSE: 0.43488680817397185
Epoch 3800: RMSE: 0.430117476604738
Epoch 3900: RMSE: 0.4293467251596722
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Epoch 5200: RMSE: 0.42668395205682674
Epoch 5300: RMSE: 0.4323421135052297
Epoch 5400: RMSE: 0.4294466304700748
Epoch 5500: RMSE: 0.4305712416520354
Epoch 5600: RMSE: 0.43463069380822844
Epoch 5700: RMSE: 0.4319859565500023
Epoch 5800: RMSE: 0.43217772442640345
Epoch 5900: RMSE: 0.4345108750990944
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Epoch 6200: RMSE: 0.4325460740023626
Epoch 6300: RMSE: 0.4324422810029442
Epoch 6400: RMSE: 0.4284110284552246
Epoch 6500: RMSE: 0.4247231559225123
Epoch 6600: RMSE: 0.4290827393236537
Epoch 6700: RMSE: 0.42504162830595593
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Epoch 7400: RMSE: 0.4317028446026094
Epoch 7500: RMSE: 0.43162482679493636
Epoch 7600: RMSE: 0.424290288069874
Epoch 7700: RMSE: 0.42882520842316163
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Epoch 8100: RMSE: 0.42814881940713767
Epoch 8200: RMSE: 0.4218382804418652
Epoch 8300: RMSE: 0.4242049403894499
Epoch 8400: RMSE: 0.43530432239727407
Epoch 8500: RMSE: 0.43301390513103577
Epoch 8600: RMSE: 0.43246234423127766
Epoch 8700: RMSE: 0.42867469895546895
Epoch 8800: RMSE: 0.42596154546866233
Epoch 8900: RMSE: 0.43250016781479206
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Epoch 9200: RMSE: 0.4323081427401147
Epoch 9300: RMSE: 0.42849714921995585
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Epoch 9400: RMSE: 0.42551801464202205
Epoch 9500: RMSE: 0.4225435489645304
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Epoch 9700: RMSE: 0.4344200438057691
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Input: [6.8 3.  5.5 2.1], Expected: [0. 0. 1.], Output: [1.784953192120081e-06, 0.23995337
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Epoch 10000: RMSE: 0.42936670206792404
Final RMSE: 0.42936670206792404
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RMSE: 1.104093148214763


## run_sin()

Input: [1.03], Expected: [0.85729899], Output: [0.5335019338300239]
Input: [0.43], Expected: [0.4168708], Output: [0.5144493502401513]
Input: [0.2], Expected: [0.19866933], Output: [0.5066958971755651]
Input: [0.46], Expected: [0.44394811], Output: [0.5153081567238902]
Input: [1.52], Expected: [0.99871014], Output: [0.5502730653392943]
Input: [0.37], Expected: [0.36161543], Output: [0.5130562048141081]
Input: [0.92], Expected: [0.79560162], Output: [0.5322655734600525]
Input: [0.93], Expected: [0.80161994], Output: [0.5333134107807456]
Input: [0.36], Expected: [0.35227423], Output: [0.5131910543715799]
Input: [0.26], Expected: [0.25708055], Output: [0.5094809118645021]
Input: [1.06], Expected: [0.87235548], Output: [0.5383647236106135]
Input: [1.14], Expected: [0.9086335], Output: [0.5424924951583359]
Input: [0.63], Expected: [0.58914476], Output: [0.5243360532241698]
Input: [1.04], Expected: [0.86240423], Output: [0.5402506650357315]
Input: [0.07], Expected: [0.06994285], Output: [0.5027878405774366]
Epoch 0: RMSE: 0.28404814329031064
Epoch 100: RMSE: 0.21741106729498702
Epoch 200: RMSE: 0.21692765908376677
Epoch 300: RMSE: 0.21691970100838076
Epoch 400: RMSE: 0.21691954920333828
Epoch 500: RMSE: 0.21691941868666997
Epoch 600: RMSE: 0.2169195236062357
Epoch 700: RMSE: 0.21691951347940158
Epoch 800: RMSE: 0.2169195385331641
Epoch 900: RMSE: 0.21691957766759604
Input: [0.92], Expected: [0.79560162], Output: [0.7345337529865714]
Input: [1.06], Expected: [0.87235548], Output: [0.7637235943165612]
Input: [0.93], Expected: [0.80161994], Output: [0.7369714084347674]
Input: [0.2], Expected: [0.19866933], Output: [0.5551950208697457]
Input: [0.46], Expected: [0.44394811], Output: [0.6246815304726604]
Input: [1.04], Expected: [0.86240423], Output: [0.7596615687470424]
Input: [1.14], Expected: [0.9086335], Output: [0.7794721914932288]
Input: [0.63], Expected: [0.58914476], Output: [0.6678653586103847]
Input: [0.43], Expected: [0.4168708], Output: [0.6169326299639929]
