

# **Numerical problem on decision tree using entropy and gain**

# ID3 Algorithm

1. Invented by J. Ross Quinlan
2. Employs a top-down greedy search through the space of possible decision trees.
3. Greedy because there is no backtracking. It picks the highest values first.
4. Select the attribute that is most useful for classifying examples (the attribute that has the highest Information Gain).

# Steps

1. Find the entropy

\*Entropy for the entire dataset

\*Entropy for each attribute

2. Find information gain

*The Formula for Entropy:*

$$\text{Entropy}(S) = -P(\text{yes})\log_2 P(\text{yes}) - P(\text{no})\log_2 P(\text{no})$$

*The formula for information gain:*

$$\text{Gain}(S, A) = \text{Entropy}(S) - \sum_{v \in \text{Value}(A)} \frac{|S_v|}{|S|} \text{Entropy}(S_v)$$

$$P(\text{YES}) = P(\text{YES}) / (P(\text{YES}) + P(\text{NO}))$$

$$P(\text{NO}) = P(\text{NO}) / (P(\text{NO}) + P(\text{YES}))$$

Day	Outlook	Temp	Humidity	Wind	PlayTennis
D1	Sunny	Hot	High	Weak	No
D2	Sunny	Hot	High	Strong	No
D3	Overcast	Hot	High	Weak	Yes
D4	Rain	Mild	High	Weak	Yes
D5	Rain	Cool	Normal	Weak	Yes
D6	Rain	Cool	Normal	Strong	No
D7	Overcast	Cool	Normal	Strong	Yes
D8	Sunny	Mild	High	Weak	No
D9	Sunny	Cool	Normal	Weak	Yes
D10	Rain	Mild	Normal	Weak	Yes
D11	Sunny	Mild	Normal	Strong	Yes
D12	Overcast	Mild	High	Strong	Yes
D13	Overcast	Hot	Normal	Weak	Yes
D14	Rain	Mild	High	Strong	No

Day	Outlook	Temp	Humidity	Wind	Play Tennis
D1	Sunny	Hot	High	Weak	No
D2	Sunny	Hot	High	Strong	No
D3	Overcast	Hot	High	Weak	Yes
D4	Rain	Mild	High	Weak	Yes
D5	Rain	Cool	Normal	Weak	Yes
D6	Rain	Cool	Normal	Strong	No
D7	Overcast	Cool	Normal	Strong	Yes
D8	Sunny	Mild	High	Weak	No
D9	Sunny	Cool	Normal	Weak	Yes
D10	Rain	Mild	Normal	Weak	Yes
D11	Sunny	Mild	Normal	Strong	Yes
D12	Overcast	Mild	High	Strong	Yes
D13	Overcast	Hot	Normal	Weak	Yes
D14	Rain	Mild	High	Strong	No

### Attribute: Outlook

Values (Outlook) = Sunny, Overcast, Rain

$$S = [9+, 5-]$$

$$Entropy(S) = -\frac{9}{14} \log_2 \frac{9}{14} - \frac{5}{14} \log_2 \frac{5}{14} = 0.94$$

$$S_{Sunny} \leftarrow [2+, 3-]$$

$$Entropy(S_{Sunny}) = -\frac{2}{5} \log_2 \frac{2}{5} - \frac{3}{5} \log_2 \frac{3}{5} = 0.971$$

$$S_{Overcast} \leftarrow [4+, 0-]$$

$$Entropy(S_{Overcast}) = -\frac{4}{4} \log_2 \frac{4}{4} - \frac{0}{4} \log_2 \frac{0}{4} = 0$$

$$S_{Rain} \leftarrow [3+, 2-]$$

$$Entropy(S_{Rain}) = -\frac{3}{5} \log_2 \frac{3}{5} - \frac{2}{5} \log_2 \frac{2}{5} = 0.971$$

$$Gain(S, Outlook) = Entropy(S) - \sum_{v \in \{Sunny, Overcast, Rain\}} \frac{|S_v|}{|S|} Entropy(S_v)$$

$$Gain(S, Outlook)$$

$$= Entropy(S) - \frac{5}{14} Entropy(S_{Sunny}) - \frac{4}{14} Entropy(S_{Overcast}) - \frac{5}{14} Entropy(S_{Rain})$$

$$Gain(S, Outlook) = 0.94 - \frac{5}{14} 0.971 - \frac{4}{14} 0 - \frac{5}{14} 0.971 = 0.2464$$

Day	Outlook	Temp	Humidity	Wind	Play Tennis
D1	Sunny	Hot	High	Weak	No
D2	Sunny	Hot	High	Strong	No
D3	Overcast	Hot	High	Weak	Yes
D4	Rain	Mild	High	Weak	Yes
D5	Rain	Cool	Normal	Weak	Yes
D6	Rain	Cool	Normal	Strong	No
D7	Overcast	Cool	Normal	Strong	Yes
D8	Sunny	Mild	High	Weak	No
D9	Sunny	Cool	Normal	Weak	Yes
D10	Rain	Mild	Normal	Weak	Yes
D11	Sunny	Mild	Normal	Strong	Yes
D12	Overcast	Mild	High	Strong	Yes
D13	Overcast	Hot	Normal	Weak	Yes
D14	Rain	Mild	High	Strong	No

