Naive Bayes

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What Is Bayes Therom About?

- P(A | B) → Probability of A happening given B is true.
- P(B | A) → Probability of B happening given A is true.
- P(A) → Prior probability of A happening.
- P(B) → Total probability of B happening.

$$P(A|B) = \frac{P(B|A) * P(A)}{P(B)}$$

Example: Diagnosing a Disease:

- P(Disease | Symptom) → Probability of having a disease given the symptom.
- P(Symptom | Disease) → Probability of the symptom if the person has the disease.

Why is Bayes' Theorem Important?

- Updates beliefs as new evidence comes in.
- Forms the foundation of Naïve Bayes Classifier for making predictions.
- Used in spam filtering, medical diagnosis, and machine learning.

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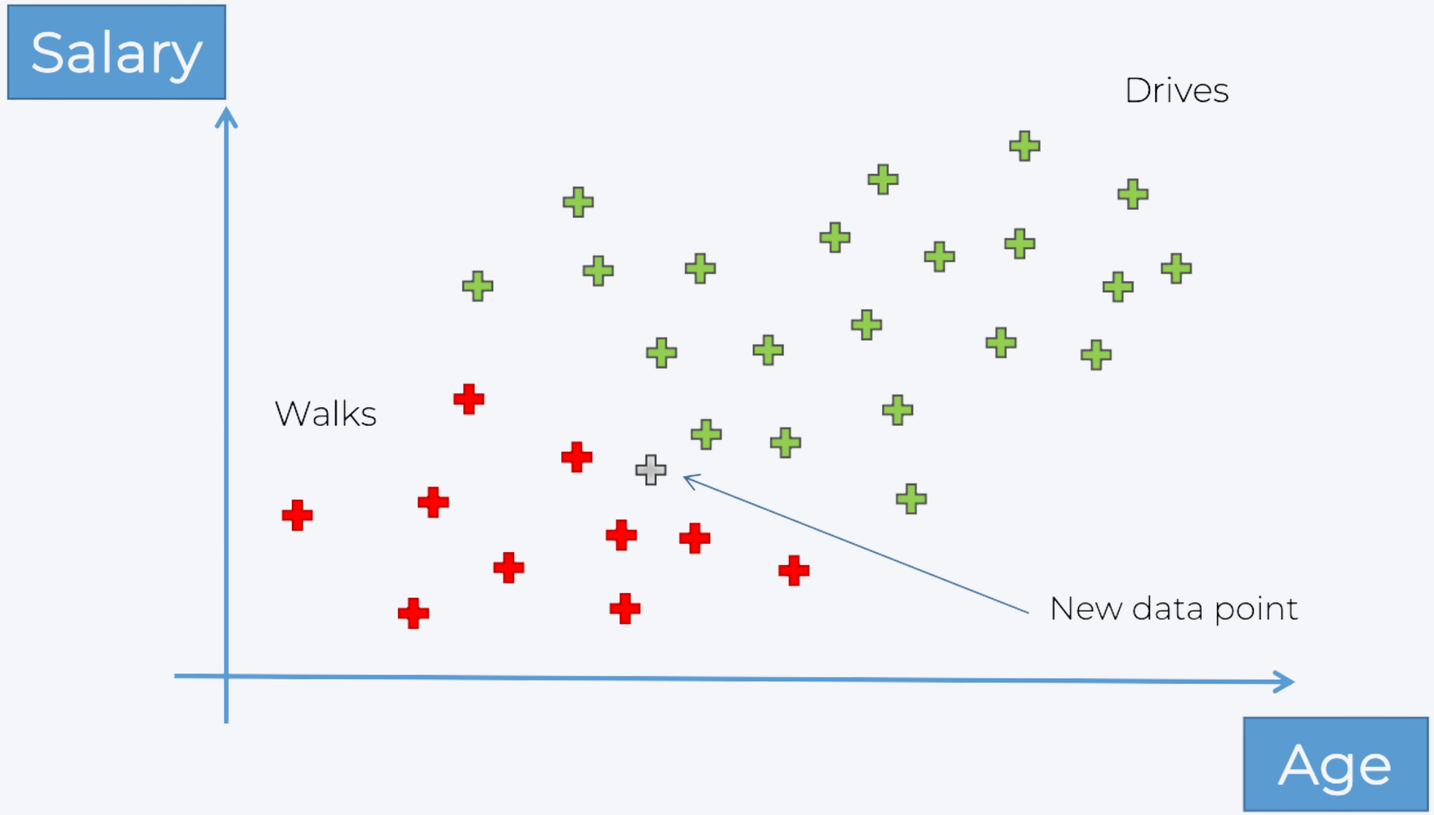
How does it work ?

When a new data point is introduced, we need to classify whether this new individual is more likely to walk or drive based on given data.