Input: [0.36], Expected: [0.35227423], Output: [0.5983525151924992]
Input: [0.37], Expected: [0.36161543], Output: [0.6009161282952613]
Input: [1.03], Expected: [0.85729899], Output: [0.7573607639834463]
Input: [0.07], Expected: [0.06994285], Output: [0.5193463251716093]
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Input: [0.26], Expected: [0.25708055], Output: [0.5713772711219669]
Input: [1.52], Expected: [0.99871014], Output: [0.8427837370924277]
Epoch 1000: RMSE: 0.21691950235103746
Epoch 1100: RMSE: 0.21691954482629405
Epoch 1200: RMSE: 0.2169195107078789
Epoch 1300: RMSE: 0.21691955821594033
Epoch 1400: RMSE: 0.2169195693788592
Epoch 1500: RMSE: 0.21691958822149637
Epoch 1600: RMSE: 0.2169194293746178
Epoch 1700: RMSE: 0.2169195909764229
Epoch 1800: RMSE: 0.21691951750058444
Epoch 1900: RMSE: 0.21691945953616265
Input: [1.52], Expected: [0.99871014], Output: [0.8430948662109913]
Input: [1.06], Expected: [0.87235548], Output: [0.7639106004173131]
Input: [0.26], Expected: [0.25708055], Output: [0.5715776161106629]
Input: [0.46], Expected: [0.44394811], Output: [0.6247108801602846]
Input: [0.43], Expected: [0.4168708], Output: [0.6167884306665202]
Input: [0.2], Expected: [0.19866933], Output: [0.5550666523518736]
Input: [1.04], Expected: [0.86240423], Output: [0.7593530503322712]
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Input: [0.93], Expected: [0.80161994], Output: [0.7365344365638025]
Input: [0.37], Expected: [0.36161543], Output: [0.6009007873310945]
Input: [1.14], Expected: [0.9086335], Output: [0.7789622592418349]
Epoch 2000: RMSE: 0.21691953008949424
Epoch 2100: RMSE: 0.21691962445449373
Epoch 2200: RMSE: 0.2169194835238264
Epoch 2300: RMSE: 0.2169194836088033
Epoch 2400: RMSE: 0.21691944219374432
Epoch 2500: RMSE: 0.21691957891106445
Epoch 2600: RMSE: 0.21691956481797836
Epoch 2700: RMSE: 0.21691930342425292
Epoch 2800: RMSE: 0.21691920829973027
Epoch 2900: RMSE: 0.2169192875277852
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Input: [0.63], Expected: [0.58914476], Output: [0.6676211799969504]
Input: [1.52], Expected: [0.99871014], Output: [0.8431549058677129]
Input: [0.43], Expected: [0.4168708], Output: [0.6169141311559686]
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Input: [0.07], Expected: [0.06994285], Output: [0.5193600223931539]
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Input: [0.26], Expected: [0.25708055], Output: [0.5715240799094704]
Input: [0.2], Expected: [0.19866933], Output: [0.5551234513329882]
Epoch 3000: RMSE: 0.2169194250597584
Epoch 3100: RMSE: 0.21691955174954305
Epoch 3200: RMSE: 0.2169195362132373
Epoch 3300: RMSE: 0.216919551603225
Epoch 3400: RMSE: 0.2169195368694579
Epoch 3500: RMSE: 0.21691958431731612
Epoch 3600: RMSE: 0.2169195495215807
Epoch 3700: RMSE: 0.21691950894821657
Epoch 3800: RMSE: 0.21691952007730297
Epoch 3900: RMSE: 0.2169195026069116
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[0.05], [0.04997917], [0.5138197594099789]
RMSE: 0.2349886647985063


## run_xor()

Input: [1. 0.], Expected: [1.], Output: [0.6389999910847122]
Input: [1. 1.], Expected: [0.], Output: [0.7142334062528745]
Input: [0. 0.], Expected: [0.], Output: [0.5]
Input: [0. 1.], Expected: [1.], Output: [0.5826241902834629]
Epoch 0: RMSE: 0.5159101015634789
Epoch 100: RMSE: 0.5053613913766907
Epoch 200: RMSE: 0.5017611758875762
Epoch 300: RMSE: 0.5009839834434848
Epoch 400: RMSE: 0.5008354432955027
Epoch 500: RMSE: 0.50080130673771
Epoch 600: RMSE: 0.5007910651181835
Epoch 700: RMSE: 0.5007869148803468
Epoch 800: RMSE: 0.5007849370444947
Epoch 900: RMSE: 0.5007838771327451
Input: [1. 0.], Expected: [1.], Output: [0.5008149396669958]
Input: [1. 1.], Expected: [0.], Output: [0.5009506446611478]
Input: [0. 0.], Expected: [0.], Output: [0.5]
Input: [0. 1.], Expected: [1.], Output: [0.49701032677323814]
Epoch 1000: RMSE: 0.500783357405887
Epoch 1100: RMSE: 0.5007818166485472
Epoch 1200: RMSE: 0.500782881789028
Epoch 1300: RMSE: 0.5007828840013377
Epoch 1400: RMSE: 0.5007828143862162