## Attribute: Temp

Values (Temp) = Hot, Mild, Cool

$$S = [9+, 5-]$$

$$Entropy(S) = -\frac{9}{14} \log_2 \frac{9}{14} - \frac{5}{14} \log_2 \frac{5}{14} = 0.94$$

$$S_{Hot} \leftarrow [2+, 2-]$$

$$Entropy(S_{Hot}) = -\frac{2}{4} \log_2 \frac{2}{4} - \frac{2}{4} \log_2 \frac{2}{4} = 1.0$$

$$S_{Mild} \leftarrow [4+, 2-]$$

$$Entropy(S_{Mild}) = -\frac{4}{6} \log_2 \frac{4}{6} - \frac{2}{6} \log_2 \frac{2}{6} = 0.9183$$

$$S_{Cool} \leftarrow [3+, 1-]$$

$$Entropy(S_{Cool}) = -\frac{3}{4} \log_2 \frac{3}{4} - \frac{1}{4} \log_2 \frac{1}{4} = 0.8113$$

$$Gain(S, Temp) = Entropy(S) - \sum_{v \in \{Hot, Mild, Cool\}} \frac{|S_v|}{|S|} Entropy(S_v)$$

$$Gain(S, Temp)$$

$$= Entropy(S) - \frac{4}{14} Entropy(S_{Hot}) - \frac{6}{14} Entropy(S_{Mild})$$

$$- \frac{4}{14} Entropy(S_{Cool})$$

$$Gain(S, Temp) = 0.94 - \frac{4}{14} 1.0 - \frac{6}{14} 0.9183 - \frac{4}{14} 0.8113 = 0.0289$$



Day	Outlook	Temp	Humidity	Wind	Play Tennis
D1	Sunny	Hot	High	Weak	No
D2	Sunny	Hot	High	Strong	No
D3	Overcast	Hot	High	Weak	Yes
D4	Rain	Mild	High	Weak	Yes
D5	Rain	Cool	Normal	Weak	Yes
D6	Rain	Cool	Normal	Strong	No
D7	Overcast	Cool	Normal	Strong	Yes
D8	Sunny	Mild	High	Weak	No
D9	Sunny	Cool	Normal	Weak	Yes
D10	Rain	Mild	Normal	Weak	Yes
D11	Sunny	Mild	Normal	Strong	Yes
D12	Overcast	Mild	High	Strong	Yes
D13	Overcast	Hot	Normal	Weak	Yes
D14	Rain	Mild	High	Strong	No

### Attribute: Humidity

Values (Humidity) = High, Normal

$$S = [9+, 5-]$$

$$Entropy(S) = -\frac{9}{14} \log_2 \frac{9}{14} - \frac{5}{14} \log_2 \frac{5}{14} = 0.94$$

$$S_{High} \leftarrow [3+, 4-]$$

$$Entropy(S_{High}) = -\frac{3}{7} \log_2 \frac{3}{7} - \frac{4}{7} \log_2 \frac{4}{7} = 0.9852$$

$$S_{Normal} \leftarrow [6+, 1-]$$

$$Entropy(S_{Normal}) = -\frac{6}{7} \log_2 \frac{6}{7} - \frac{1}{7} \log_2 \frac{1}{7} = 0.5916$$

$$Gain(S, Humidity) = Entropy(S) - \sum_{v \in \{High, Normal\}} \frac{|S_v|}{|S|} Entropy(S_v)$$

$$Gain(S, Humidity)$$

$$= Entropy(S) - \frac{7}{14} Entropy(S_{High}) - \frac{7}{14} Entropy(S_{Normal})$$

$$Gain(S, Humidity) = 0.94 - \frac{7}{14} 0.9852 - \frac{7}{14} 0.5916 = 0.1516$$



Day	Outlook	Temp	Humidity	Wind	Play Tennis
D1	Sunny	Hot	High	Weak	No
D2	Sunny	Hot	High	Strong	No
D3	Overcast	Hot	High	Weak	Yes
D4	Rain	Mild	High	Weak	Yes
D5	Rain	Cool	Normal	Weak	Yes
D6	Rain	Cool	Normal	Strong	No
D7	Overcast	Cool	Normal	Strong	Yes
D8	Sunny	Mild	High	Weak	No
D9	Sunny	Cool	Normal	Weak	Yes
D10	Rain	Mild	Normal	Weak	Yes
D11	Sunny	Mild	Normal	Strong	Yes
D12	Overcast	Mild	High	Strong	Yes
D13	Overcast	Hot	Normal	Weak	Yes
D14	Rain	Mild	High	Strong	No

### Attribute: Wind

Values (Wind) = Strong, Weak

$$S = [9+, 5-]$$

$$Entropy(S) = -\frac{9}{14} \log_2 \frac{9}{14} - \frac{5}{14} \log_2 \frac{5}{14} = 0.94$$

$$S_{Strong} \leftarrow [3+, 3-]$$

$$Entropy(S_{Strong}) = 1.0$$

$$S_{Weak} \leftarrow [6+, 2-]$$

$$Entropy(S_{Weak}) = -\frac{6}{8} \log_2 \frac{6}{8} - \frac{2}{8} \log_2 \frac{2}{8} = 0.8113$$

$$Gain(S, Wind) = Entropy(S) - \sum_{v \in \{Strong, Weak\}} \frac{|S_v|}{|S|} Entropy(S_v)$$

$$Gain(S, Wind) = Entropy(S) - \frac{6}{14} Entropy(S_{Strong}) - \frac{8}{14} Entropy(S_{Weak})$$

$$Gain(S, Wind) = 0.94 - \frac{6}{14} 1.0 - \frac{8}{14} 0.8113 = 0.0478$$

Day	Outlook	Temp	Humidity	Wind	Play Tennis
D1	Sunny	Hot	High	Weak	No
D2	Sunny	Hot	High	Strong	No
D3	Overcast	Hot	High	Weak	Yes
D4	Rain	Mild	High	Weak	Yes
D5	Rain	Cool	Normal	Weak	Yes
D6	Rain	Cool	Normal	Strong	No
D7	Overcast	Cool	Normal	Strong	Yes
D8	Sunny	Mild	High	Weak	No
D9	Sunny	Cool	Normal	Weak	Yes
D10	Rain	Mild	Normal	Weak	Yes
D11	Sunny	Mild	Normal	Strong	Yes
D12	Overcast	Mild	High	Strong	Yes
D13	Overcast	Hot	Normal	Weak	Yes
D14	Rain	Mild	High	Strong	No