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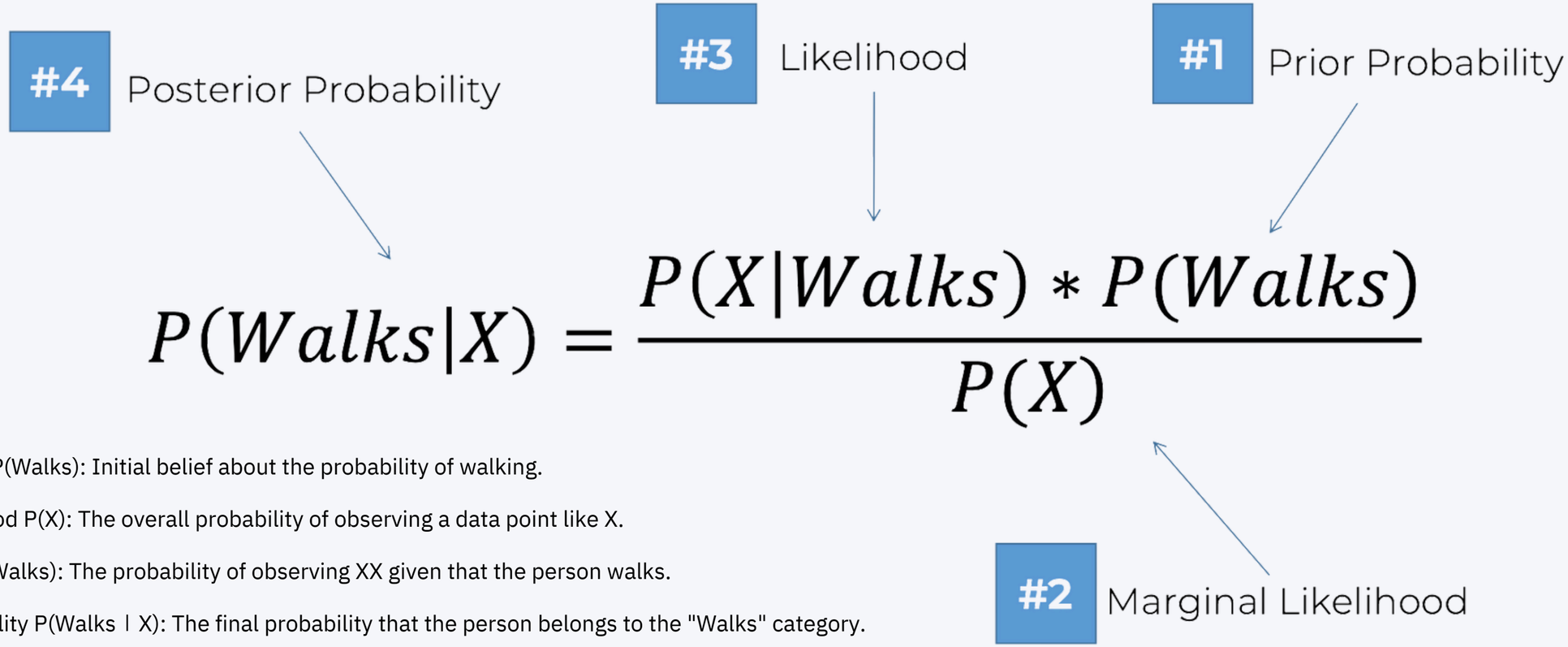
Step #1



- Prior Probability P(Walks): Initial belief about the probability of walking.
- Marginal Likelihood P(X): The overall probability of observing a data point like X.
- Likelihood P(X | Walks): The probability of observing XX given that the person walks.
- Posterior Probability P(Walks | X): The final probability that the person belongs to the "Walks" category.

The probability of a person walking given their data point **P(Walks|X)** is computed using Bayes' Theorem.