Epoch 1500: RMSE: 0.5007828174647252
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Epoch 1600: RMSE: 0.5007827709083438
Epoch 1700: RMSE: 0.5007827894779928
Epoch 1800: RMSE: 0.5007827618370787
Epoch 1900: RMSE: 0.500782759940363
Input: [1. 0.], Expected: [1.], Output: [0.49970893557467483]
Input: [0. 1.], Expected: [1.], Output: [0.49961384290188054]
Input: [1. 1.], Expected: [0.], Output: [0.5024498736162446]
Input: [0. 0.], Expected: [0.], Output: [0.5]
Epoch 2000: RMSE: 0.5007827200633597
Epoch 2100: RMSE: 0.5007827447621771
Epoch 2200: RMSE: 0.5007827547967191
Epoch 2300: RMSE: 0.5007815176099032
Epoch 2400: RMSE: 0.5007827853078315
Epoch 2500: RMSE: 0.5007829030060793
Epoch 2600: RMSE: 0.5007815755950114
Epoch 2700: RMSE: 0.5007828178791488
Epoch 2800: RMSE: 0.5007827798461064
Epoch 2900: RMSE: 0.5007827877627956
Input: [0. 1.], Expected: [1.], Output: [0.4997993885129873]
Input: [1. 0.], Expected: [1.], Output: [0.499728251700658]
Input: [0. 0.], Expected: [0.], Output: [0.5]
Input: [1. 1.], Expected: [0.], Output: [0.5026540906586895]
Epoch 3000: RMSE: 0.5007827894243111
Epoch 3100: RMSE: 0.5007827619421307
Epoch 3200: RMSE: 0.5007827534240266
Epoch 3300: RMSE: 0.5007827457014837
Epoch 3400: RMSE: 0.5007828537229612
Epoch 3500: RMSE: 0.5007827857759598
Epoch 3600: RMSE: 0.5007828465884676
Epoch 3700: RMSE: 0.5007815522741265
Epoch 3800: RMSE: 0.5007827773552629
Epoch 3900: RMSE: 0.5007827717326457
Input: [1. 1.], Expected: [0.], Output: [0.4993085791025578]
Input: [1. 0.], Expected: [1.], Output: [0.49810793986860025]
Input: [0. 0.], Expected: [0.], Output: [0.5]
Input: [0. 1.], Expected: [1.], Output: [0.49807998461009684]
Epoch 4000: RMSE: 0.5007814890342285
Epoch 4100: RMSE: 0.5007827454670492
Epoch 4200: RMSE: 0.5007827690205988
Epoch 4300: RMSE: 0.5007815036196684
Epoch 4400: RMSE: 0.5007827564727485
Epoch 4500: RMSE: 0.5007827683447301
Epoch 4600: RMSE: 0.5007827678301954
Epoch 4700: RMSE: 0.5007827901126723
Epoch 4800: RMSE: 0.5007815707068436
Epoch 4900: RMSE: 0.5007828188288168
Input: [1. 1.], Expected: [0.], Output: [0.4995107327734016]
Input: [0. 1.], Expected: [1.], Output: [0.4981980611167658]
Input: [1. 0.], Expected: [1.], Output: [0.49819074810779107]
Input: [0. 0.], Expected: [0.], Output: [0.5]
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Epoch 5000: RMSE: 0.5007815599908337
Epoch 5100: RMSE: 0.5007816229640063
Epoch 5200: RMSE: 0.5007816271906012
Epoch 5300: RMSE: 0.5007827764999998
Epoch 5400: RMSE: 0.5007828314320133
Epoch 5500: RMSE: 0.5007828518504505
Epoch 5600: RMSE: 0.5007815159324362
Epoch 5700: RMSE: 0.5007815569556181
Epoch 5800: RMSE: 0.5007827688423384
Epoch 5900: RMSE: 0.5007827603962969
Input: [1. 0.], Expected: [1.], Output: [0.49972124066067136]
Input: [0. 0.], Expected: [0.], Output: [0.5]
Input: [0. 1.], Expected: [1.], Output: [0.4997235485496808]
Input: [1. 1.], Expected: [0.], Output: [0.5025715005503388]
Epoch 6000: RMSE: 0.500782756813581
Epoch 6100: RMSE: 0.5007827540418057
Epoch 6200: RMSE: 0.5007827792166537
Epoch 6300: RMSE: 0.5007828210582821
Epoch 6400: RMSE: 0.5007828072273222
Epoch 6500: RMSE: 0.500782797940004
Epoch 6600: RMSE: 0.5007816066031221
Epoch 6700: RMSE: 0.5007827890257015
Epoch 6800: RMSE: 0.5007827912182761
Epoch 6900: RMSE: 0.500782781602821
Input: [1. 1.], Expected: [0.], Output: [0.4996257444680585]
Input: [1. 0.], Expected: [1.], Output: [0.49826683571731817]
Input: [0. 1.], Expected: [1.], Output: [0.4982362637845542]
Input: [0. 0.], Expected: [0.], Output: [0.5]
Epoch 7000: RMSE: 0.500781613993879
Epoch 7100: RMSE: 0.5007828171370887
Epoch 7200: RMSE: 0.5007828367226558
Epoch 7300: RMSE: 0.5007828187036032
Epoch 7400: RMSE: 0.5007815524871542
Epoch 7500: RMSE: 0.5007827952368972
Epoch 7600: RMSE: 0.5007827974619119
Epoch 7700: RMSE: 0.5007815579722944
Epoch 7800: RMSE: 0.5007827910832644
Epoch 7900: RMSE: 0.5007827225492025
Input: [0. 1.], Expected: [1.], Output: [0.4997381124803434]
Input: [1. 0.], Expected: [1.], Output: [0.49976721887359626]
Input: [1. 1.], Expected: [0.], Output: [0.5026318520780381]