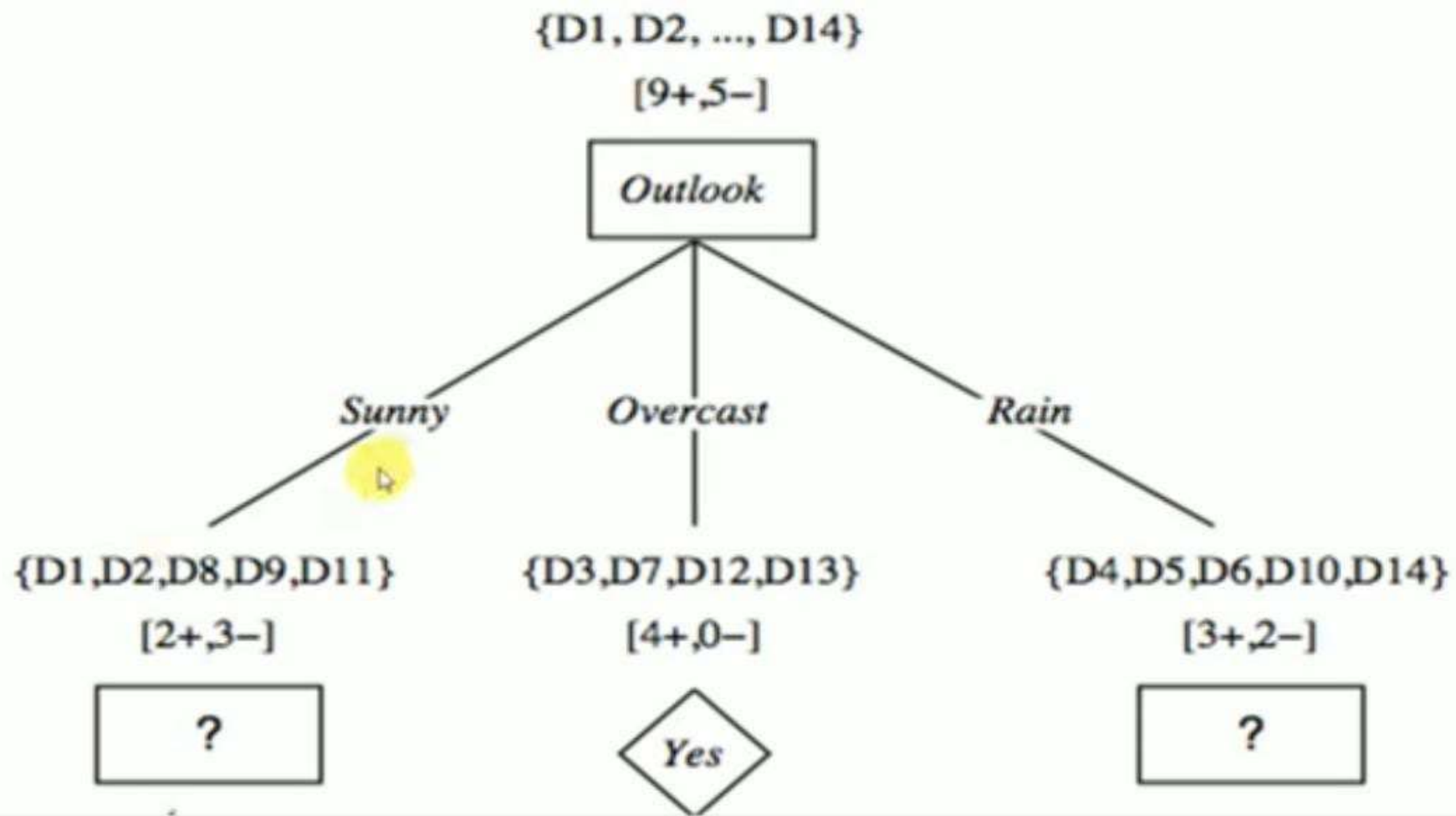
$$\text{Gain}(S, \text{Outlook}) = 0.2464$$

$$\text{Gain}(S, \text{Temp}) = 0.0289$$

$$\text{Gain}(S, \text{Humidity}) = 0.1516$$

$$\text{Gain}(S, \text{Wind}) = 0.0478$$

**NOTE:** As we can see gain is maximum for Outlook attribute so this will be consider as a root node



Day	Temp	Humidity	Wind	Play Tennis
D1	Hot	High	Weak	No
D2	Hot	High	Strong	No
D8	Mild	High	Weak	No
D9	Cool	Normal	Weak	Yes
D11	Mild	Normal	Strong	Yes

## Attribute: Temp

Values (Temp) = Hot, Mild, Cool

$$S_{Sunny} = [2+, 3-]$$

$$Entropy(S_{Sunny}) = -\frac{2}{5}\log_2\frac{2}{5} - \frac{3}{5}\log_2\frac{3}{5} = 0.97$$

$$S_{Hot} \leftarrow [0+, 2-]$$

$$Entropy(S_{Hot}) = 0.0$$

$$S_{Mild} \leftarrow [1+, 1-]$$

$$Entropy(S_{Mild}) = 1.0$$

$$S_{Cool} \leftarrow [1+, 0-]$$

$$Entropy(S_{Cool}) = 0.0$$

$$Gain(S_{Sunny}, Temp) = Entropy(S) - \sum_{v \in \{Hot, Mild, Cool\}} \frac{|S_v|}{|S|} Entropy(S_v)$$

$$Gain(S_{Sunny}, Temp)$$

$$= Entropy(S) - \frac{2}{5} Entropy(S_{Hot}) - \frac{2}{5} Entropy(S_{Mild})$$

$$- \frac{1}{5} Entropy(S_{Cool})$$

$$Gain(S_{sunny}, Temp) = 0.97 - \frac{2}{5} 0.0 - \frac{2}{5} 1 - \frac{1}{5} 0.0 = 0.570$$