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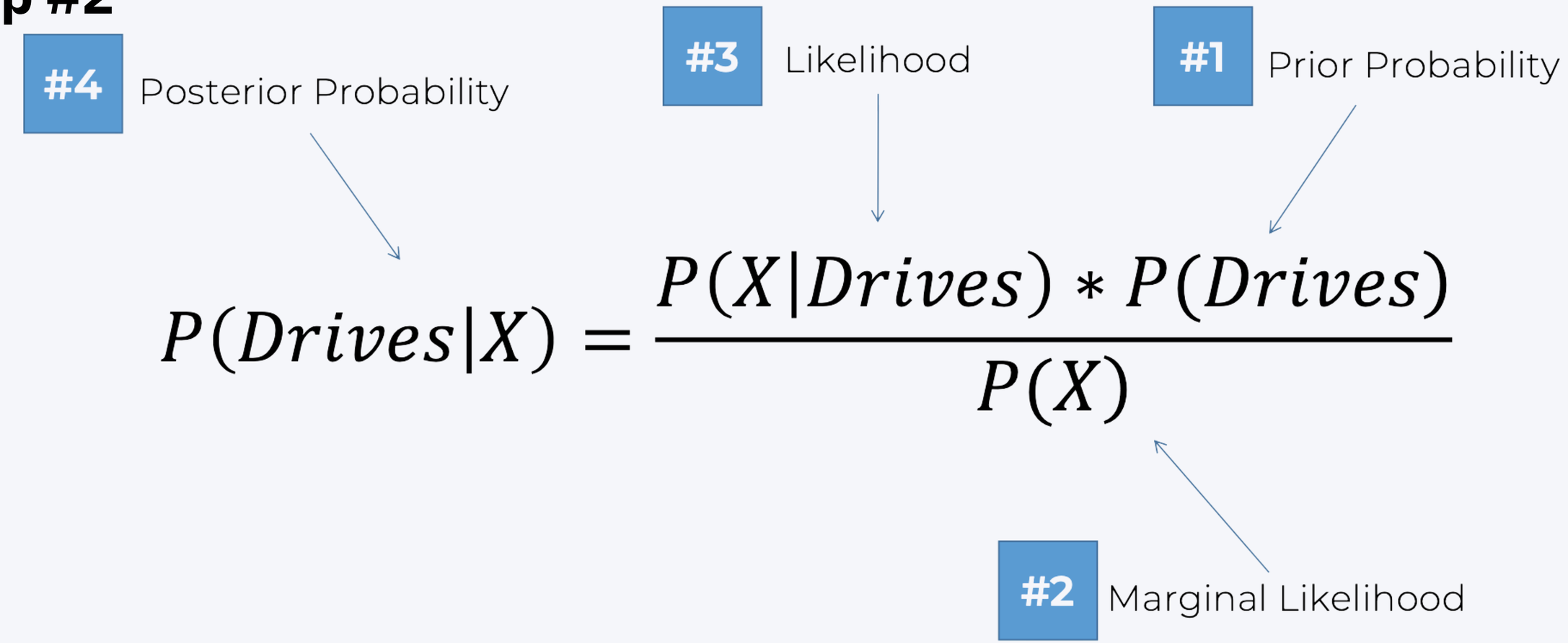
Step #2



Similarly, the probability of a person driving given their data point **P(Drives|X)** is computed using the same formula.

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Step #3

$$P(Walks|X) \; v.s. \; P(Drives|X)$$

- The classification decision is made by comparing **P(Walks | X) vs. P(Drives | X).**
- The category with the higher probability is chosen.

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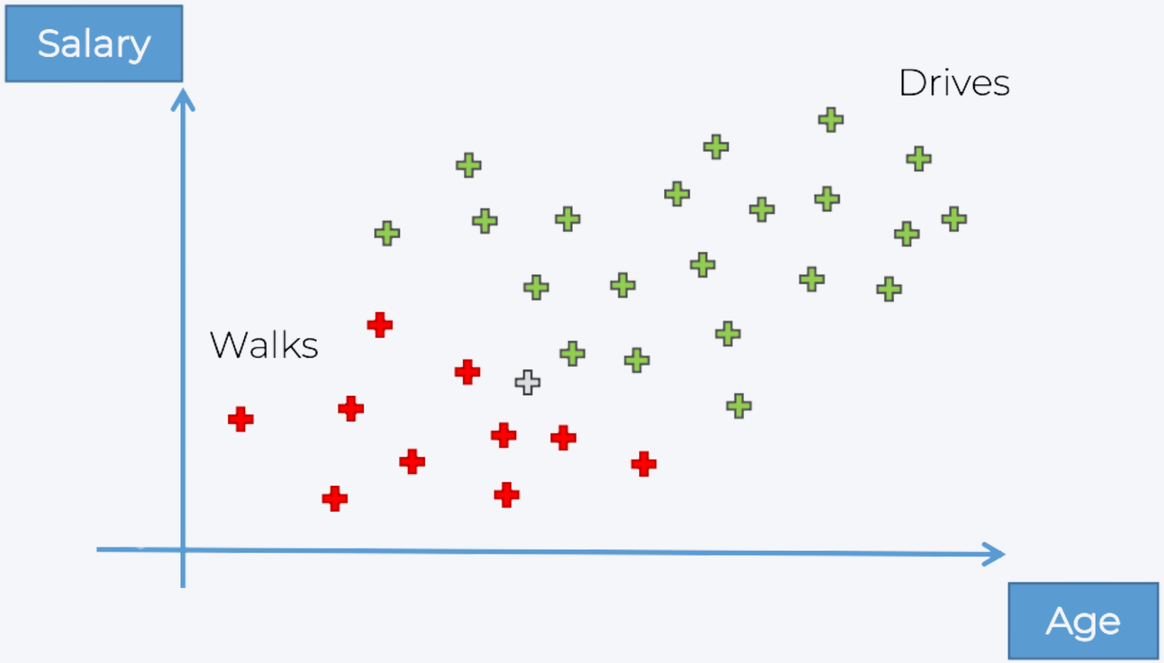
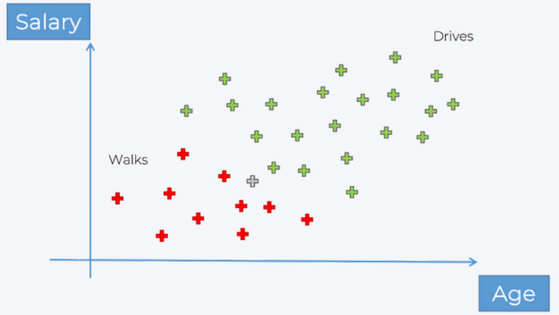
Naive bayes | In Action >> Step #1





