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1) a.

Iteration	b	x1	x2	w0	w1	w2	x1 AND x2	z	a(z)	delta(w0)	delta(w1)	delta(w2)
1	1	0	0	1	1	1	0	1	1	-0.4	0	0
	1	1	0	0.6	1	1	0	1.6	1	-0.4	-0.4	0
	1	1	0	0.2	0.6	1	0	0.8	1	-0.4	-0.4	0
	1	1	1	-0.2	0.2	1	1	1	1	0	0	0

All  $\delta(w_i)$  are 0 at the end of iteration 1. Thus, our perceptron is correctly trained. If you try to train the perceptron further by moving on to iteration 2, it will perfectly classify the data and all  $\delta(w_i)$  will remain 0.

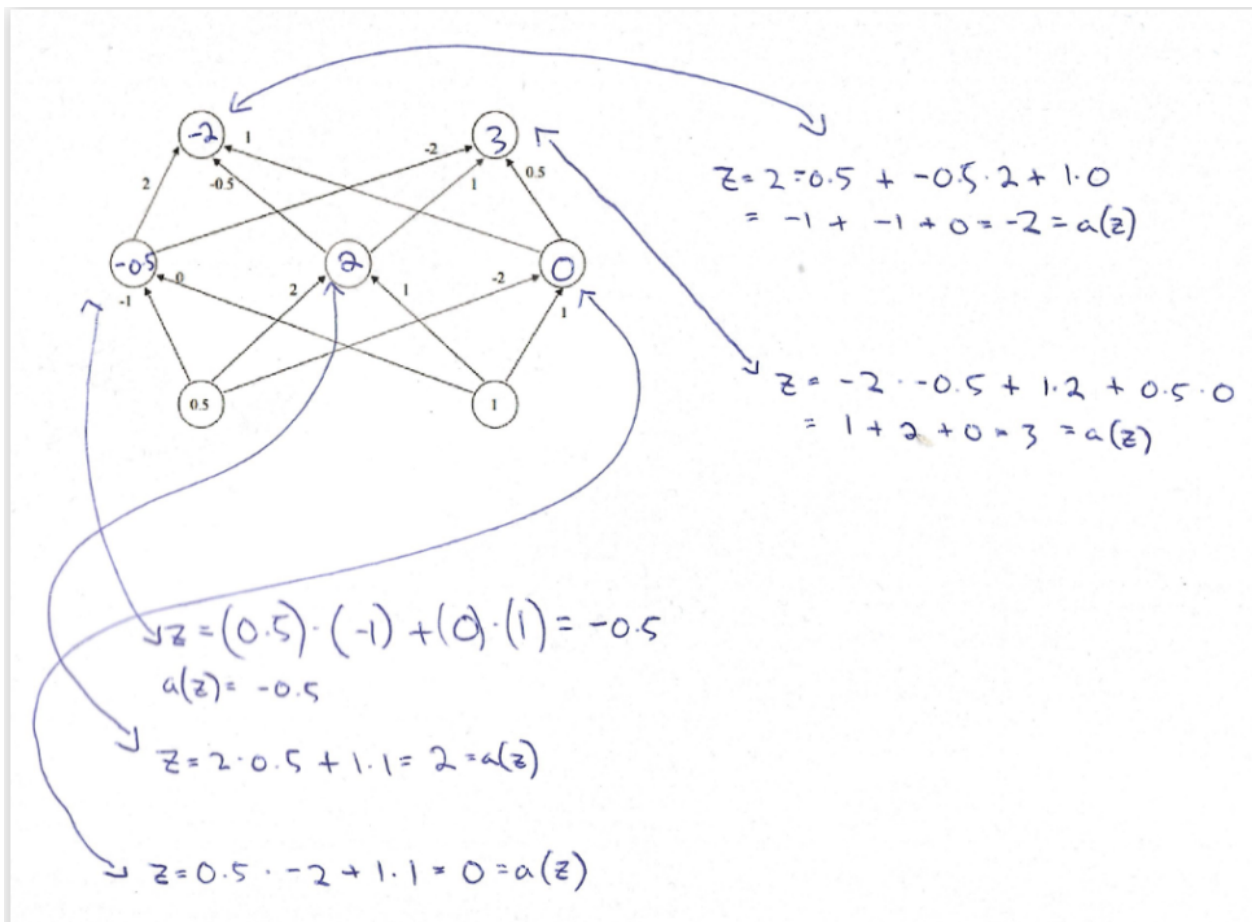
b.