Input: [0. 0.], Expected: [0.], Output: [0.5]
Epoch 8000: RMSE: 0.5007827797911947
Epoch 8100: RMSE: 0.5007827164468072
Epoch 8200: RMSE: 0.5007827503476
Epoch 8300: RMSE: 0.500782772181569
Epoch 8400: RMSE: 0.5007828086103927
Epoch 8500: RMSE: 0.5007814821214944
Epoch 8600: RMSE: 0.5007827419422363
Epoch 8700: RMSE: 0.5007815146788673
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Epoch 8800: RMSE: 0.5007828580664028
Epoch 8900: RMSE: 0.5007815961261428
Input: [1. 1.], Expected: [0.], Output: [0.49955659659644747]
Input: [1. 0.], Expected: [1.], Output: [0.49820775564743014]
Input: [0. 0.], Expected: [0.], Output: [0.5]
Input: [0. 1.], Expected: [1.], Output: [0.49822662967145215]
Epoch 9000: RMSE: 0.5007815803487298
Epoch 9100: RMSE: 0.500782776361138
Epoch 9200: RMSE: 0.5007827817767788
Epoch 9300: RMSE: 0.5007827469243333
Epoch 9400: RMSE: 0.5007827612217828
Epoch 9500: RMSE: 0.5007828454648137
Epoch 9600: RMSE: 0.5007816248198801
Epoch 9700: RMSE: 0.5007827865229504
Epoch 9800: RMSE: 0.5007815204494722
Epoch 9900: RMSE: 0.5007815261730301
Input: [1. 0.], Expected: [1.], Output: [0.49973821568469484]
Input: [0. 1.], Expected: [1.], Output: [0.4996935652546442]
Input: [0. 0.], Expected: [0.], Output: [0.5]
Input: [1. 1.], Expected: [0.], Output: [0.5025585332142813]
Epoch 10000: RMSE: 0.5007827524986338
Epoch 10100: RMSE: 0.5007827934293811
Epoch 10200: RMSE: 0.5007815103305969
Epoch 10300: RMSE: 0.5007827369730513
Epoch 10400: RMSE: 0.5007827476415582
Epoch 10500: RMSE: 0.5007827451000315
Epoch 10600: RMSE: 0.5007815511059529
Epoch 10700: RMSE: 0.500781578461193
Epoch 10800: RMSE: 0.5007827608085548
Epoch 10900: RMSE: 0.5007815719291288
Input: [0. 1.], Expected: [1.], Output: [0.4997814859466559]
Input: [1. 0.], Expected: [1.], Output: [0.4997911592115264]
Input: [0. 0.], Expected: [0.], Output: [0.5]
Input: [1. 1.], Expected: [0.], Output: [0.5026989538307807]
Epoch 11000: RMSE: 0.5007828083079644
Epoch 11100: RMSE: 0.5007815285231231
Epoch 11200: RMSE: 0.5007827812149718
Epoch 11300: RMSE: 0.5007828977671578
Epoch 11400: RMSE: 0.5007827986511244
Epoch 11500: RMSE: 0.5007815696250537
Epoch 11600: RMSE: 0.5007827821141035
Epoch 11700: RMSE: 0.5007827911814958
Epoch 11800: RMSE: 0.5007827554932623
Epoch 11900: RMSE: 0.5007815843872029
Input: [1. 0.], Expected: [1.], Output: [0.4996882358511099]
Input: [1. 1.], Expected: [0.], Output: [0.5009707060708399]
Input: [0. 1.], Expected: [1.], Output: [0.4981534786634399]
Input: [0. 0.], Expected: [0.], Output: [0.5]
Epoch 12000: RMSE: 0.5007827474725186
Epoch 12100: RMSE: 0.5007827013476037
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Epoch 12200: RMSE: 0.5007815105443659
Epoch 12300: RMSE: 0.5007827368793099
Epoch 12400: RMSE: 0.5007814989267103
Epoch 12500: RMSE: 0.5007827529330893
Epoch 12600: RMSE: 0.5007827952658654
Epoch 12700: RMSE: 0.5007828361484346
Epoch 12800: RMSE: 0.5007828055203829
Epoch 12900: RMSE: 0.5007815470432906
Input: [0. 0.], Expected: [0.], Output: [0.5]
Input: [1. 0.], Expected: [1.], Output: [0.49972238900839533]
Input: [0. 1.], Expected: [1.], Output: [0.4997368712316678]
Input: [1. 1.], Expected: [0.], Output: [0.5025859260275637]
Epoch 13000: RMSE: 0.5007827620599405
Epoch 13100: RMSE: 0.5007827714193969
Epoch 13200: RMSE: 0.5007827812064023
Epoch 13300: RMSE: 0.5007815604619003
Epoch 13400: RMSE: 0.5007828074522397
Epoch 13500: RMSE: 0.5007827509632395
Epoch 13600: RMSE: 0.5007827981874274
Epoch 13700: RMSE: 0.5007827649434267
Epoch 13800: RMSE: 0.5007828146408287
Epoch 13900: RMSE: 0.5007828268374532
Input: [0. 1.], Expected: [1.], Output: [0.4997293037694734]
Input: [0. 0.], Expected: [0.], Output: [0.5]
Input: [1. 0.], Expected: [1.], Output: [0.49977269799965046]
Input: [1. 1.], Expected: [0.], Output: [0.5026285329751052]
Epoch 14000: RMSE: 0.5007827785912349
Epoch 14100: RMSE: 0.5007815821661491
Epoch 14200: RMSE: 0.5007827685019988
Epoch 14300: RMSE: 0.5007828233436032
Epoch 14400: RMSE: 0.5007827439721046
Epoch 14500: RMSE: 0.5007827561292031