Day	Temp	Humidity	Wind	Play Tennis
D1	Hot	High	Weak	No
D2	Hot	High	Strong	No
D8	Mild	High	Weak	No
D9	Cool	Normal	Weak	Yes
D11	Mild	Normal	Strong	Yes

### Attribute: Humidity

Values (Humidity) = High, Normal

$$S_{Sunny} = [2+, 3-]$$

$$Entropy(S) = -\frac{2}{5} \log_2 \frac{2}{5} - \frac{3}{5} \log_2 \frac{3}{5} = 0.97$$

$$S_{High} \leftarrow [0+, 3-]$$

$$Entropy(S_{High}) = 0.0$$

$$S_{Normal} \leftarrow [2+, 0-]$$

$$Entropy(S_{Normal}) = 0.0$$

$$Gain(S_{Sunny}, Humidity) = Entropy(S) - \sum_{v \in \{High, Normal\}} \frac{|S_v|}{|S|} Entropy(S_v)$$

$$Gain(S_{Sunny}, Humidity) = Entropy(S) - \frac{3}{5} Entropy(S_{High}) - \frac{2}{5} Entropy(S_{Normal})$$

$$Gain(S_{Sunny}, Humidity) = 0.97 - \frac{3}{5} 0.0 - \frac{2}{5} 0.0 = 0.97$$

Day	Temp	Humidity	Wind	Play Tennis
D1	Hot	High	Weak	No
D2	Hot	High	Strong	No
D8	Mild	High	Weak	No
D9	Cool	Normal	Weak	Yes
D11	Mild	Normal	Strong	Yes

### Attribute: Wind

Values (Wind) = Strong, Weak

$$S_{Sunny} = [2+, 3-]$$

$$Entropy(S) = -\frac{2}{5} \log_2 \frac{2}{5} - \frac{3}{5} \log_2 \frac{3}{5} = 0.97$$

$$S_{Strong} \leftarrow [1+, 1-]$$

$$Entropy(S_{Strong}) = 1.0$$

$$S_{Weak} \leftarrow [1+, 2-]$$

$$Entropy(S_{Weak}) = -\frac{1}{3} \log_2 \frac{1}{3} - \frac{2}{3} \log_2 \frac{2}{3} = 0.9183$$

$$Gain(S_{Sunny}, Wind) = Entropy(S) - \sum_{v \in \{Strong, Weak\}} \frac{|S_v|}{|S|} Entropy(S_v)$$

$$Gain(S_{Sunny}, Wind) = Entropy(S) - \frac{2}{5} Entropy(S_{Strong}) - \frac{3}{5} Entropy(S_{Weak})$$