Iteration	b	x1	NOT x1	w0	w1	z	a(z)	delta(w0)	delta(w1)
1	1	0	1	0	0	0	0	0.1	0
	1	1	0	0.1	0	0.1	1	-0.1	-0.1
2	1	0	1	0	-0.1	0	0	0.1	0
	1	1	0	0.1	-0.1	0	0	0	0

All  $\delta(w_i)$  are 0 after iteration 2. Thus, our perceptron is correctly trained.

2) <https://github.com/garyjsk271/Machine-Learning.git>

3) a.



The output at each node is written inside the node circle. The calculations are shown on the side with the corresponding edges.

b. The calculations do not need to be repeated as there the input is just doubled. So the output is just doubled.

For the 1st layer, going left to right, the outputs are -1, 4, 0.

For the 2nd layer, going left to right, the outputs are -4, 6.

If you repeat the calculations, you will get exactly these results. The reason for this is because of the linear activation function. Since at every layer, all you're doing is taking a sum of the product of the weights and inputs, if inputs are doubled, output is doubled.

4) <https://github.com/garyjsk271/Machine-Learning.git>

5)

**Initial Population (C1=1001001, C2=0100101, C3=1011000, C4=1101100)**

C1 = 100 100 1 (Sunny) && (Hot) → Yes

C2 = 010 010 1 (Overcast) && (Mild) → Yes

C3 = 101 100 0 (Sunny || Rain) && (Hot) → No

C4 = 110 110 0 (Sunny || Overcast) && (Hot || Mild) → No

### **Fitness Calculation**

Correct classification of C1 = { D4 },  $\text{fitness}(C1) = \frac{1}{5} = 0.2$

Correct classification of C2 = { D1, D4, D5 },  $\text{fitness}(C2) = \frac{3}{5} = 0.6$

Correct classification of C3 = { D1, D2, D3, D5 },  $\text{fitness}(C3) = \frac{4}{5} = 0.8$

Correct classification of C4 = { D1, D2 },  $\text{fitness}(C4) = \frac{2}{5} = 0.4$

**1st generation (C1=1001001, C2=0100101, C3=1011000, C4=1101100)**

$\text{Pr}(C1) = 0.2 / (0.2 + 0.6 + 0.8 + 0.4) = 0.2 / 2 = 0.1$

$\text{Pr}(C2) = 0.6 / 2 = 0.3$

$\text{Pr}(C3) = 0.8 / 2 = 0.4$

$\text{Pr}(C4) = 0.4 / 2 = 0.2$

$\text{Pr}(C1) = 0.1$  (4th)

$\text{Pr}(C4) = 0.2$  (3rd)

$\text{Pr}(C2) = 0.3$  (2nd)

$\text{Pr}(C3) = 0.4$  (1st)

1st and 3rd (C3, C4) chosen for crossover.

C3 = 101 | 1000

C4 = 110 | 1100

→ 1011100

→ 1101000

2 fittest and offsprings move on to next generation.

**C1** = 101 100 0 (Sunny || Rain) && (Hot) → No

**C2** = 010 010 1 (Overcast) && (Mild) → Yes

**C3** = 101 110 0 (Sunny || Rain) && (Hot || Mild) → No

**C4** = 110 100 0 (Sunny || Overcast) && (Hot) → No

### **Fitness Calculation**

Correct classification of C1 = { D1, D2, D3, D5 },  $\text{fitness}(C1) = \frac{4}{5} = 0.8$

Correct classification of C2 = { D1, D4, D5 },  $\text{fitness}(C2) = \frac{3}{5} = 0.6$

Correct classification of C3 = { D1, D2, D3, D5 },  $\text{fitness}(C3) = \frac{4}{5} = 0.8$

Correct classification of C4 = { D1, D2, D5 },  $\text{fitness}(C4) = \frac{3}{5} = 0.6$

**2nd Generation (C1 = 1011000, C2 = 0100101, C3 = 1011100, C4 = 1101000)**

$\Pr(C1) = 0.8/(0.8 + 0.6 + 0.8 + 0.6) = 0.8/2.8 = 0.286$

$\Pr(C2) = 0.6/2.8 = 0.214$

$\Pr(C3) = 0.8/2.8 = 0.286$

$\Pr(C4) = 0.6/2.8 = 0.214$

$\Pr(C2) = 0.214$  (4th)

$\Pr(C4) = 0.214$  (3rd)

$\Pr(C3) = 0.286$  (2nd)

$\Pr(C1) = 0.286$  (1st)

1st and 2nd chosen for crossover for 2nd generation.

