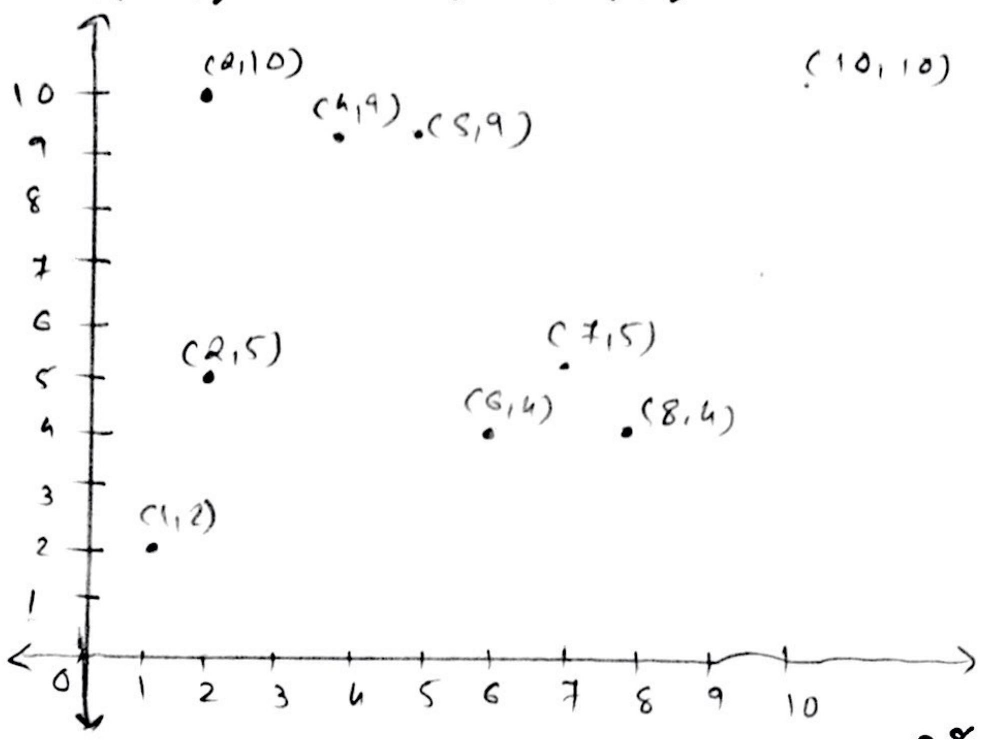
Assignment - 4

Question - A   K-means Algo : clustering

2D points: (2,10), (2,5), (8,4), (5,9), (7,5), (6,4), (1,2), (4,9), (10,10)

(i)



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Initial cluster centers: (2,5), (5,8), (4,9)

(ii) find Euclidean distance betn points and cluster centers

	(2,10)	(2,5)	(8,4)	(5,9)	(7,5)	(6,4)	(1,2)	(4,9)	(10,10)
(2,5)	5	0	6.08	5	5	4.12	3.16	4.47	9.43
(5,8)	3.60	4.24	5	1	3.60	6.12	7.21	1.41	5.38
(4,9)	2.23	4.47	6.40	1	5	5.38	7.61	0	6.08

Initial clusters are:

C_1 : (1,2), (2,5)

C_2 : (8,4), (7,5), (10,10), (6,4)

C_3 : (2,10), (5,9), (4,9)

(iii) New cluster centers:

$$\mu_1 = \left(\frac{2+1}{2}, \frac{5+2}{2}\right) = (1.5, 3.5)$$

$$\mu_2 = \left(\frac{8+7+10+6}{4}, \frac{4+5+10+4}{4}\right) = (7.75, 5.75)$$

$$\mu_3 = \left(\frac{4+2+5}{3}, \frac{9+10+9}{3}\right) = (3.67, 9.33)$$

New distances from given points to New cluster centeroids

	(2,10)	(2,5)	(8,4)	(5,9)	(7,5)	(6,4)	(1,2)	(4,9)	(10,10)
(1.5 3.5)	6.51	1.58	6.57	6.51	5.7	4.52	1.58	6.04	10.70
(7.75 5.75)	7.15	5.79	1.76	4.25	1.06	2.47	7.72	4.96	4.80
(3.67 9.33)	1.79	4.64	6.87	1.37	5.46	5.82	7.80	0.467	6.36

μ_1 : (2,5), (1,2)

μ_2 : (8,4), (7,5), (6,4), (10,10)

μ_3 : (2,10), (5,9), (4,9)

New cluster centers

μ_1 : (1.5, 3.5)

μ_2 : (7.75, 5.75)

μ_3 : (3.67, 9.33)

Here cluster centers are not changing so these are final cluster assignments.