$$Gain(S_{sunny}, Wind) = 0.97 - \frac{2}{5} 1.0 - \frac{3}{5} 0.918 = 0.0192$$

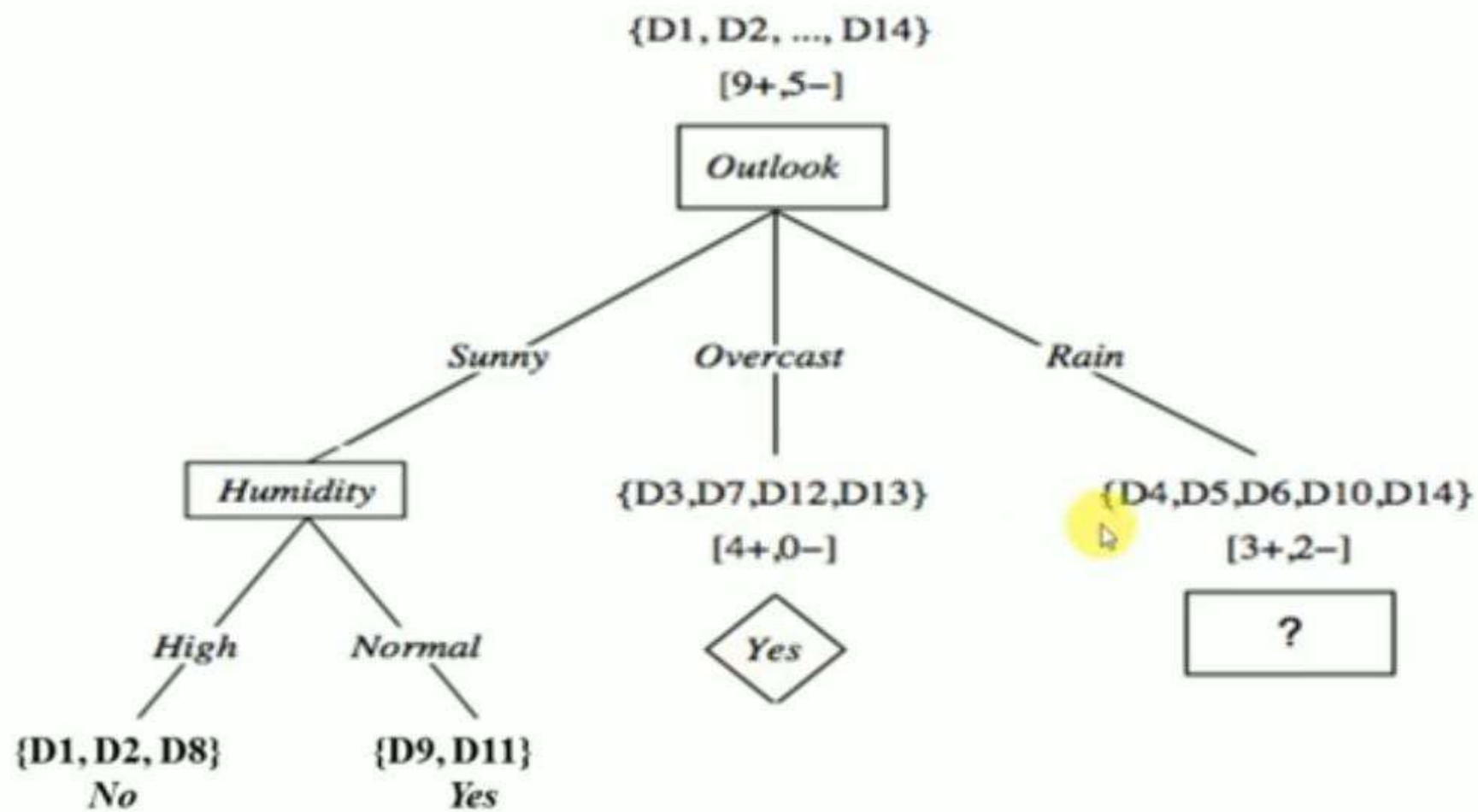


Day	Temp	Humidity	Wind	Play Tennis
D1	Hot	High	Weak	No
D2	Hot	High	Strong	No
D8	Mild	High	Weak	No
D9	Cool	Normal	Weak	Yes
D11	Mild	Normal	Strong	Yes

$$Gain(S_{\text{sunny}}, Temp) = 0.570$$

$$Gain(S_{\text{sunny}}, Humidity) = 0.97$$

$$Gain(S_{\text{sunny}}, Wind) = 0.0192$$



Day	Temp	Humidity	Wind	Play Tennis
D4	Mild	High	Weak	Yes
D5	Cool	Normal	Weak	Yes
D6	Cool	Normal	Strong	No
D10	Mild	Normal	Weak	Yes
D14	Mild	High	Strong	No

### Attribute: Temp

Values (Temp) = Hot, Mild, Cool

$$S_{Rain} = [3+, 2-]$$

$$Entropy(S_{Sunny}) = -\frac{3}{5} \log_2 \frac{3}{5} - \frac{2}{5} \log_2 \frac{2}{5} = 0.97$$

$$S_{Hot} \leftarrow [0+, 0-]$$

$$Entropy(S_{Hot}) = 0.0$$

$$S_{Mild} \leftarrow [2+, 1-]$$

$$Entropy(S_{Mild}) = -\frac{2}{3} \log_2 \frac{2}{3} - \frac{1}{3} \log_2 \frac{1}{3} = 0.9183$$

$$S_{Cool} \leftarrow [1+, 1-]$$

$$Entropy(S_{Cool}) = 1.0$$

$$Gain(S_{Rain}, Temp) = Entropy(S) - \sum_{v \in \{Hot, Mild, Cool\}} \frac{|S_v|}{|S|} Entropy(S_v)$$

$$Gain(S_{Rain}, Temp)$$

$$= Entropy(S) - \frac{0}{5} Entropy(S_{Hot}) - \frac{3}{5} Entropy(S_{Mild}) - \frac{2}{5} Entropy(S_{Cool})$$

$$Gain(S_{Rain}, Temp) = 0.97 - \frac{0}{5} 0.0 - \frac{3}{5} 0.918 - \frac{2}{5} 1.0 = 0.0192$$

Day	Temp	Humidity	Wind	Play Tennis
D4	Mild	High	Weak	Yes
D5	Cool	Normal	Weak	Yes
D6	Cool	Normal	Strong	No
D10	Mild	Normal	Weak	Yes
D14	Mild	High	Strong	No

### Attribute: Humidity

Values (Humidity) = High, Normal

$$S_{Rain} = [3+, 2-]$$

$$Entropy(S_{Sunny}) = -\frac{3}{5} \log_2 \frac{3}{5} - \frac{2}{5} \log_2 \frac{2}{5} = 0.97$$

$$S_{High} \leftarrow [1+, 1-]$$

$$Entropy(S_{High}) = 1.0$$

$$S_{Normal} \leftarrow [2+, 1-]$$

$$Entropy(S_{Normal}) = -\frac{2}{3} \log_2 \frac{2}{3} - \frac{1}{3} \log_2 \frac{1}{3} = 0.9183$$



$$Gain(S_{Rain}, Humidity) = Entropy(S) - \sum_{v \in \{High, Normal\}} \frac{|S_v|}{|S|} Entropy(S_v)$$

$$Gain(S_{Rain}, Humidity) = Entropy(S) - \frac{2}{5} Entropy(S_{High}) - \frac{3}{5} Entropy(S_{Normal})$$

$$Gain(S_{Rain}, Humidity) = 0.97 - \frac{2}{5} 1.0 - \frac{3}{5} 0.918 = 0.0192$$

Day	Temp	Humidity	Wind	Play Tennis
D4	Mild	High	Weak	Yes
D5	Cool	Normal	Weak	Yes
D6	Cool	Normal	Strong	No
D10	Mild	Normal	Weak	Yes
D14	Mild	High	Strong	No

### Attribute: Wind

Values (wind) = Strong, Weak

$$S_{Rain} = [3+, 2-]$$

$$Entropy(S_{Sunny}) = -\frac{3}{5}\log_2\frac{3}{5} - \frac{2}{5}\log_2\frac{2}{5} = 0.97$$

$$S_{Strong} \leftarrow [0+, 2-]$$

$$Entropy(S_{Strong}) = 0.0$$

$$S_{Weak} \leftarrow [3+, 0-]$$

$$Entropy(S_{Weak}) = 0.0$$

$$Gain(S_{Rain}, Wind) = Entropy(S) - \sum_{v \in \{Strong, Weak\}} \frac{|S_v|}{|S|} Entropy(S_v)$$

$$Gain(S_{Rain}, Wind) = Entropy(S) - \frac{2}{5} Entropy(S_{Strong}) - \frac{3}{5} Entropy(S_{Weak})$$

$$Gain(S_{Rain}, Wind) = 0.97 - \frac{2}{5} 0.0 - \frac{3}{5} 0.0 = 0.97$$

Day	Temp	Humidity	Wind	Play Tennis
D4	Mild	High	Weak	Yes
D5	Cool	Normal	Weak	Yes
D6	Cool	Normal	Strong	No
D10	Mild	Normal	Weak	Yes
D14	Mild	High	Strong	No