#1. P(Walks)

$$P(Walks) = \frac{Number\ of\ Walkers}{Total\ Observations}$$

$$P(Walks) = \frac{10}{30}$$

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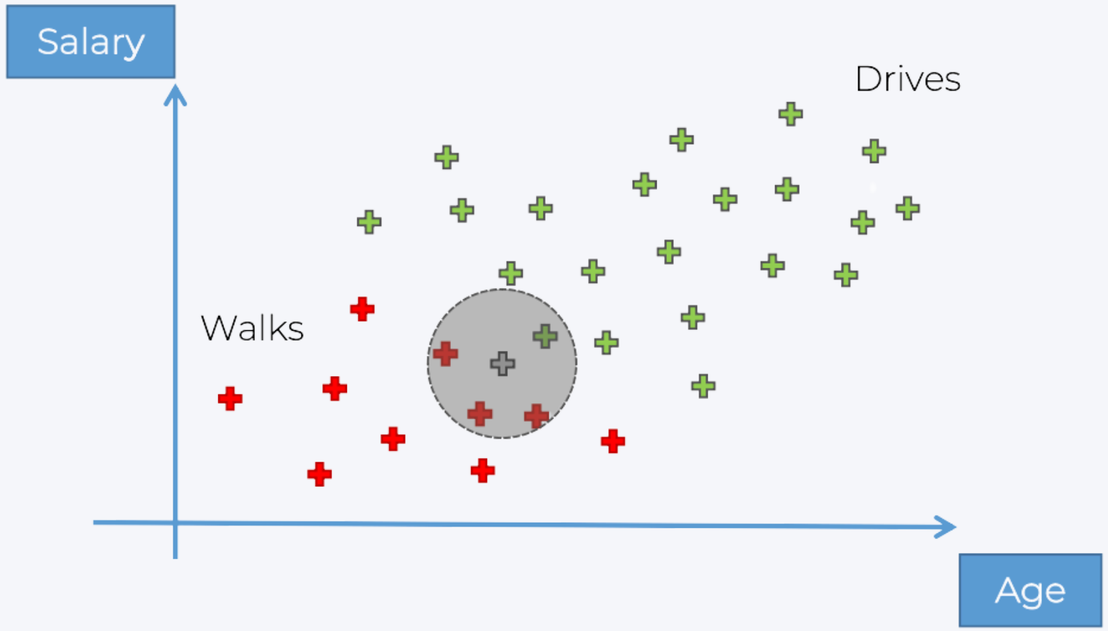
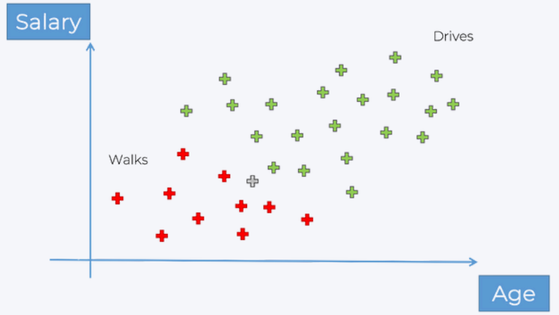
Naive bayes | In Action >> Step #1





#2. P(X)