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Question-B

	P1	P2	P3	P4	P5
P1	1.00	0.10	0.41	0.55	0.35
P2	0.10	1.00	0.64	0.47	0.98
P3	0.41	0.64	1.00	0.44	0.85
P4	0.55	0.47	0.44	1.00	0.76
P5	0.35	0.98	0.85	0.76	1.00

1. single link: maximum similarity betn any two points are selected first.

order of merge

1. maximum similarity is 0.98 betn P_2 & P_5 so, they are merged together.

so, (P_2, P_5)

2.

	P1	P2P5	P3	P4
P1	1.00	0.35	0.41	0.55
P2P5		1.00	0.85	0.76
P3			1.00	0.~~44~~
P4				1.00

$\max(P_1, P_2P_5) = \max(0.10, 0.35) = 0.35$

$\max(P_3, P_2P_5) = \max(0.64, 0.85) = 0.85$

$\max(P_4, P_2P_5) = \max(0.47, 0.76) = 0.76$

$\max(0.35, 0.85, 0.76) = 0.85$

so, P_3, P_2, P_5 merge together

	P1	P2P3P5	P4
P1	1.0	0.41	0.55
P2P3P5		1.0	0.~~76~~
P4			1.0

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$\max(P_2P_3P_5, P_1) = \max((P_1, P_2P_5) \,\&\, (P_1, P_3))$
$= \max(0.35, 0.41)$
$= 0.41$

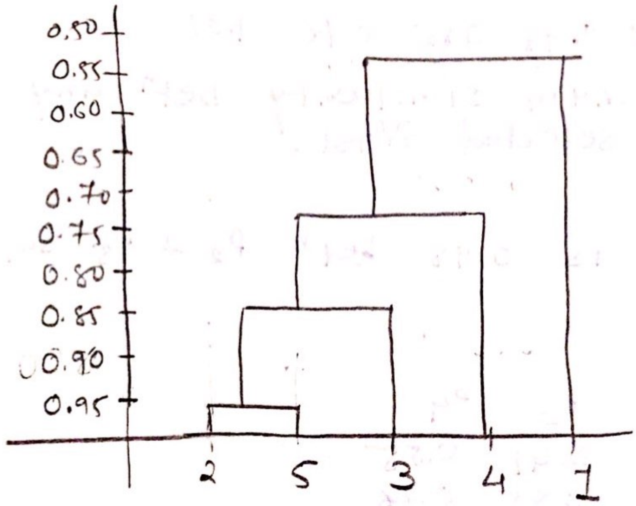
$\max(P_4, P_2P_3P_5) = \max((P_4, P_2P_5), (P_4, P_3))$
$= \max(0.76, 0.44)$
$= 0.76$

$\max(0.41, 0.76) = \cancel{0.55}\ \underline{0.76}$

so, we will merge P_2, P_3, P_4, P_5.

$\max(P_1, P_2P_3P_4P_5) = \max((P_1, P_2P_3P_5), (P_1, P_4))$
$= \max(0.41, 0.55)$
$= \underline{0.55}$

Final dendogram:



2. Complete link:

maximum similarity is 0.98 betn P_2 & P_5. so they are merged

$\min(P_1, P_2P_5) = \min(0.10, 0.35) = 0.10$
$\min(P_3, P_2P_5) = \min(0.64, 0.85) = 0.64$
$\min(P_4, P_2P_5) = \min(0.47, 0.76) = 0.47$