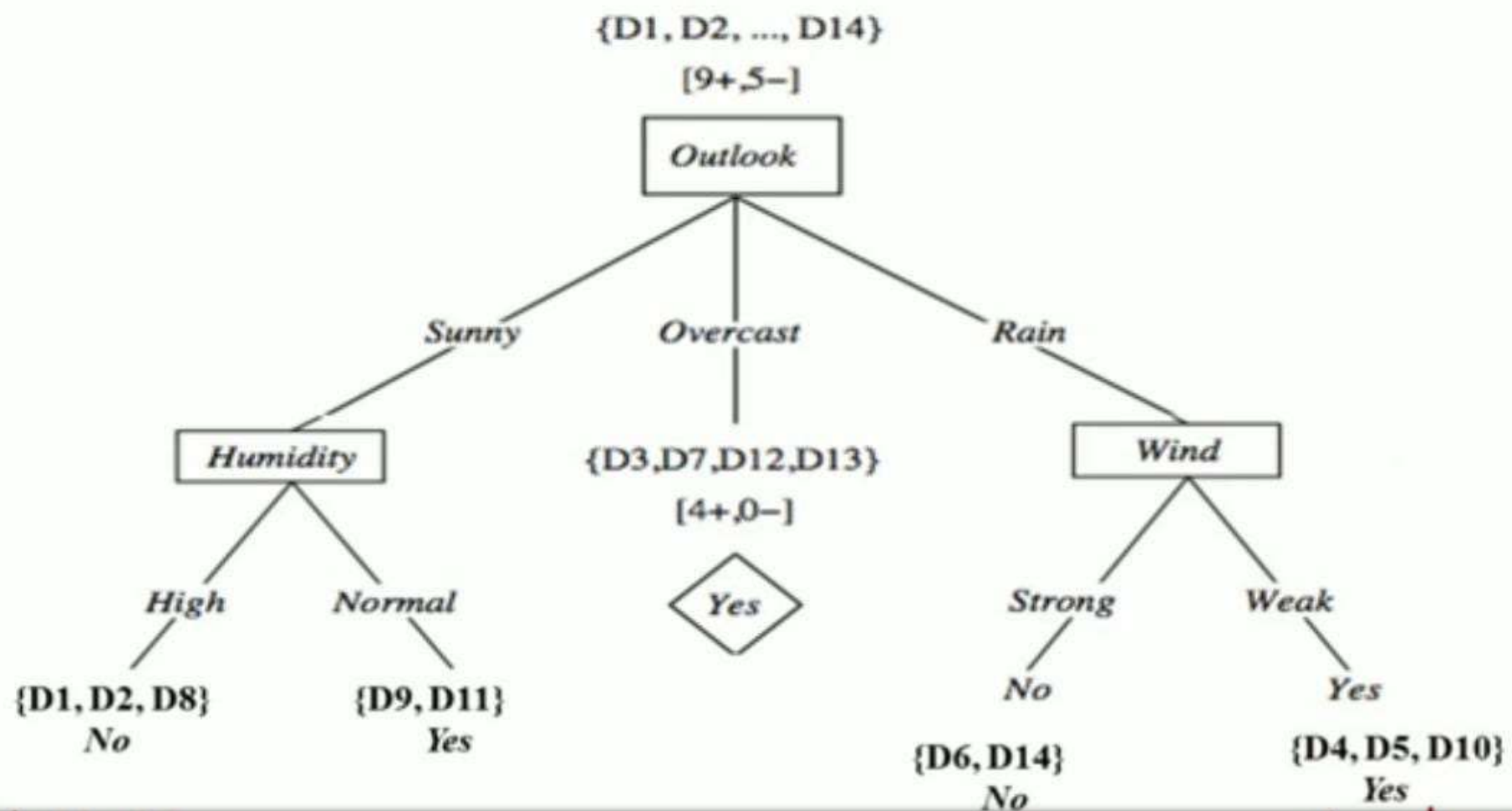
$$Gain(S_{Rain}, Temp) = 0.0192$$

$$Gain(S_{Rain}, Humidity) = 0.0192$$

$$Gain(S_{Rain}, Wind) = 0.97$$







# **Numerical problem on decision tree using GINI INDEX**

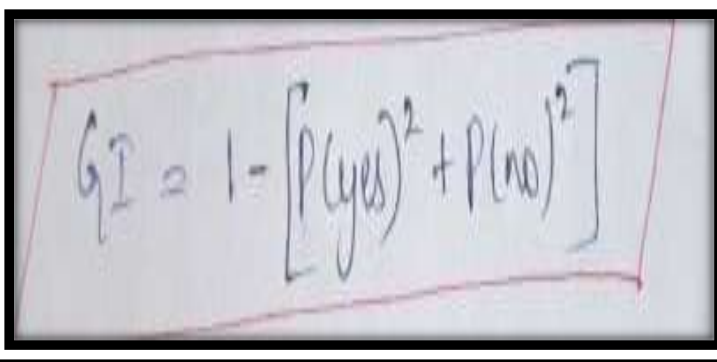
# Steps

Find the Gini index for the entire dataset

Find the Gini index for each attribute

***Formula for Gini index:***

$$\text{Gini} = 1 - \sum_{i=1}^n (p_i)^2$$



A photograph of a piece of paper with the Gini index formula written in black ink. The formula is  $G I = 1 - [P(\text{yes})^2 + P(\text{no})^2]$ . The paper is slightly tilted and has a white border. The entire image is framed by a thick black border.