Epoch 14600: RMSE: 0.500782741370254
Epoch 14700: RMSE: 0.5007827745934932
Epoch 14800: RMSE: 0.5007815721578552
Epoch 14900: RMSE: 0.500782783334131
Input: [1. 0.], Expected: [1.], Output: [0.4998245543140362]
Input: [1. 1.], Expected: [0.], Output: [0.5011481817956962]
Input: [0. 0.], Expected: [0.], Output: [0.5]
Input: [0. 1.], Expected: [1.], Output: [0.49819450946953286]
Epoch 15000: RMSE: 0.5007828189222369
Epoch 15100: RMSE: 0.5007815200310354
Epoch 15200: RMSE: 0.5007827853572899
Epoch 15300: RMSE: 0.5007815565644771
Epoch 15400: RMSE: 0.5007828867209184
Epoch 15500: RMSE: 0.5007827870066242
Epoch 15600: RMSE: 0.5007827411307375
Epoch 15700: RMSE: 0.5007815448985428
Epoch 15800: RMSE: 0.5007828162556018
Epoch 15900: RMSE: 0.5007827747704091
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Input: [1. 0.], Expected: [1.], Output: [0.4997117897257638]
Input: [1. 1.], Expected: [0.], Output: [0.5009736326717225]
Input: [0. 1.], Expected: [1.], Output: [0.49813291608332794]
Input: [0. 0.], Expected: [0.], Output: [0.5]
Epoch 16000: RMSE: 0.5007827482778147
Epoch 16100: RMSE: 0.5007827458552728
Epoch 16200: RMSE: 0.5007815378904611
Epoch 16300: RMSE: 0.5007815660310597
Epoch 16400: RMSE: 0.5007827984809605
Epoch 16500: RMSE: 0.5007827465377294
Epoch 16600: RMSE: 0.5007827179892631
Epoch 16700: RMSE: 0.5007828512421175
Epoch 16800: RMSE: 0.5007815284883241
Epoch 16900: RMSE: 0.5007827766835768
Input: [0. 1.], Expected: [1.], Output: [0.49969076280103564]
Input: [1. 0.], Expected: [1.], Output: [0.49968212905201753]
Input: [0. 0.], Expected: [0.], Output: [0.5]
Input: [1. 1.], Expected: [0.], Output: [0.5024998294244214]
Epoch 17000: RMSE: 0.5007827331758016
Epoch 17100: RMSE: 0.500782847038087
Epoch 17200: RMSE: 0.5007815574917261
Epoch 17300: RMSE: 0.5007816091641785
Epoch 17400: RMSE: 0.5007828202420338
Epoch 17500: RMSE: 0.5007827520258336
Epoch 17600: RMSE: 0.5007827161872292
Epoch 17700: RMSE: 0.5007815450218575
Epoch 17800: RMSE: 0.5007827906368124
Epoch 17900: RMSE: 0.5007827366580327
Input: [0. 1.], Expected: [1.], Output: [0.4997634045784771]
Input: [1. 0.], Expected: [1.], Output: [0.4997879155311205]
Input: [0. 0.], Expected: [0.], Output: [0.5]
Input: [1. 1.], Expected: [0.], Output: [0.5026776959731968]
Epoch 18000: RMSE: 0.5007827989449467
Epoch 18100: RMSE: 0.5007827706260461
Epoch 18200: RMSE: 0.5007827651486499
Epoch 18300: RMSE: 0.5007827054182099
Epoch 18400: RMSE: 0.5007827344599355
Epoch 18500: RMSE: 0.5007827233797548
Epoch 18600: RMSE: 0.5007827385936292
Epoch 18700: RMSE: 0.5007827693510606
Epoch 18800: RMSE: 0.5007815726030571
Epoch 18900: RMSE: 0.5007827669566682
Input: [1. 1.], Expected: [0.], Output: [0.4993546603300841]
Input: [0. 0.], Expected: [0.], Output: [0.5]
Input: [0. 1.], Expected: [1.], Output: [0.49808493260222836]
Input: [1. 0.], Expected: [1.], Output: [0.4981487837651338]
Epoch 19000: RMSE: 0.5007815029807655
Epoch 19100: RMSE: 0.5007814777021754
Epoch 19200: RMSE: 0.5007815424107853
Epoch 19300: RMSE: 0.5007827916055174
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Epoch 19400: RMSE: 0.5007827609943328
Epoch 19500: RMSE: 0.500781527877257
Epoch 19600: RMSE: 0.500782754351581
Epoch 19700: RMSE: 0.5007828268109031
Epoch 19800: RMSE: 0.5007827573908452
Epoch 19900: RMSE: 0.5007815298271486
Input: [1. 1.], Expected: [0.], Output: [0.49946183693338464]
Input: [0. 1.], Expected: [1.], Output: [0.4981532821438413]
Input: [1. 0.], Expected: [1.], Output: [0.49818693806119935]
Input: [0. 0.], Expected: [0.], Output: [0.5]
Epoch 20000: RMSE: 0.5007815401720257
Epoch 20100: RMSE: 0.5007827700401328
Epoch 20200: RMSE: 0.5007828036676532
Epoch 20300: RMSE: 0.5007814972365084
Epoch 20400: RMSE: 0.5007827465986063
Epoch 20500: RMSE: 0.5007828024430273
Epoch 20600: RMSE: 0.50078282092016
Epoch 20700: RMSE: 0.5007815853589305
Epoch 20800: RMSE: 0.5007827697461877
Epoch 20900: RMSE: 0.5007815596871896
Input: [1. 1.], Expected: [0.], Output: [0.4994730483820385]
Input: [1. 0.], Expected: [1.], Output: [0.49819697044843186]