	P_1	P_2P_5	P_3	P_4
P_1	1.0	0.10	0.41	0.55
P_2P_5		1.0	0.64	0.47
P_3			1.0	0.44
P_4				1.0

$\max(0.10, 0.64, 0.47) = \cancel{0.10}\ 0.64$

So, P_3, P_2, P_5 are merged. → 0.64//

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min(P_1, $P_3P_2P_5$) = min(0.10, 0.41) = 0.10

min (P_4, $P_2P_3P_5$) = min (0.64, 0.44) = 0.44

min (P_1, P_4) = 0.55

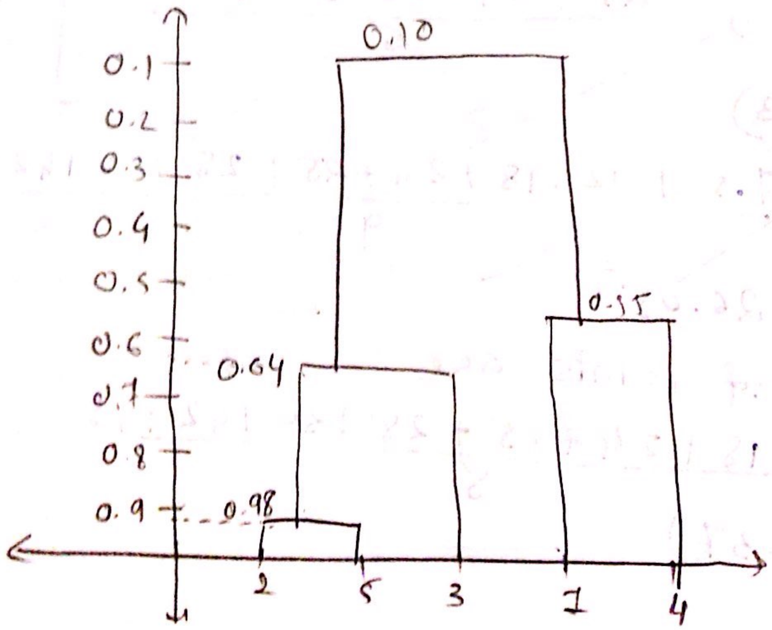
~~max~~

max (0.10, 0.44, 0.55) = 0.55

So, P_1 & P_4 will be merged.

	$P_2P_3P_5$	P_1P_4
$P_2P_3P_5$	1.0	0.10
P_1P_4		1.0

final dendogram:



Question-c

$\{6, 12, 18, 24, 25, 28, 30, 42, 48\}$

9.
(1)

	6	12	18	24	25	28	30	42	48
5	1	7	13	19	20	23	25	37	43
7.5	1.5	4.5	10.5	16.5	17.5	20.5	22.5	34.5	40.5

cluster 1 : 5, 6
cluster 2 : 7.5, 12, 18, 24, 25, 28, 30, 42, 48

sum of squared error for C_1: $0^2 + 1^2 = 1$

$C_2 = 1.5^2 + 4.5^2 + 10.5^2 + 16.5^2 + 17.5^2 + 20.5^2 + 22.5^2 + 34.5^2 + 40.5^2$

$= $ ~~[illegible]~~

$= 4466$

(2) (15, 25)

	6	12	18	24	28	28	30	42	48
15	9	3	3	9	10	13	15	27	33
25	19	13	7	1	0	3	5	17	23

C1 : 15, 6, 18, 12
C_2 : 25, ~~[illegible]~~, 24, 28, 30, 42, 48

sum of squared error for C_1: $0^2 + 9^2 + 3^2 = 90 + 9 = 99$

C_2: $0^2 + \cancel{?}^2 + 1^2 + 3^2 + 5^2 + 17^2 + 23^2 = 853$

~~b.~~ ~~New centroid points are:~~

$$\left.\frac{15+6+18+12}{4},\ \frac{25+24+28+30+42+48}{6}\right] \text{ for } (15, 25)$$

$\therefore (12.75, 32.83)$

and

$$\left.\frac{5+6}{2},\ \frac{7.5+12+18+24+25+28+30+42+48}{9}\right] \text{ for } (5, 7.5)$$

$(5.5, 26.05)$

b. New centroid points are

(1) $6,\ \dfrac{12+18+24+25+28+30+42+48}{8}$ } for (5, 7.5) set

$\therefore (6, 28.37)$

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(2) $\frac{6+18+12}{3}$, $\frac{24+28+30+42+48+25}{6}$ for (15, 25) set

∴ (12, 39.8)

	6	12	18	24	25	28	30	42	48
6	0	6	12	18.	19	22	24	36	42
28.37	22.37	16.37	10.37	4.37	3.37	0.37	1.63	13.63	20.37

for first set of points

C1 : 6, 12,
C2 : 28.37, 18, 24, 25, 30, 42, 48, 28

~~Here 12 is included in cluster I which was previously in in the C2. So given set of point (5, 7.5) is not stable~~

