DECISION TREE AND RANDOM FOREST

1

Decision Tree Algorithm

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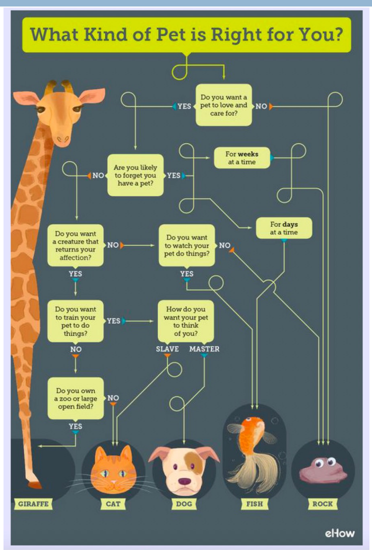
- Similar to how humans make many different decisions
- Decision trees look at one feature/variable at a time



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Decision Tree Algorithm

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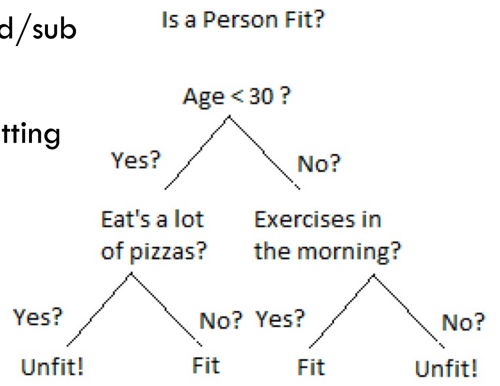
- Root node
- Parent, child/sub nodes
- Branch, splitting
- Leaf nodes



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Decision Tree Algorithm

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- Training dataset

root

Day	Outlook	Temp	Humidity	Wind	Tennis?
1	Sunny	Hot	High	Weak	No
2	Sunny	Hot	High	Strong	No
3	Overcast	Hot	High	Weak	Yes
4	Rain	Mild	High	Weak	Yes
5	Rain	Cool	Normal	Weak	Yes
6	Rain	Cool	Normal	Strong	No
7	Overcast	Cool	Normal	Strong	Yes
8	Sunny	Mild	High	Weak	No
9	Sunny	Cool	Normal	Weak	Yes
10	Rain	Mild	Normal	Weak	Yes
11	Sunny	Mild	Normal	Strong	Yes
12	Overcast	Mild	High	Strong	Yes
13	Overcast	Hot	Normal	Weak	Yes
14	Rain	Mild	High	Strong	No

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Decision Tree Algorithm

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- How can we build a decision tree given a data set?

5

Decision Tree Algorithm

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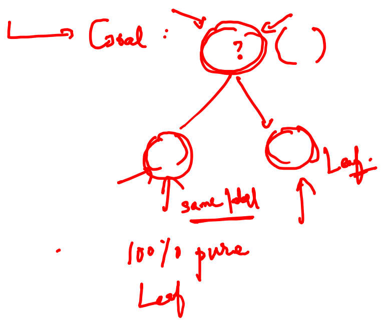
- We will make the best choice at each step
- Identify the best feature/attribute for the each node



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Decision Tree Algorithm

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- Identify the best feature/attribute for root node
  - Best split: results of each branch should be as homogeneous (or pure) as possible
  - a feature that reduces impurity as much as possible
  - How do we measure the impurity in a set of examples
    - Entropy from information theory
    - Alternatively, use Gini Index

$\text{Info Gain} = (H)_{\text{before}} - H_{\text{after}}$

$\text{Info Gain(feature)} = (\;) - (\;)$ weighted avg. of entropy of child nodes.

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Decision Tree Algorithm

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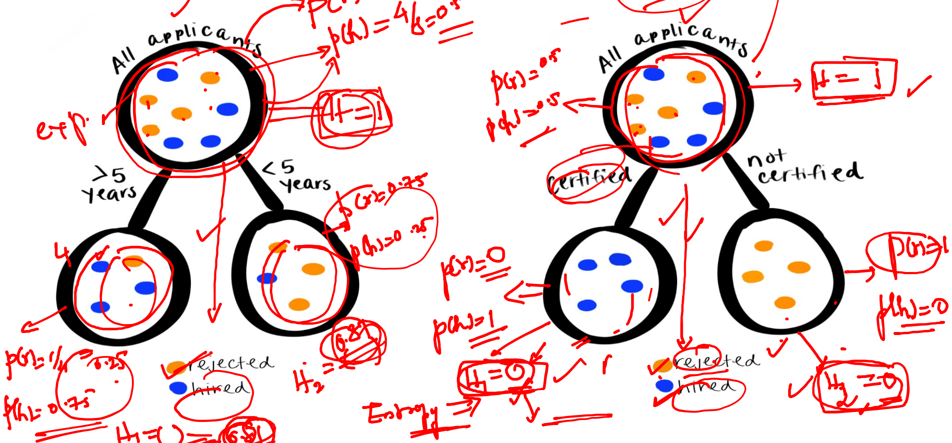
- Information Gain (entropy reduction)