Weekend	Weather	Parents	Money	Decision
W1	Sunny	Yes	Rich	Cinema
W2	Sunny	No	Rich	Tennis
W3	Windy	Yes	Rich	Cinema
W4	Rainy	Yes	Poor	Cinema
W5	Rainy	No	Rich	Stay In
W6	Rainy	Yes	Poor	Cinema
W7	Windy	No	Poor	Cinema
W8	Windy	No	Rich	Shopping
W9	Windy	Yes	Rich	Cinema
W10	Sunny	No	Rich	Tennis

## Decision Tree using Gini Index – Solved Example

Weekend	Weather	Parents	Money	Decision
W1	Sunny	Yes	Rich	Cinema
W2	Sunny	No	Rich	Tennis
W3	Windy	Yes	Rich	Cinema
W4	Rainy	Yes	Poor	Cinema
W5	Rainy	No	Rich	Stay In
W6	Rainy	Yes	Poor	Cinema
W7	Windy	No	Poor	Cinema
W8	Windy	No	Rich	Shopping
W9	Windy	Yes	Rich	Cinema
W10	Sunny	No	Rich	Tennis

- Compute the **Gini Index** for the overall collection of training examples.
- There are **four possible output variables** **Cinema**, **Tennis**, **Stay In** and **Shopping**.
- The data has **6 instances of Cinema**, **2 instances of Tennis**, **1 instance of Stay In** and **1 of shopping**.

$$Gini(S) = 1 - \left[ \left( \frac{6}{10} \right)^2 + \left( \frac{2}{10} \right)^2 + \left( \frac{1}{10} \right)^2 + \left( \frac{1}{10} \right)^2 \right] = 0.58$$

# Decision Tree using Gini Index – Solved Example

Weekend	Weather	Parents	Money	Decision
W1	Sunny	Yes	Rich	Cinema
W2	Sunny	No	Rich	Tennis
W3	Windy	Yes	Rich	Cinema
W4	Rainy	Yes	Poor	Cinema
W5	Rainy	No	Rich	Stay In
W6	Rainy	Yes	Poor	Cinema
W7	Windy	No	Poor	Cinema
W8	Windy	No	Rich	Shopping
W9	Windy	Yes	Rich	Cinema
W10	Sunny	No	Rich	Tennis

- Computation of **Gini Index for Money** Attribute
- It has **two possible values of Rich (7 examples)** and **Poor (3 examples)**.
- For **Money = Poor**, there are **3 examples with "Cinema"**.
- $Gini(S) = 1 - \left[\left(\frac{3}{3}\right)^2\right] = 0$  ✓ 7
- For **Money = Rich**, there are **2 examples with "Tennis"**, **3 examples with "Cinema"** and **1 example with "Stay in", "Shopping" each**
- $Gini(S) = 1 - \left[\left(\frac{2}{7}\right)^2 + \left(\frac{3}{7}\right)^2 + \left(\frac{1}{7}\right)^2 + \left(\frac{1}{7}\right)^2\right] = 0.694$
- **Weighted Average(Money)**

$$= 0 * \left(\frac{3}{10}\right) + 0.694 * \left(\frac{7}{10}\right) = 0.486$$



# Decision Tree using Gini Index – Solved Example

Weekend	Weather	Parents	Money	Decision
W1	Sunny	Yes	Rich	Cinema
W2	Sunny	No	Rich	Tennis
W3	Windy	Yes	Rich	Cinema
W4	Rainy	Yes	Poor	Cinema
W5	Rainy	No	Rich	Stay In
W6	Rainy	Yes	Poor	Cinema
W7	Windy	No	Poor	Cinema
W8	Windy	No	Rich	Shopping
W9	Windy	Yes	Rich	Cinema
W10	Sunny	No	Rich	Tennis

- Computation of **Gini Index for Parents Attribute**
- It has two possible values of **Yes (5 examples)** and **No (5 examples)**.
- For **Parents = Yes**, there are **5 examples**, all with "Cinema".
- $Gini(S) = 1 - \left[\left(\frac{5}{5}\right)^2\right] = 0$
- For **Parents = No**, there are **2 examples with "Tennis"**, **1 example with "Stay in"**, **"Shopping"** and **"Cinema"** each
- $Gini(S) = 1 - \left[\left(\frac{2}{5}\right)^2 + \left(\frac{1}{5}\right)^2 + \left(\frac{1}{5}\right)^2 + \left(\frac{1}{5}\right)^2\right] = 0.72$
- **Weighted Average(Parents)**

$$= 0 * \left(\frac{5}{10}\right) + [0.72 * \left(\frac{5}{10}\right)] = 0.36$$

Weekend	Weather	Parents	Money	Decision
W1	Sunny	Yes	Rich	Cinema
W2	Sunny	No	Rich	Tennis
W3	Windy	Yes	Rich	Cinema
W4	Rainy	Yes	Poor	Cinema
W5	Rainy	No	Rich	Stay In
W6	Rainy	Yes	Poor	Cinema
W7	Windy	No	Poor	Cinema
W8	Windy	No	Rich	Shopping
W9	Windy	Yes	Rich	Cinema
W10	Sunny	No	Rich	Tennis

- Computation of **Gini Index for Weather** Attribute
- It has three possible values of **Sunny (3 examples)**, **Rainy (3 examples)** and **Windy (4 examples)**.
- For **Weather = Sunny**, there are **2 examples** with "Cinema" and **1** with "Tennis".
 
$$Gini(Sunny) = 1 - \left[ \left( \frac{2}{3} \right)^2 + \left( \frac{1}{3} \right)^2 \right] = 0.444$$
- For **Weather = Rainy**, there are **2 examples** with "Cinema" and **1 example** with "Stay in"
 
$$Gini(Rainy) = 1 - \left[ \left( \frac{2}{3} \right)^2 + \left( \frac{1}{3} \right)^2 \right] = 0.444$$
- For **Weather = Windy**, there are **3 examples** with "Cinema" and **1 example** with "Shopping"
 
$$Gini(Windy) = 1 - \left[ \left( \frac{3}{4} \right)^2 + \left( \frac{1}{4} \right)^2 \right] = 0.375$$