	6	12	18	24	25	28	30	42	48
12	6	0	6	12	13	16	18	30	36
39.83	26.8	20.83	14.13	8.83	7.83	4.83	2.83	9.17	15.17

for second set of points

C1 : 12, 6, 18,
C2 : 34.4, 24, 25, 28, 30, 42, 48

Here points are in the same cluster, they were previously in.
So No change
⇒ They are stable points

New centroid points: (9, 30.77)

To be continued for first set of points (5, 7.5)

(d) MIN produces "most Natural" clustering in this situation.

	6	12	18	24	25	28	30	42	48
9	3	3	9	15	16	19	21	33	39
30.71	24.71	18.71	12.71	6.71	5.71	2.71	0.71	11.29	17.29

C1 : 9, 6, 12, 18

C2 : 30.71, 24, 25, 28, 30, 42, 48

New centroid points: (12, 32.83)

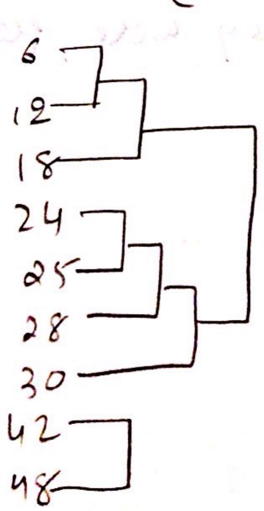
	6	12	18	24	25	28	30	42	48
12	6	0	6	12	13	16	18	30	36
32.83	26.83	10.83	14.83	8.83	7.83	4.83	2.83	9.17	15.17

C_1 : 12, 6, 18

C2 : 32.83, 24, 25, 28, 30, 42, 48

Here points are in the same clusters as they were in the previously, but points 12 and 18 are in the second cluster in first iteration so, the points (5, 7.5) is not stable solution.

(c)
6 12 18 24 25 28 30 42 48
6 12 18 (24 25) 28 30 42 48
6 12 18 (24 25 28) 30 42 48
6 12 18 (24 25 28 30) 42 48
6 (12 18) (24 25 28 30) 42 48
(6 12 18) (24 25 28 30) 42 48
(6 12 18) (24 25 28 30) (42 48)
(6 12 18 24 25 28 30) (42 48).
(6 12 18 24 25 28 30 42 48)



Two clusters: (6 12 18 24 25 28 30)
(42 48)

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(d) MIN produces "most Natural" clustering in this situation.

(e) K-means is not good for finding cluster of diff. size when they are not clearly seperated.

Reason: objective function is to minimize SSE lets break it down large cluster into small ones

So K-means ~~is~~ solution (low error clustering) does not give natural clustering in this solution

Part - II

(i) Naive Bayes:

① 1. $P(A|+) \Rightarrow P(A=1|+) = 3/5$
$P(A=0|+) = 2/5$

2. $P(B|+) = P(B=1|+) = 1/5$
$P(B=0|+) = 4/5$

3. $P(C|+) = P(C=1|+) = 4/5$
$P(C=0|+) = 1/5$

4. $P(A|-) = P(A=1|-) = 2/5$
$P(A=0|-) = 3/5$

5. $P(B|-) = P(B=1|-) = 2/5$
$P(B=0|-) = 3/5$

6. $P(C|-) = P(C=1|-) = 1$
$P(C=0|-) = 0$

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and conference facility.

(2) $$P(+/A=1, B=\phi, C=0) = \frac{P(A=1, B=\phi, C=0/+) \cdot P(+)}{P(A=1, B=\phi, C=0)}$$

$$= \frac{P(+) \cdot P(A=1/+) \cdot P(B=\phi/+) \cdot P(C=0/+)}{P(A=1, B=\phi, C=0)}$$

$$= \frac{5/10 \cdot 3/5 \cdot 4/5 \cdot 1/5}{P(A=1, B=\phi, C=0)} = \frac{8/250}{P(A=1, B=1, C=0)}$$