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Decision Tree Algorithm

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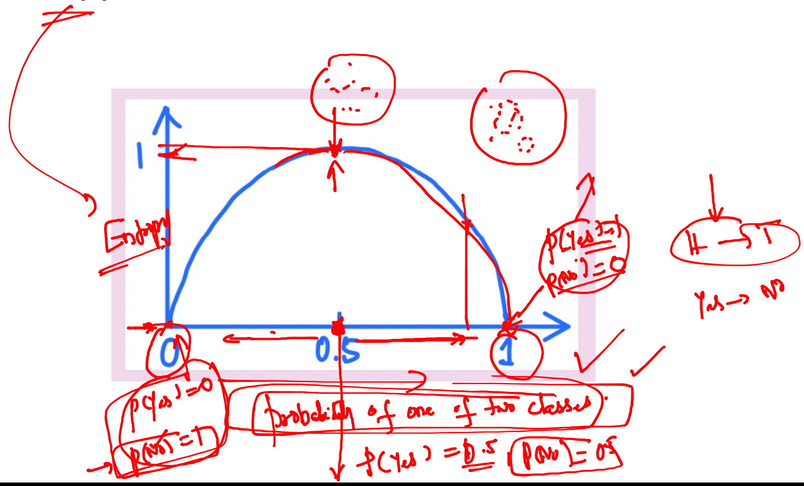
- Entropy for a distribution over two outcomes



Decision Tree Algorithm

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- Quantifying the information content of a feature
  - entropy of the examples (Data points) before testing the feature minus the entropy of the examples after testing the feature – Information Gain

after the split

$H_{before} - H_{after}$

Decision Tree Algorithm

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- Quantifying the information content of a feature
  - Information gain or entropy reduction

$$\text{InfoGain} = I_{\text{before}} - I_{\text{after}}$$

node ( )

Lowest

Entropy

Entropy

$(0.5)\,3 + (0.5)\,5$

$\frac{3+5}{2}$

$(0.7)\,3 + (0.3)(5)$

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Decision Tree Algorithm

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- Entropy of the examples before we select a feature for the root node

$$H_{\text{before}} = -\left(\frac{9}{14}\log_2\left(\frac{9}{14}\right) + \frac{5}{14}\log_2\left(\frac{5}{14}\right)\right) \approx 0.94$$

leaf node

14 datapoints

No → 5

Yes → 9

$P(No) = \frac{5}{14}$

$P(Yes) = \frac{9}{14}$

Day	Outlook	Temp	Humidity	Wind	Tennis?
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5	Rain	Cool	Normal	Weak	Yes
6	Rain	Cool	Normal	Strong	No
7	Overcast	Cool	Normal	Strong	Yes
8	Sunny	Mild	High	Weak	No
9	Sunny	Cool	Normal	Weak	Yes
10	Rain	Mild	Normal	Weak	Yes
11	Sunny	Mild	Normal	Strong	Yes
12	Overcast	Mild	High	Strong	Yes
13	Overcast	Hot	Normal	Weak	Yes
14	Rain	Mild	High	Strong	No

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Decision Tree Algorithm

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- Information gain if we select Outlook for the root node

$w_1 H_1 + w_2 H_2 + w_3 H_3$ $\quad w_1 = 5/14,\ w_2 = 4/14,\ w_3 = 5/14$

$w_1 + w_2 + w_3 = 14/14 = 1$

$$\text{Outlook} = \begin{cases} \text{Sunny} & 2+ \quad 3- \quad 5 \text{ total} \\ \text{Overcast} & 4+ \quad 0- \quad 4 \text{ total} \\ \text{Rain} & 3+ \quad 2- \quad 5 \text{ total} \end{cases}$$

$$\text{Gain(Outlook)} = 0.94 - \left(\frac{5}{14}\cdot I\left(\frac{2}{5},\frac{3}{5}\right) + \frac{4}{14}\cdot I\left(\frac{4}{4},\frac{0}{4}\right) + \frac{5}{14}\cdot I\left(\frac{3}{5},\frac{2}{5}\right)\right)$$
$$= 0.247$$

Day	Outlook	Temp	Humidity	Wind	Tennis?
1	Sunny	Hot	High	Weak	No
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root node

3-way split

100% pure leaf node

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Decision Tree Algorithm

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- Information gain if we select Humidity for the root node

$$\text{Humidity} = \begin{cases} \text{Normal} & 6+ \quad 1- \quad 7 \text{ total} \\ \text{High} & 3+ \quad 4- \quad 7 \text{ total} \end{cases}$$

$$\text{Gain(Humidity)} = 0.94 - \left(\frac{7}{14}\cdot I\left(\frac{6}{7},\frac{1}{7}\right) + \frac{7}{14}\cdot I\left(\frac{3}{7},\frac{4}{7}\right)\right)$$
$$= 0.151$$