C1 = 101 | 10 | 00

C3 = 101 | 11 | 00

→ 1011000 (6th bit mutated) → 1011010

→ 1011100

2 fittest and offsprings move on to next generation.

**C1** = 101 100 0

(sunny || rain) && (hot) → no

**C2** = 101 110 0

(sunny || rain) && (hot || mild) → no

**C3** = 101 101 0

(sunny || rain) && (hot || cool) → no

**C4** = 101 110 0

(sunny || rain) && (hot || mild) → no

### **Fitness Calculation**

Correct classification of C1 = {D1, D2, D3, D5}, fitness(C1) = 0.8

Correct classification of C2 = { D1, D2, D3, D5}, fitness(C2) =  $\frac{4}{5} = 0.8$

Correct classification of C3 = { D1, D2, D3, D4, D5 }, fitness(C3) = 1.0

Correct classification of C4 = {D1, D2, D3, D5}, fitness(C4) = 0.8

**GA terminated since C3's accuracy is 1.0.**

**Model returned is C3 = 1011010 = (Sunny || Rain) && (hot || cold) → PlayTennis = no**

6)

**Initial population (000, 001, 010, 100)**

### **Fitness Calculations**

$F(C1) = 570 * 0 + 710 * 0 + 640 * 0 = 0$

$F(C2) = 640 * 1 = 640$

$F(C3) = 710 * 1 = 710$

$F(C4) = 570 * 1 = 570$

### 1st Generation (000, 001, 010, 100)

$$\Pr(C1) = 0/(640+710+570) = 0/1920 = 0.0$$

$$\Pr(C2) = 640/1920 = 0.33$$

$$\Pr(C3) = 710/1920 = 0.37$$

$$\Pr(C4) = 570/1920 = 0.30$$

$$\Pr(C1) = 0.0 \text{ (4th)}$$

$$\Pr(C4) = 0.30 \text{ (3rd)}$$

$$\Pr(C2) = 0.33 \text{ (2nd)}$$

$$\Pr(C3) = 0.37 \text{ (1st)}$$

2nd and 3rd crossover

$$C2 = 00 \mid 1$$

$$C4 = 10 \mid 0$$

$$\rightarrow 000$$

$$\rightarrow 101$$

Constraint check:

$$5 * 0 + 8 * 0 + 10 * 0 \leq 15$$

$$1 * 5 + 10 * 1 = 15 \leq 15$$

2nd and 1st crossover

$$C2 = 00 \mid 1$$

$$C3 = 01 \mid 0$$

$$\rightarrow 000$$

$$\rightarrow 011$$

Constraint check:

$$5 * 0 + 8 * 0 + 10 * 0 \leq 15$$

$$1 * 8 + 10 * 1 = 18 \not\leq 15$$

011 replicates C3 = 010

**C1 = 000, C2 = 101, C3 = 000, C4 = 010**

$$F(C1) = 0$$

$$F(C2) = 570 * 1 + 640 * 1 = 1210$$

$$F(C3) = 0$$

$$F(C4) = 710 * 1 = 710$$

**2nd Generation (C1 = 000, C2 = 101, C3 = 000, C4 = 010)**

$$\text{Pr}(C1) = 0/1920 = 0.0 \text{ (4th)}$$

$$\text{Pr}(C3) = 0/1920 = 0.0 \text{ (3rd)}$$

$$\text{Pr}(C4) = 710/1920 = 0.37 \text{ (2nd)}$$

$$\text{Pr}(C2) = 1210/1920 = 0.63 \text{ (1st)}$$

1st and 1st crossover

$$C4 = 1 \mid 01$$

$$C4 = 1 \mid 01$$

$$\rightarrow 101 \text{ (3rd bit mutation)} \rightarrow 100$$

$$\rightarrow 101 \text{ (3rd bit mutation)} \rightarrow 100$$

Constraint check:

$$5 \leq 15$$

$$5 \leq 15$$

1st and 2nd crossover

$$C2 = 1 \mid 01$$

$$C4 = 0 \mid 10$$

$$\rightarrow 110$$

$$\rightarrow 001$$

Constraint check:

$$13 < 15$$

$$8 < 15$$

**C1 = 100, C2 = 100, C3 = 110, C4 = 001**

$$F(C1) = 570$$

$$F(C2) = 570$$

$$F(C3) = 570 + 710 = 1280$$

$$F(C4) = 640$$

**3rd Generation (C1 = 010, C2 = 010, C3 = 001, C4 = 010)**

**Terminate in 3rd Generation.**

**Return best chromosome = C3 = 110**