$$P(-|A=1, B=1, C=0) = \frac{P(A=1, B=1, C=0) \cdot P(-)}{P(A=1, B=1, C=0)}$$

$$= \frac{P(A=1|-) \cdot P(B=1|-) \cdot P(C=0|-) \cdot P(-)}{P(A=1, B=1, C=0)}$$

$$= \frac{2/5 \cdot 2/5 \cdot 0}{P(A=1, B=1, C=0)}$$

$$= 0$$

So label of $(A=1, B=1, C=0)$ is positive $(+)$

(3) $m=4$, $p=1/2$

1. $P(A=1/+) = \frac{3+4 \times 1/2}{5+4} = \frac{5}{9}$ $\left(\because P(x_j = a_{jk} | C=c_i) = \frac{n_c + mp}{n+m} \right)$

$\left(\because n = \text{Total Number of positive class} \right.$
$\left. n_c = \text{Total Number of } A=1 \text{ values in positive class.} \right)$

2. $P(A=1/-) = 4/9$
3. $P(A=0/+) = 4/9$
4. $P(A=0/-) = 5/9$
5. $P(B=1/+) = 3/9$, $P(B=0/+) = 6/9$
6. $P(B=1/-) = 4/9$, $P(B=0/-) = 5/9$
7. $P(C=1/+) = 6/9$, $P(C=0/+) = 3/9$
8. $P(C=1/-) = 3/4$, $P(C=0/-) = 1/4$

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4. $P(+ / A=1, B=1, C=0) = \dfrac{P(A=1, B=1, C=0 / +) . P(+)}{P(A=1, B=1, C=0)}$

$\Rightarrow \dfrac{P(+) . P(A=1/+) . P(B=1/+) . P(C=0/+)}{P(A=1, B=1, C=0)}$

$\Rightarrow \dfrac{5/10 \cdot 5/9 \cdot 3/9 \cdot 3/9}{P(A=1, B=1, C=0)} = \dfrac{5}{216} = \cancel{0.02314}\ 0.0308$

$P(- / A=1, B=1, C=0) = \dfrac{P(A=1, B=1, C=0 / -) . P(-)}{P(A=1, B=1, C=0)}$

$\Rightarrow \dfrac{P(-) . P(A=1/-) . P(B=1/-) . P(C=0/-)}{P(A=1, B=1, C=0)}$

$\Rightarrow \dfrac{5/10 \cdot 4/9 \cdot 4/9 \cdot 1/4}{P(A=1, B=1, C=0)} = \dfrac{2/81}{P(A=1, B=1, C=0)} = 0.02469$

So here $0.03\cancel{989}$ > 0.02314. So (+) ~~Negative~~ positive class has high probability. So (A=1, B=1, C=0) has ~~Negative~~ Positive class

(5) when one of the probabilities is zero, the estimate for conditional probabilities using m-estimate is better.

(ii) Ada Boosting

$x_1 = (-1, 0, +)$, $x_2 = (-0.5, 0.5, +)$, $x_3 = (0, 1, -)$,
$x_4 = (0.5, 1, -)$, $x_5 = (1, 0, +)$, $x_6 = (1, -1, +)$,
$x_7 = (0, -1, -)$, $x_8 = (0, 0, -)$.

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Weight for all points = 1/no. of Points

= 1/8

Round-1

If $x > 0.75$ class - positive

$x <= 0.75$ class - Negative x_1 x_2 are miss classified

Training error 2 positives : $1/8 + 1/8 = 0.25$

$$\varepsilon_1 = \frac{0.25}{1} = 0.25$$

$$\alpha_1 = \frac{1}{2} \ln\left(\frac{1-\varepsilon_1}{\varepsilon_1}\right) = \frac{1}{2} \ln\left(\frac{1-0.25}{0.25}\right)$$

$$= 0.549$$

correct classified : $D_2(i) = \frac{0.125 \times \exp(-0.549)}{z_1}$

$$= \frac{0.125 \times 0.577}{z_1}$$

$$= \frac{0.072125}{z_1}$$

Incorrect classified $D_2(i) = \frac{0.125 \times \exp(\alpha_1)}{z_1}$ ($\because$ 0.125 is initial weight)

$$= \frac{0.125 \times \exp(0.549)}{z_1}$$

$$= \frac{0.125 \times 1.731}{z_1}$$

$$= \frac{0.216375}{z_1}$$

No of correct classified $\times \frac{0.072}{z_1}$ + incorrect classified $\times \frac{0.216}{z_1}$