$$P(X) = \frac{Number\ of\ Similar\ Observations}{Total\ Observations}$$

$$P(X) = \frac{4}{30}$$

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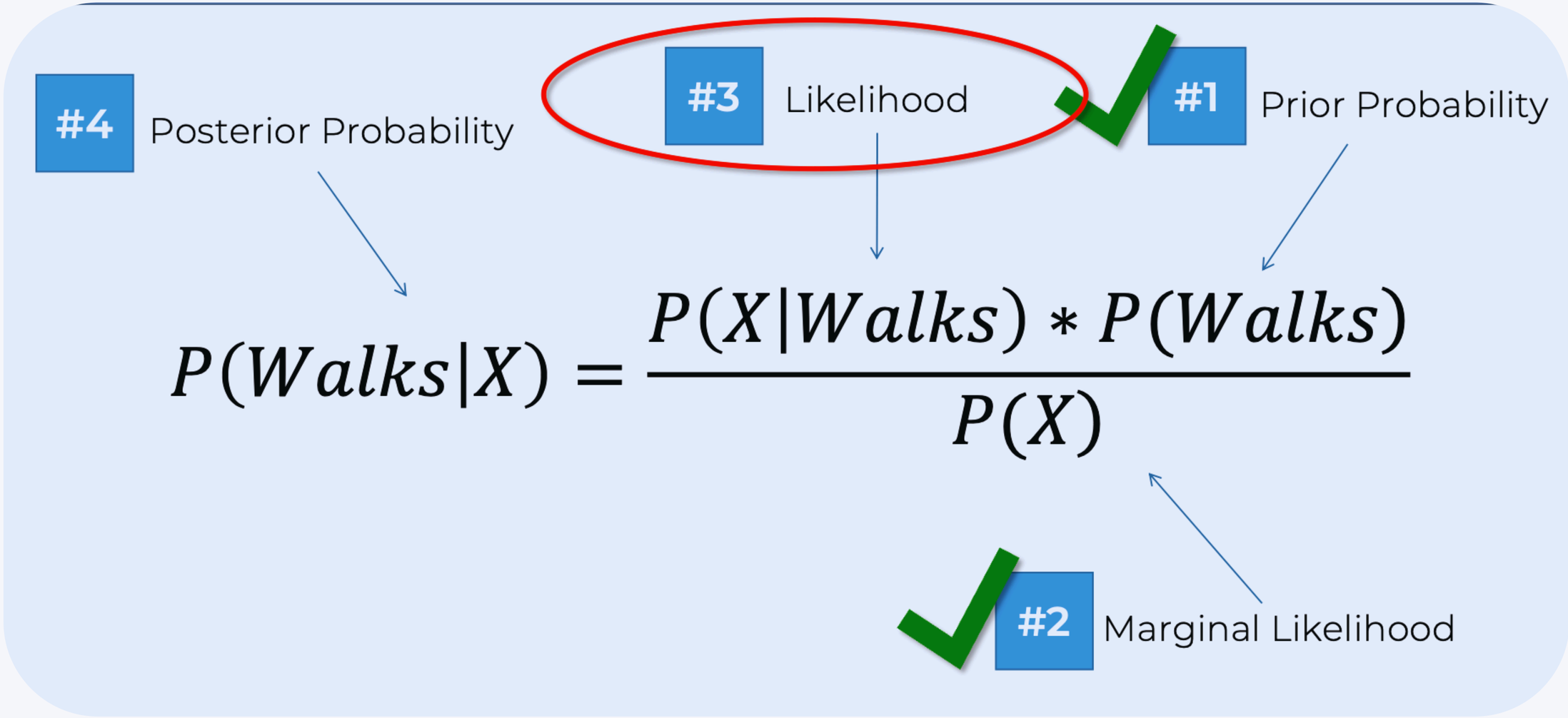
Naive bayes | In Action >> Step #1



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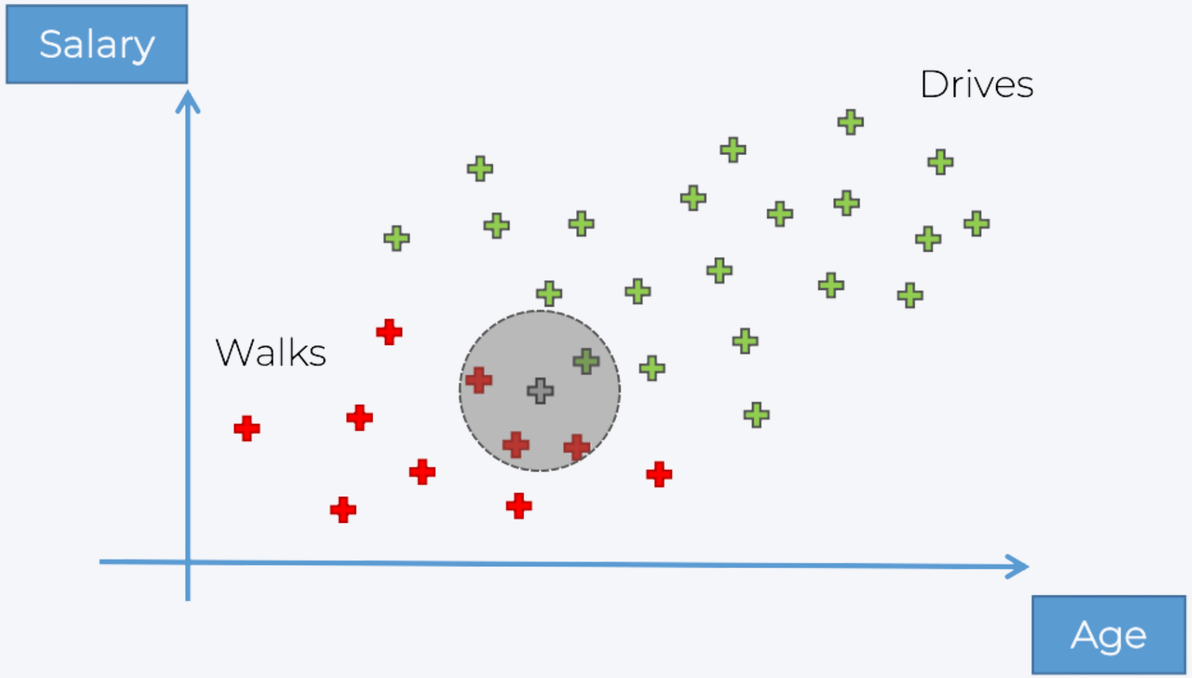
Naive bayes | In Action >> Step #1