Weekend	Weather	Parents	Money	Decision
W1	Sunny	Yes	Rich	Cinema
W2	Sunny	No	Rich	Tennis
W3	Windy	Yes	Rich	Cinema
W4	Rainy	Yes	Poor	Cinema
W5	Rainy	No	Rich	Stay In
W6	Rainy	Yes	Poor	Cinema
W7	Windy	No	Poor	Cinema
W8	Windy	No	Rich	Shopping
W9	Windy	Yes	Rich	Cinema
W10	Sunny	No	Rich	Tennis

Weighted Average(Weather)

$$= 0.444 * \left(\frac{3}{10}\right) + 0.444 * \left(\frac{3}{10}\right) + 0.375 * \left(\frac{4}{10}\right)$$

$$= 0.416$$

For Weather - Gini Index: 0.416

For Parents - Gini Index: 0.36 ✓

For Money - Gini Index: 0.486

**Parents is selected as it has smallest  
Gini index.**



Parents

Yes

No

Weekend	Weather	Parents	Money	Decision
W1	Sunny	Yes	Rich	Cinema
W3	Windy	Yes	Rich	Cinema
W4	Rainy	Yes	Poor	Cinema
W6	Rainy	Yes	Poor	Cinema
W9	Windy	Yes	Rich	Cinema

Weekend	Weather	Parents	Money	Decision
W2	Sunny	No	Rich	Tennis
W5	Rainy	No	Rich	Stay In
W7	Windy	No	Poor	Cinema
W8	Windy	No	Rich	Shopping
W10	Sunny	No	Rich	Tennis

**Parents**

Yes

No

Cinema

No

Weekend	Weather	Parents	Money	Decision
W2	Sunny	No	Rich	Tennis
W5	Rainy	No	Rich	Stay In
W7	Windy	No	Poor	Cinema
W8	Windy	No	Rich	Shopping
W10	Sunny	No	Rich	Tennis

Weekend	Weather	Parents	Money	Decision
W2	Sunny	No	Rich	Tennis
W5	Rainy	No	Rich	Stay In
W7	Windy	No	Poor	Cinema
W8	Windy	No	Rich	Shopping
W10	Sunny	No	Rich	Tennis

Computation of Gini Index for Parents = No | Weather Attribute

- **Sunny (2 examples)**
- For Parent= No | Weather = Sunny, there are 2 example with "Tennis."
- $Gini(S) = 1 - \left[\left(\frac{2}{2}\right)^2\right] = 0$



## Decision Tree using Gini Index – Solved Example

Weekend	Weather	Parents	Money	Decision
W2	Sunny	No	Rich	Tennis
W5	Rainy	No	Rich	Stay In
W7	Windy	No	Poor	Cinema
W8	Windy	No	Rich	Shopping
W10	Sunny	No	Rich	Tennis

Computation of Gini Index for Parents = No | Weather Attribute

- **Rainy (1 example).**
- For Parents = No | Weather = Rainy, there is 1 example with "Stay In".
- $Gini(S) = 1 - \left[\left(\frac{1}{1}\right)^2\right] = 0$

## Decision Tree using Gini Index – Solved Example

Weekend	Weather	Parents	Money	Decision
W2	Sunny	No	Rich	Tennis
W5	Rainy	No	Rich	Stay In
W7	Windy	No	Poor	Cinema
W8	Windy	No	Rich	Shopping
W10	Sunny	No	Rich	Tennis

Computation of Gini Index for Parents = No | Weather Attribute

- **Windy (2 example)**
  - For Parents = No | Weather = Windy, there is 1 example with "Cinema" and 1 example with "Shopping".
  - $Gini(S) = 1 - \left[ \left(\frac{1}{2}\right)^2 + \left(\frac{1}{2}\right)^2 \right] = \underline{0.5}$

$$\text{Weighted Average}(\text{Parents} = \text{No} | \text{Weather}) = 0 * \left(\frac{2}{5}\right) + 0 * \left(\frac{1}{5}\right) + 0.5 * \left(\frac{2}{5}\right) = 0.2$$

Weekend	Weather	Parents	Money	Decision
W2	Sunny	No	Rich	Tennis
W5	Rainy	No	Rich	Stay In -
W7	Windy	No	Poor	Cinema
W8	Windy	No	Rich	Shopping ✓
W10	Sunny	No	Rich	Tennis

### Computation of Gini Index for Parents = No | Money Attribute

- Rich (4 examples)
- For Parents = No | Money = Rich, there is 1 example with "stay in" and "Shopping" each and 2 examples of "Tennis".
- $Gini(S) = 1 - \left[ \left( \frac{1}{4} \right)^2 + \left( \frac{1}{4} \right)^2 + \left( \frac{2}{4} \right)^2 \right] = 0.625$

Weekend	Weather	Parents	Money	Decision
W2	Sunny	No	Rich	Tennis
W5	Rainy	No	Rich	Stay In
W7	Windy	No	Poor	Cinema
W8	Windy	No	Rich	Shopping
W10	Sunny	No	Rich	Tennis

For Parents = No | Weather - Gini Index: 0.2

For Parents = No | Money - Gini Index: 0.5

**Weather** is selected as it has smallest Gini index.



Weekend	Weather	Parents	Money	Decision
W2	Sunny	No	Rich	Tennis
W5	Rainy	No	Rich	Stay In
W7	Windy	No	Poor	Cinema
W8	Windy	No	Rich	Shopping
W10	Sunny	No	Rich	Tennis

Now, for Parent=No & Weather=Sunny, we have all instances as Tennis.

Weekend	Weather	Parents	Money	Decision
W2	Sunny	No	Rich	Tennis ✓
W10	Sunny	No	Rich	Tennis ✓

Now, for Parent=No & Weather=Windy, we need to split.

Now, for Parents=No & Weather=Rainy, we have all instances as Stay In.

Weekend	Weather	Parents	Money	Decision
W5	Rainy	No	Rich	Stay In ✓

Weekend	Weather	Parents	Money	Decision
W7	Windy	No	Poor	Cinema ✓
W8	Windy	No	Rich	Shopping ✓