$$\therefore 6 \times \frac{0.072}{z_1} + 2 \times \frac{0.216}{z_1}$$

$$= \frac{0.864}{z_1}$$

Total weight = 1 $\therefore$ $\boxed{z_1 = 0.864}$

correct $= \frac{0.072}{0.864} = 0.083$

in correct $= \frac{0.216}{0.864} = 0.25$

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Round :

hypothesis $\alpha_1 I(x > 0.75) \Rightarrow 0.549\ I(x > 0.75)$

Round 2:

x_1	x_2	x_3	x_4	x_5	x_6	x_7	x_8
-1, 0	-0.5, 0.5	0, 1	0.5, 1	1, 0	1, -1	0, -1	0, 0
+	+	-	-	+	+	-	-
0.25	0.25	0.08	0.08	0.08	0.08	0.08	0.08

Now take $x > -0.25$ - Negative
$x \leq -0.25$ + positive

Incorrectly classified : x_5 & x_6

$\varepsilon_2 = 0.08 + 0.08 = 0.16$

$\alpha_2 = \frac{1}{2} \ln\left(\frac{1-\varepsilon_2}{\varepsilon_2}\right) = \frac{1}{2} \ln\left(\frac{1-0.16}{0.16}\right) = 0.829$

Correct classified $(x_1, x_2) = D_3(i) = \frac{0.25 \times e(-0.829)}{z_2}$

$= \frac{0.109}{z_2}$

incorrect classified $(x_5, x_6) = D_3(i) = \frac{0.08 \times e(0.829)}{z_2}$

$= \frac{0.183}{z_2}$

Correct classified $(x_3, x_4, x_8\ x_7) = D_3(i) = \frac{0.08 \times e(-0.829)}{z_2}$

$= \frac{0.034}{z_2}$

Sum of weights should be 1

$2 \times \frac{0.109}{z_2} + \frac{2 \times 0.183}{z_2} + 4 \times \frac{0.034}{z_2} = 1 \Rightarrow z_2 = 0.72$

$x_1, x_2 \rightarrow 0.109 / 0.72 = 0.151$

$x_5, x_6 \rightarrow 0.183 / 0.72 = 0.254$

$x_3, x_4, x_8, x_7 \rightarrow 0.034 / 0.72 = 0.047$

hypo $0.829\ I(x \leq -0.25)$

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Round-3

x_1	x_2	x_3	x_4	x_5	x_6	x_7	x_8
+	+	−	−	+	+	−	−
0.151	0.151	0.047	0.047	0.254	0.254	0.047	0.047

take $y > 0.75$ −

$y \leq 0.75$ +

Incorrect x_8, x_7

$\varepsilon_3 = 0.047 + 0.047 = 0.094$

$\alpha_3 = \frac{1}{2} \ln\left(\frac{1-0.094}{0.094}\right) = 1.132$

correct classified $= D_4(i) = \frac{0.047 \times \exp(-1.132)}{Z_3} = \frac{0.015}{Z_3}$

x_3, x_4

correct classified $= D_4(i) = \frac{0.151 \times \exp(-1.132)}{Z_3} = \frac{0.048}{Z_3}$

x_1

correct classified $D_4(i) = \frac{0.254 \times \exp(-1.132)}{Z_3} = \frac{0.081}{Z_3}$

x_2, x_5, x_6

incorrect classified $D_4(i) = \frac{0.047 \times \exp(1.132)}{Z_3} = \frac{0.145}{Z_3}$

x_7, x_8

$$\frac{1 \times 0.048}{Z_3} + \frac{2 \times 0.015}{Z_3} + \frac{3 \times 0.081}{Z_3} + \frac{2 \times 0.145}{Z_3} = 1 \Rightarrow Z_3 = 0.611$$

weights

$x_3, x_4 \to 0.024$

$x_1 \to 0.078$

$x_2, x_5, x_6 \to 0.132$

$x_7, x_8 \to 0.237$

HYPO: $1.132 \cdot I(y \leq 0.75)$

HYPO: $0.549\, I(x > 0.75) + 0.829\, I(x \leq -0.25) + 1.132\, I(y \leq 0.75)$

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	x_1	x_2	x_3	x_4	x_5	x_6	x_7	x_8
original class	+	+	−	−	+	+	−	−
predicted class	+	+	−	−	+	+	−	−