#3. P(X|Walks)

$$P(X|Walks) = \frac{Number\ of\ Similar\ Observations\ Among\ those\ who\ Walk}{Total\ number\ of\ Walkers}$$

$$P(X|Walks) = \frac{3}{10}$$

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Naive Bayes

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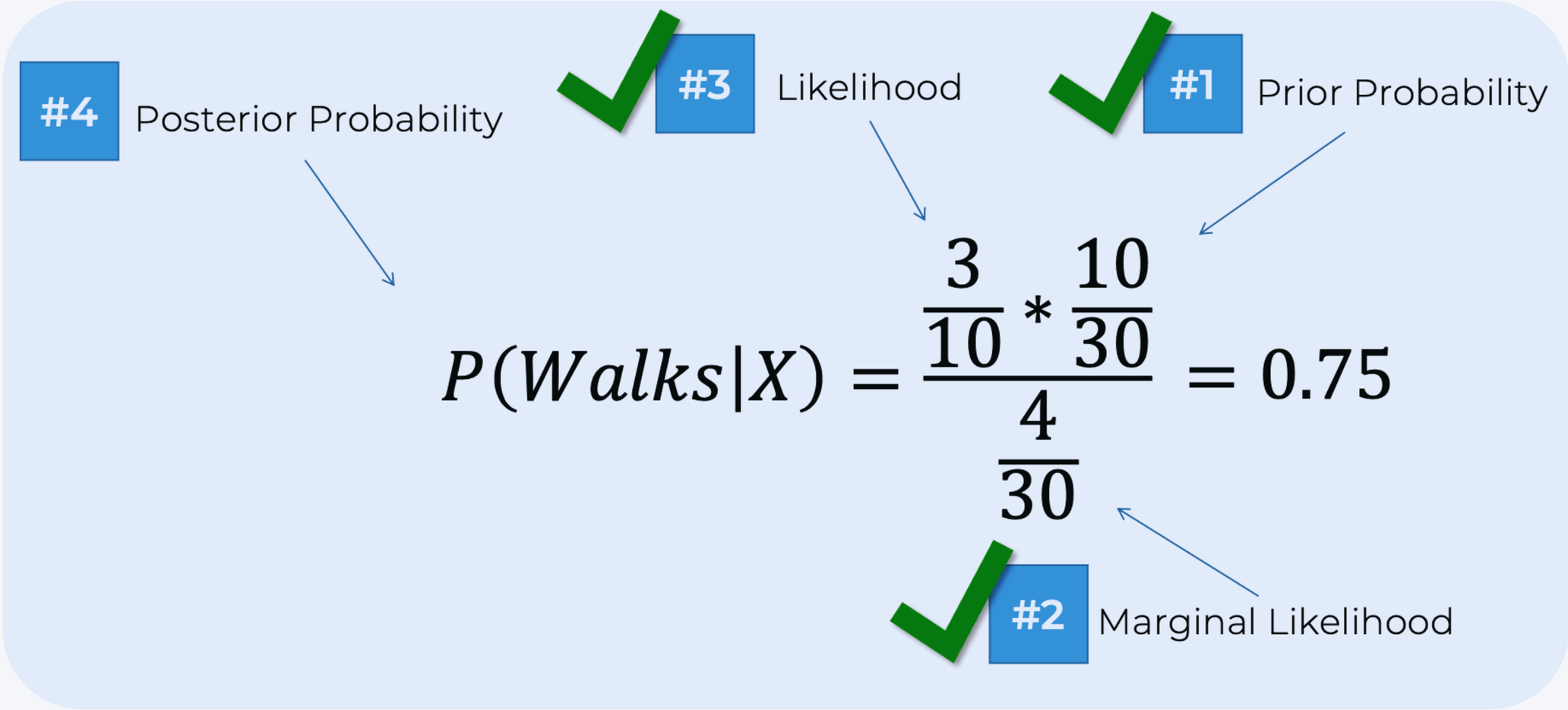