Input: [0. 1.], Expected: [1.], Output: [0.49815439085109575]
Input: [0. 0.], Expected: [0.], Output: [0.5]
Epoch 21000: RMSE: 0.5007815446752238
Epoch 21100: RMSE: 0.500782771921721
Epoch 21200: RMSE: 0.5007828008688353
Epoch 21300: RMSE: 0.5007827204900822
Epoch 21400: RMSE: 0.5007815335031773
Epoch 21500: RMSE: 0.5007828043767989
Epoch 21600: RMSE: 0.5007828108937603
Epoch 21700: RMSE: 0.5007815809140852
Epoch 21800: RMSE: 0.5007815414366885
Epoch 21900: RMSE: 0.500782757325799
Input: [1. 0.], Expected: [1.], Output: [0.4996991713728682]
Input: [0. 0.], Expected: [0.], Output: [0.5]
Input: [1. 1.], Expected: [0.], Output: [0.5009734079306996]
Input: [0. 1.], Expected: [1.], Output: [0.4981452708413031]
Epoch 22000: RMSE: 0.5007827482445962
Epoch 22100: RMSE: 0.5007827660331174
Epoch 22200: RMSE: 0.5007827474440799
Epoch 22300: RMSE: 0.5007815482559437
Epoch 22400: RMSE: 0.5007827846960183
Epoch 22500: RMSE: 0.5007815373172484
Epoch 22600: RMSE: 0.5007828146530834
Epoch 22700: RMSE: 0.5007827739712465
Epoch 22800: RMSE: 0.5007827441856372
Epoch 22900: RMSE: 0.5007815151524302
Input: [1. 1.], Expected: [0.], Output: [0.4994212758501032]
Input: [1. 0.], Expected: [1.], Output: [0.49817419905841515]
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Input: [0. 0.], Expected: [0.], Output: [0.5]
Input: [0. 1.], Expected: [1.], Output: [0.49812571463521493]
Epoch 23000: RMSE: 0.5007815251117052
Epoch 23100: RMSE: 0.5007827835443392
Epoch 23200: RMSE: 0.5007827715349019
Epoch 23300: RMSE: 0.5007815907417464
Epoch 23400: RMSE: 0.5007827849377233
Epoch 23500: RMSE: 0.5007827932813576
Epoch 23600: RMSE: 0.5007816271058049
Epoch 23700: RMSE: 0.5007828339915816
Epoch 23800: RMSE: 0.5007815915447414
Epoch 23900: RMSE: 0.5007827713798585
Input: [1. 0.], Expected: [1.], Output: [0.499695773839324]
Input: [0. 0.], Expected: [0.], Output: [0.5]
Input: [0. 1.], Expected: [1.], Output: [0.499696763603884013]
Input: [1. 1.], Expected: [0.], Output: [0.5025194132123044]
Epoch 24000: RMSE: 0.5007827392487543
Epoch 24100: RMSE: 0.5007827348421535
Epoch 24200: RMSE: 0.5007827171128606
Epoch 24300: RMSE: 0.5007827456100203
Epoch 24400: RMSE: 0.5007815075311887
Epoch 24500: RMSE: 0.5007816187540923
Epoch 24600: RMSE: 0.5007816192179624
Epoch 24700: RMSE: 0.5007827947289015
Epoch 24800: RMSE: 0.500782748410351
Epoch 24900: RMSE: 0.5007827722848743
Input: [0. 0.], Expected: [0.], Output: [0.5]
Input: [1. 1.], Expected: [0.], Output: [0.49946739801395645]
Input: [0. 1.], Expected: [1.], Output: [0.49815601363317924]
Input: [1. 0.], Expected: [1.], Output: [0.498189732753845]
Epoch 25000: RMSE: 0.5007815423528086
Epoch 25100: RMSE: 0.5007827678889464
Epoch 25200: RMSE: 0.5007827134931817
Epoch 25300: RMSE: 0.5007815045920145
Epoch 25400: RMSE: 0.5007827562778497
Epoch 25500: RMSE: 0.5007815128028718
Epoch 25600: RMSE: 0.5007827158871608
Epoch 25700: RMSE: 0.5007827317685265
Epoch 25800: RMSE: 0.5007827350806284
Epoch 25900: RMSE: 0.500782757595544
Input: [0. 0.], Expected: [0.], Output: [0.5]
Input: [1. 0.], Expected: [1.], Output: [0.4996394025270779]
Input: [1. 1.], Expected: [0.], Output: [0.5008659005674286]
Input: [0. 1.], Expected: [1.], Output: [0.4980976808486291]
Epoch 26000: RMSE: 0.5007827163112275
Epoch 26100: RMSE: 0.5007827689694703
Epoch 26200: RMSE: 0.5007815747954578
Epoch 26300: RMSE: 0.5007827554379868
Epoch 26400: RMSE: 0.5007827268943088
Epoch 26500: RMSE: 0.5007827494425773
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Epoch 26600: RMSE: 0.5007827502082055
Epoch 26700: RMSE: 0.5007828518236186
Epoch 26800: RMSE: 0.5007814857178364
Epoch 26900: RMSE: 0.5007827662310185
Input: [0. 0.], Expected: [0.], Output: [0.5]
Input: [0. 1.], Expected: [1.], Output: [0.4997732223696642]
Input: [1. 1.], Expected: [0.], Output: [0.5010647002525054]
Input: [1. 0.], Expected: [1.], Output: [0.49816245933363784]
Epoch 27000: RMSE: 0.5007827822818056
Epoch 27100: RMSE: 0.5007815452832884
Epoch 27200: RMSE: 0.5007827595810956