Assignment of sign based on Hypo is

+ for x_1 x_2 x_5 x_6

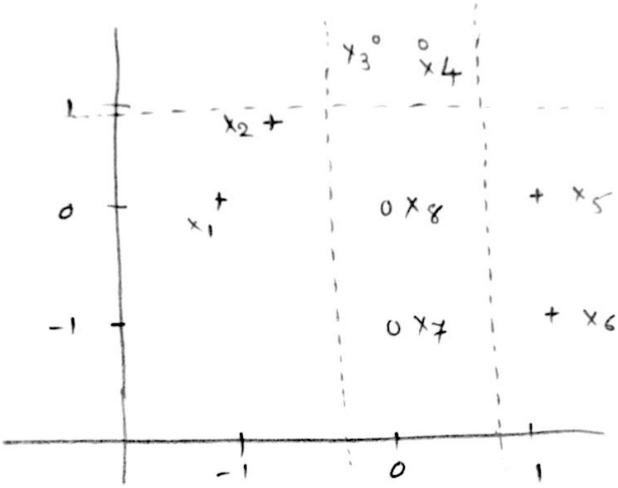
− for x_3 x_4 x_7 x_8

Table ①

t	ε_t	α_t	Z_t	$\omega(1)$	$\omega(2)$	$\omega(3)$	$\omega(4)$	$\omega(5)$	$\omega(6)$	$\omega(7)$	$\omega(8)$
1	0.25	0.549	0.864	1/8	1/8	1/8	1/8	1/8	1/8	1/8	1/8
2	0.16	0.829	0.722	0.25	0.25	0.08	0.08	0.08	0.08	0.08	0.08
3	0.094	1.132	0.611	0.151	0.254	0.047	0.047	0.254	0.254	0.047	0.047

② Training Error is 0, all predictions are same as actual value

Decision stump



AdaBoost combines several weak classifiers (linear classifiers) together to produce nonlinear decision boundary unlike a single decision stump which creates linear boundary

Question-4

a. Total 6 Negative class,
5 positive class.

so, $\text{Infogain}(D) = -\frac{6}{11}\log_2 6/11 - 5/11 \log_2 5/11$

$= 0.9940$

$\text{Infogain}_{x_1}(D) = \frac{5}{11}\left(-\frac{3}{5}\log_2\frac{3}{5} - \frac{2}{5}\log_2\frac{2}{5}\right) + \frac{6}{11}\left(-\frac{3}{6}\log\frac{3}{6} - \frac{3}{6}\log\frac{3}{6}\right)$

(∵ b — 3
a — 2
for positive
and b — 3
a — 3
for Negative)

$= 0.9867$

$\text{Infogain}\ x_2(D) = \frac{5}{11}\left(-\frac{2}{5}\log\frac{2}{5} - \frac{3}{5}\log\frac{3}{5}\right) + \frac{4}{11}\left(-\frac{2}{4}\log\frac{2}{4} - \frac{2}{4}\log\frac{2}{4}\right) + \frac{1}{11}\left(-\frac{1}{1}\log\frac{1}{1} - \frac{0}{1}\log\frac{0}{1}\right) + \frac{1}{11}\left(-\frac{1}{1}\log\frac{1}{1} - \frac{0}{1}\log\frac{0}{1}\right)$

(∵ c — 3 for positive
w — 2
w — 2 for Negative
c — 2 for Negative
4 — 1 for Negative
9 — 1 for Negative)

$= 0.8049$

$\text{Infogain}\ x_3(D) = \frac{3}{11}\left(-\frac{3}{3}\log 3/3\right) + \frac{5}{11}\left(-2/5\log 2/5 - \frac{3}{5}\log 3/5\right) + \frac{3}{11}\left(-\frac{3}{3}\log 3/3\right)$

$= 0.4413$

so Infogain x_3 < Infogain x_2 < Infogain x_1

$\text{Infogain}(x_3) = 0.9940 - 0.4413 = 0.5527$

First spliting Attribute is x_3

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(i)