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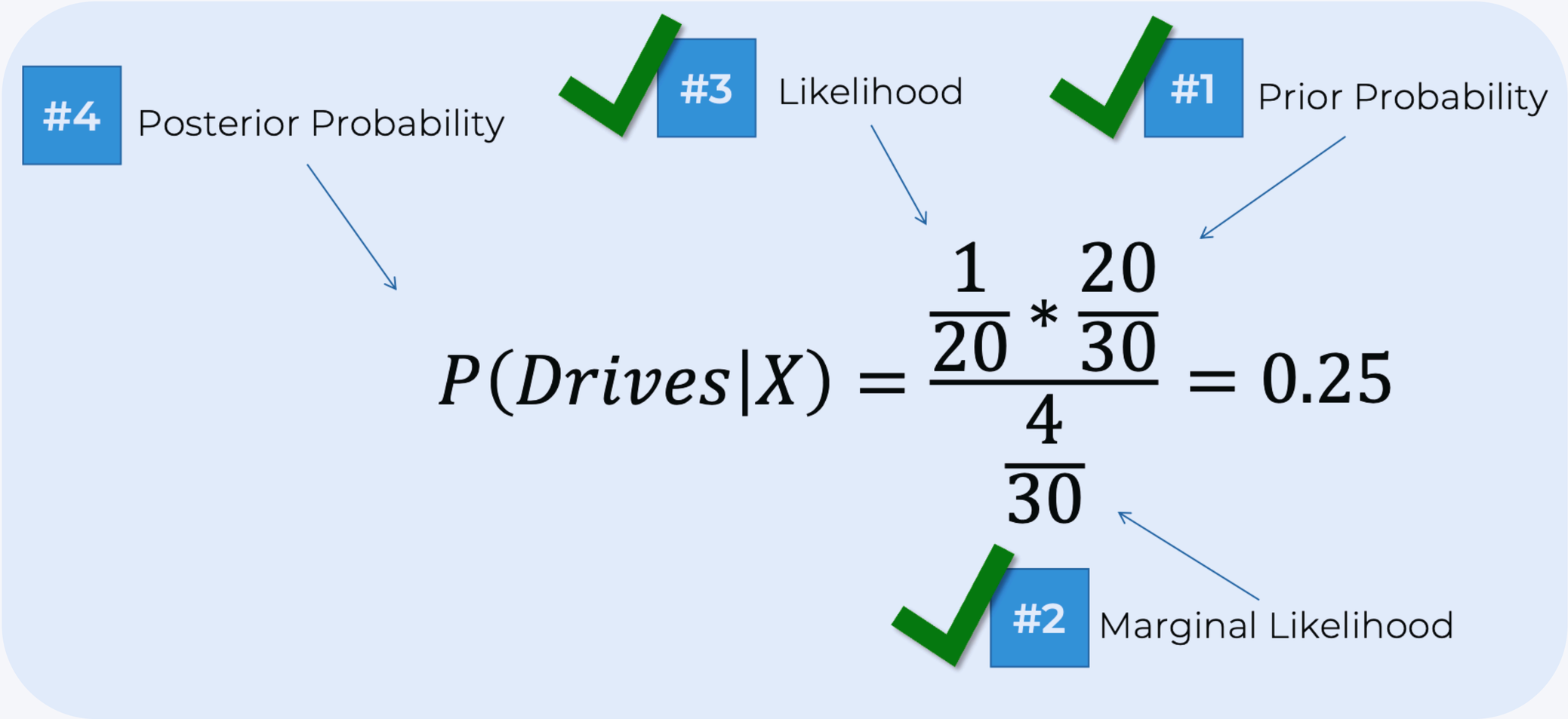
Naive Bayes