Epoch 27300: RMSE: 0.5007815078008019
Epoch 27400: RMSE: 0.5007828640461714
Epoch 27500: RMSE: 0.500782820973876
Epoch 27600: RMSE: 0.5007815339164381
Epoch 27700: RMSE: 0.5007815502818224
Epoch 27800: RMSE: 0.5007827783712709
Epoch 27900: RMSE: 0.5007827688807333
Input: [0. 1.], Expected: [1.], Output: [0.49972315245943955]
Input: [0. 0.], Expected: [0.], Output: [0.5]
Input: [1. 0.], Expected: [1.], Output: [0.4997148407007061]
Input: [1. 1.], Expected: [0.], Output: [0.5025647258904118]
Epoch 28000: RMSE: 0.5007827544228999
Epoch 28100: RMSE: 0.500782774169518
Epoch 28200: RMSE: 0.5007827870755197
Epoch 28300: RMSE: 0.5007827523326333
Epoch 28400: RMSE: 0.5007816262521807
Epoch 28500: RMSE: 0.5007816340785244
Epoch 28600: RMSE: 0.5007815869307776
Epoch 28700: RMSE: 0.5007827736582686
Epoch 28800: RMSE: 0.5007827716453228
Epoch 28900: RMSE: 0.5007828187507165
Input: [1. 0.], Expected: [1.], Output: [0.49978315882550045]
Input: [0. 1.], Expected: [1.], Output: [0.49975327692312077]
Input: [0. 0.], Expected: [0.], Output: [0.5]
Input: [1. 1.], Expected: [0.], Output: [0.5026628585024324]
Epoch 29000: RMSE: 0.5007827926011403
Epoch 29100: RMSE: 0.5007828228382885
Epoch 29200: RMSE: 0.5007828454781648
Epoch 29300: RMSE: 0.5007827353301697
Epoch 29400: RMSE: 0.5007827718603247
Epoch 29500: RMSE: 0.5007827729553472
Epoch 29600: RMSE: 0.5007827704704347
Epoch 29700: RMSE: 0.5007815536463153
Epoch 29800: RMSE: 0.5007815692574054
Epoch 29900: RMSE: 0.5007816127467836
Input: [1. 1.], Expected: [0.], Output: [0.4994538172960323]
Input: [1. 0.], Expected: [1.], Output: [0.4981737856688809]
Input: [0. 0.], Expected: [0.], Output: [0.5]
Input: [0. 1.], Expected: [1.], Output: [0.4981584652243251]
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Epoch 30000: RMSE: 0.5007815369568565
Epoch 30100: RMSE: 0.5007814942000326
Epoch 30200: RMSE: 0.5007815103022851
Epoch 30300: RMSE: 0.5007815832008395
Epoch 30400: RMSE: 0.5007828063334218
Epoch 30500: RMSE: 0.5007827387810648
Epoch 30600: RMSE: 0.5007815257423847
Epoch 30700: RMSE: 0.5007815513660779
Epoch 30800: RMSE: 0.5007827905832414
Epoch 30900: RMSE: 0.5007827242583616
Input: [0. 1.], Expected: [1.], Output: [0.49971659994931533]
Input: [1. 1.], Expected: [0.], Output: [0.5010317888766277]
Input: [1. 0.], Expected: [1.], Output: [0.4981860955841644]
Input: [0. 0.], Expected: [0.], Output: [0.5]
Epoch 31000: RMSE: 0.5007827693961355
Epoch 31100: RMSE: 0.5007827486457437
Epoch 31200: RMSE: 0.5007827843056121
Epoch 31300: RMSE: 0.5007827231379715
Epoch 31400: RMSE: 0.5007815075519471
Epoch 31500: RMSE: 0.5007815560808395
Epoch 31600: RMSE: 0.5007827707253049
Epoch 31700: RMSE: 0.5007815411934078
Epoch 31800: RMSE: 0.5007827636572669
Epoch 31900: RMSE: 0.5007815004121007
Input: [1. 0.], Expected: [1.], Output: [0.499615349019614]
Input: [1. 1.], Expected: [0.], Output: [0.5008638139773034]
Input: [0. 0.], Expected: [0.], Output: [0.5]
Input: [0. 1.], Expected: [1.], Output: [0.49811957890266767]
Epoch 32000: RMSE: 0.5007827163974135
Epoch 32100: RMSE: 0.5007827843271818
Epoch 32200: RMSE: 0.5007827844477145
Epoch 32300: RMSE: 0.5007815126745468
Epoch 32400: RMSE: 0.5007827877667399
Epoch 32500: RMSE: 0.5007827762904046
Epoch 32600: RMSE: 0.5007815526488293
Epoch 32700: RMSE: 0.5007827447048206
Epoch 32800: RMSE: 0.5007815307098249
Epoch 32900: RMSE: 0.5007827957535718
Input: [1. 1.], Expected: [0.], Output: [0.49943526097726276]
Input: [0. 1.], Expected: [1.], Output: [0.49814524090022416]
Input: [1. 0.], Expected: [1.], Output: [0.49816857013601257]
Input: [0. 0.], Expected: [0.], Output: [0.5]
Epoch 33000: RMSE: 0.5007815299953301
Epoch 33100: RMSE: 0.5007827870847399
Epoch 33200: RMSE: 0.5007815161808473
Epoch 33300: RMSE: 0.5007827736711689
Epoch 33400: RMSE: 0.5007815549544465
Epoch 33500: RMSE: 0.5007827823791189
Epoch 33600: RMSE: 0.5007827413128235
Epoch 33700: RMSE: 0.500782743652061
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Epoch 33800: RMSE: 0.5007815053011402
Epoch 33900: RMSE: 0.5007827388902644