X_3

K

x_1	x_2	y
a	c	-1
a	w	-1
b	w	-1

V

x_1	x_2	y
b	w	+1
a	c	+1
a	y	-1
b	c	-1
b	g	-1

S

x_1	x_2	y
a	c	+1
b	w	+1
b	c	+1

$X_3 = K \quad Y = -1$

$Info(D_K) = -\frac{3}{3}\log_2 3/3 = 0$

$Info_{x_1}(D_K) = 2/3\left(-\frac{2}{2}\log \frac{2}{2}\right) + \frac{1}{3}\left(-\frac{1}{1}\log_2 \frac{1}{1}\right) = 0$

$Info_{x_2}(D_V) = \frac{2}{3}\left(-\frac{2}{2}\log \frac{2}{2}\right) + \frac{1}{3}\left(-\frac{1}{1}\log_2 \frac{1}{1}\right) = 0$

$X_3 = V \quad D_V$

$Info_{x_1}(D_V) = \frac{3}{5}\left(-\frac{1}{3}\log\frac{1}{3} - \frac{2}{3}\log\frac{2}{3}\right) + \frac{2}{5}\left(-\frac{1}{2}\log\frac{1}{2} - \frac{1}{2}\log\frac{1}{2}\right)$

$= 0.9509$

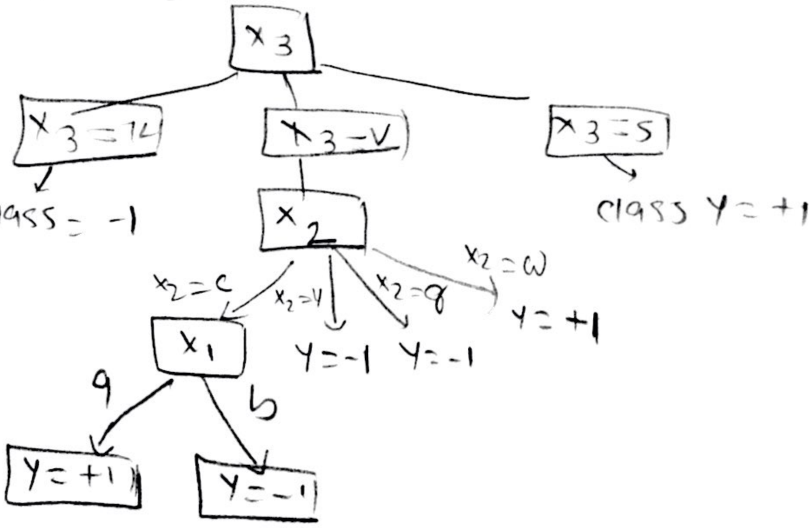
$Info_{x_2}(D_V) = \frac{3}{5}\left(-\frac{1}{3}\log\frac{1}{3} - \frac{1}{3}\log\frac{1}{3} - \frac{1}{3}\log\frac{1}{3}\right) + \frac{2}{5}\left(-\frac{1}{2}\log\frac{1}{2} - \frac{1}{2}\log\frac{1}{2}\right)$

$= 0.4$

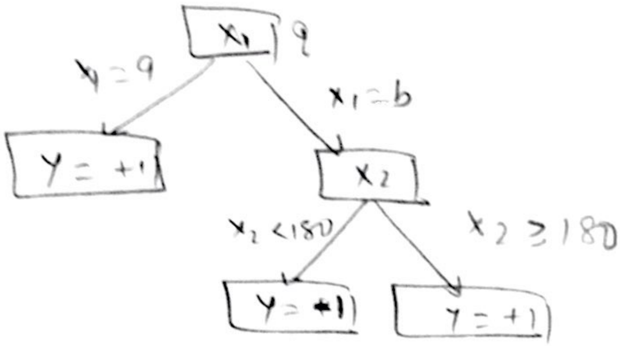
$Info\ gain(X_2) = 0 - 0.4 = -0.40$

$Info\ gain(X_1) = 0 - 0.9509 = -0.9509$

X_2 is spliting Attribute



b.



(i) Decision Tree with x_1 & x_2 as a asked attributes and 3 leaf class nodes which gives 100% training accuracy on the given training data.

(ii) given Test data
$x_1 = b$ $x_2 = 170$ $x_3 = f$ $x_4 = d$ $y = -1$ and
$x_1 = a$ $x_2 = 150$ $x_3 = f$ $x_4 = d$ $y = +1$ are correctly classified
last sample is not correctly classified
so Accuracy is $2/3 = 0.67$ (67%)

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