Day	Outlook	Temp	Humidity	Wind	Tennis?
1	Sunny	Hot	High	Weak	No
2	Sunny	Hot	High	Strong	No
3	Overcast	Hot	High	Weak	Yes
4	Rain	Mild	High	Weak	Yes
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13	Overcast	Hot	Normal	Weak	Yes
14	Rain	Mild	High	Strong	No

High

3 Yes
4 No

6 Yes
1 No

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Decision Tree Algorithm

- **Outlook** has the **greatest information gain**

Gain(**Outlook**) = **0.247** Gain(Humidity) = 0.151
Gain(Temp) = 0.029 Gain(Wind) = 0.048

Day	Outlook	Temp	Humidity	Wind	Tennis?
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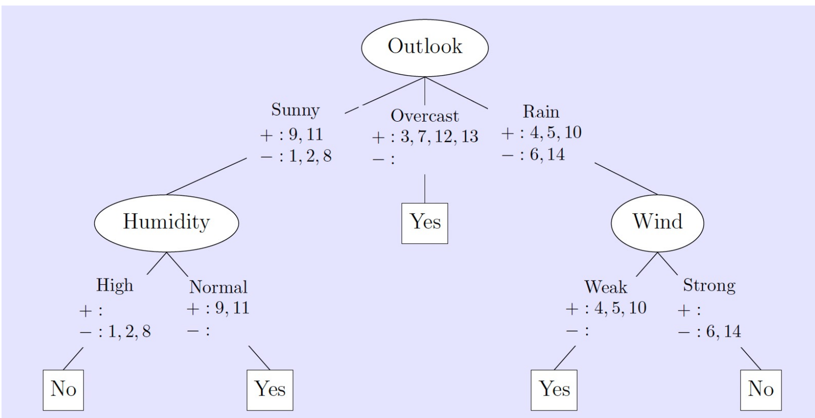
Decision Tree Algorithm

- **Outlook** has the **greatest information gain**



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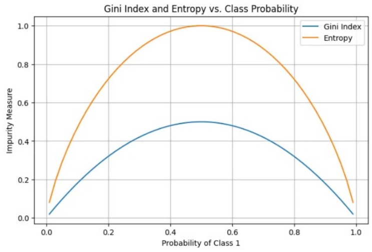
Gini Impurity to Build Decision Trees

$$Gini(D) = 1 - \sum_{i=1}^{k} p_i^2$$

$$Gini_A(D) = \frac{n_1}{n} Gini(D_1) + \frac{n_2}{n} Gini(D_2)$$

$$\triangle Gini(A) = Gini(D) - Gini_A(D)$$



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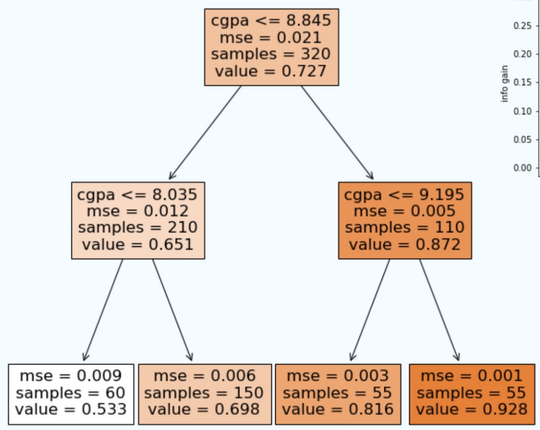
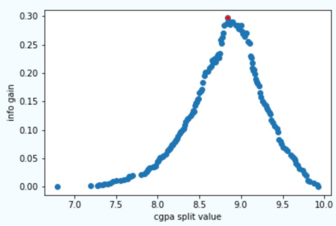
Decision Tree for Regression





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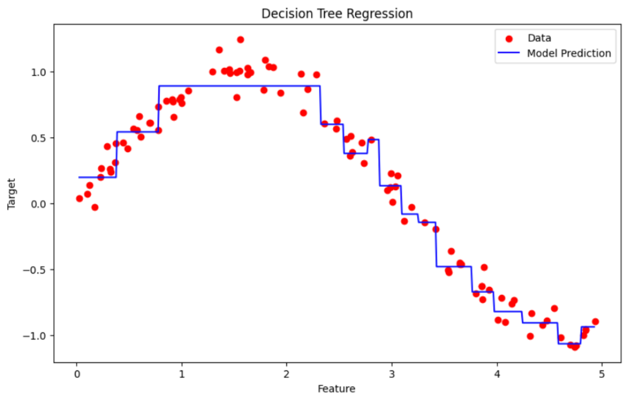
Decision Tree for Regression



Decision Tree Regression

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Thank You!

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