Input: [1. 1.], Expected: [0.], Output: [0.49952779139479475]
Input: [0. 0.], Expected: [0.], Output: [0.5]
Input: [1. 0.], Expected: [1.], Output: [0.4981929851914109]
Input: [0. 1.], Expected: [1.], Output: [0.4982127756303917]
Epoch 34000: RMSE: 0.5007815674092411
Epoch 34100: RMSE: 0.500781553123785
Epoch 34200: RMSE: 0.5007815728739123
Epoch 34300: RMSE: 0.5007827228178884
Epoch 34400: RMSE: 0.5007827828495808
Epoch 34500: RMSE: 0.5007815735507885
Epoch 34600: RMSE: 0.5007827596403102
Epoch 34700: RMSE: 0.5007815342414074
Epoch 34800: RMSE: 0.500782766667915
Epoch 34900: RMSE: 0.5007827083154898
Input: [0. 0.], Expected: [0.], Output: [0.5]
Input: [1. 1.], Expected: [0.], Output: [0.4994678649319055]
Input: [0. 1.], Expected: [1.], Output: [0.49816911497601707]
Input: [1. 0.], Expected: [1.], Output: [0.49817709539492644]
Epoch 35000: RMSE: 0.5007815424039366
Epoch 35100: RMSE: 0.5007827409256456
Epoch 35200: RMSE: 0.5007827961043659
Epoch 35300: RMSE: 0.5007827543523228
Epoch 35400: RMSE: 0.5007815579806323
Epoch 35500: RMSE: 0.5007815112571022
Epoch 35600: RMSE: 0.5007827896599689
Epoch 35700: RMSE: 0.5007827775006676
Epoch 35800: RMSE: 0.5007815102815129
Epoch 35900: RMSE: 0.5007827969748038
Input: [1. 0.], Expected: [1.], Output: [0.49970769794678743]
Input: [1. 1.], Expected: [0.], Output: [0.5009708630099265]
Input: [0. 0.], Expected: [0.], Output: [0.5]
Input: [0. 1.], Expected: [1.], Output: [0.49813423402253476]
Epoch 36000: RMSE: 0.50078274734129
Epoch 36100: RMSE: 0.5007828074294054
Epoch 36200: RMSE: 0.500781576396426
Epoch 36300: RMSE: 0.500781580557766
Epoch 36400: RMSE: 0.5007827869893957
Epoch 36500: RMSE: 0.5007827164126681
Epoch 36600: RMSE: 0.5007827472247277
Epoch 36700: RMSE: 0.5007815131516299
Epoch 36800: RMSE: 0.5007827523677522
Epoch 36900: RMSE: 0.5007815195436389
Input: [1. 0.], Expected: [1.], Output: [0.4997689031615449]
Input: [0. 1.], Expected: [1.], Output: [0.49978211725041427]
Input: [0. 0.], Expected: [0.], Output: [0.5]
Input: [1. 1.], Expected: [0.], Output: [0.502677397221304]
Epoch 37000: RMSE: 0.5007827987620649
Epoch 37100: RMSE: 0.5007828837795287
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Epoch 37200: RMSE: 0.5007828280196404
Epoch 37300: RMSE: 0.5007815311180784
Epoch 37400: RMSE: 0.500781586803241
Epoch 37500: RMSE: 0.5007828163936097
Epoch 37600: RMSE: 0.5007815872351753
Epoch 37700: RMSE: 0.500782781892397
Epoch 37800: RMSE: 0.5007815280073956
Epoch 37900: RMSE: 0.5007827406395124
Input: [1. 1.], Expected: [0.], Output: [0.4995477633944584]
Input: [1. 0.], Expected: [1.], Output: [0.49821701094665827]
Input: [0. 1.], Expected: [1.], Output: [0.4982085965802774]
Input: [0. 0.], Expected: [0.], Output: [0.5]
Epoch 38000: RMSE: 0.5007815762789318
Epoch 38100: RMSE: 0.500782846783347
Epoch 38200: RMSE: 0.5007815952863837
Epoch 38300: RMSE: 0.5007828192208195
Epoch 38400: RMSE: 0.5007815461659061
Epoch 38500: RMSE: 0.5007827832868909
Epoch 38600: RMSE: 0.5007828221666257
Epoch 38700: RMSE: 0.50078280181684
Epoch 38800: RMSE: 0.5007827774098779
Epoch 38900: RMSE: 0.5007827501006159
Input: [0. 0.], Expected: [0.], Output: [0.5]
Input: [0. 1.], Expected: [1.], Output: [0.49973046559307904]
Input: [1. 0.], Expected: [1.], Output: [0.4997398041738915]
Input: [1. 1.], Expected: [0.], Output: [0.5025969008953515]
Epoch 39000: RMSE: 0.500782766120527
Epoch 39100: RMSE: 0.5007827387244606
Epoch 39200: RMSE: 0.5007815153252447
Epoch 39300: RMSE: 0.5007827708741325
Epoch 39400: RMSE: 0.5007814830471229
Epoch 39500: RMSE: 0.5007814802549931
Epoch 39600: RMSE: 0.5007827327461135
Epoch 39700: RMSE: 0.5007827342389554
Epoch 39800: RMSE: 0.5007814965292303
Epoch 39900: RMSE: 0.5007815248046886
Input: [1. 0.], Expected: [1.], Output: [0.49969510887009944]
Input: [0. 1.], Expected: [1.], Output: [0.4996864193924444]
Input: [0. 0.], Expected: [0.], Output: [0.5]
Input: [1. 1.], Expected: [0.], Output: [0.5025084386661783]
Epoch 40000: RMSE: 0.5007827358145384
Final RMSE: 0.5007827358145384

Process finished with exit code 0
```