Naive bayes | In Action >> Step #2



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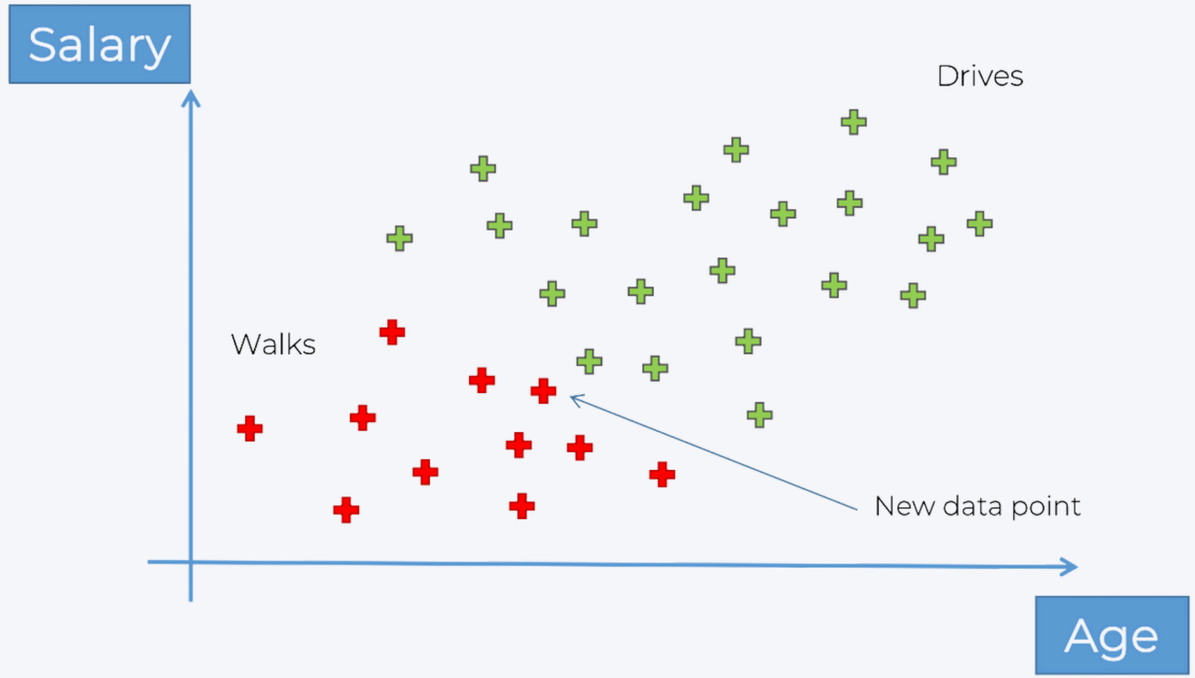
Naive bayes | In Action >> Step #2

$$P(Walks|X)\ v.s.\ P(Drives|X)$$

$$0.75\ v.s.\ 0.25$$

$$0.75 > 0.25$$

$$P(Walks|X) > P(Drives|X)$$



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Why is it called "Naive"?

Because it assumes independence between features, meaning each feature contributes to the classification independently.

Why Can We Ignore P(X)?

- Since P(X) is the same for all classes, it cancels out when comparing probabilities.

More than Two Classes?

- The method extends to multiple classes by computing the probability for each and picking the highest.

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QUIZ

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Hands-On Code

Naive Bayes

Decision Tree Classification

Decision Tree Classification

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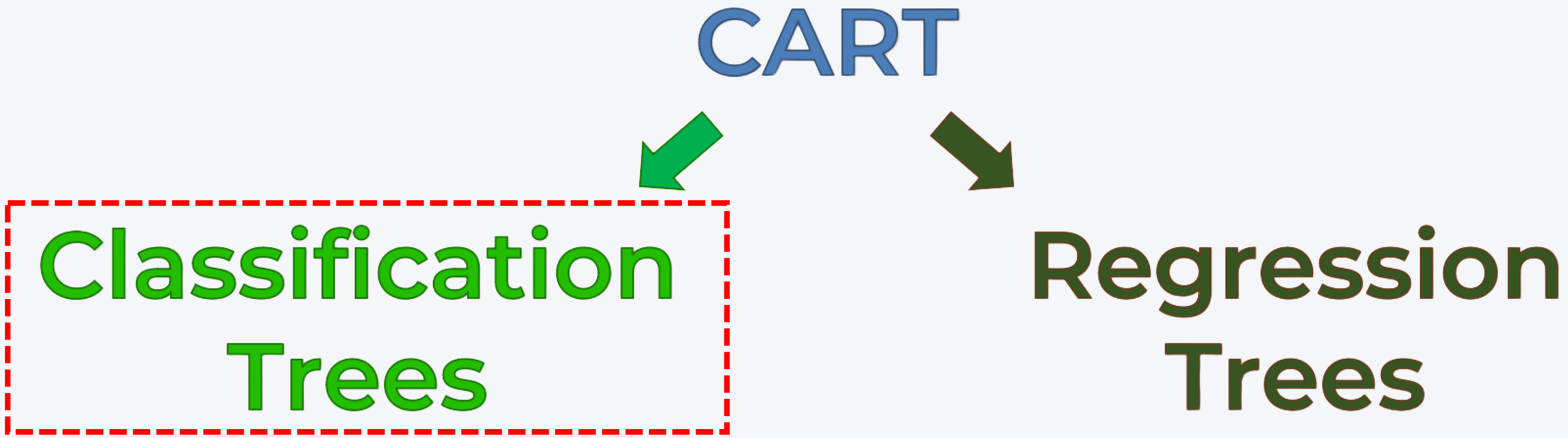
CART



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Decision Tree Classification

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Difference Between Decision Tree Regression and Classification:

- **Decision Tree Regression:** Predicts a continuous numerical value based on input features. The tree is built using splits that minimize variance within groups.

- **Decision Tree Classification:** Assigns an input to a specific category (class) by recursively splitting the data based on features that best separate different classes.

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Decision Tree Classification

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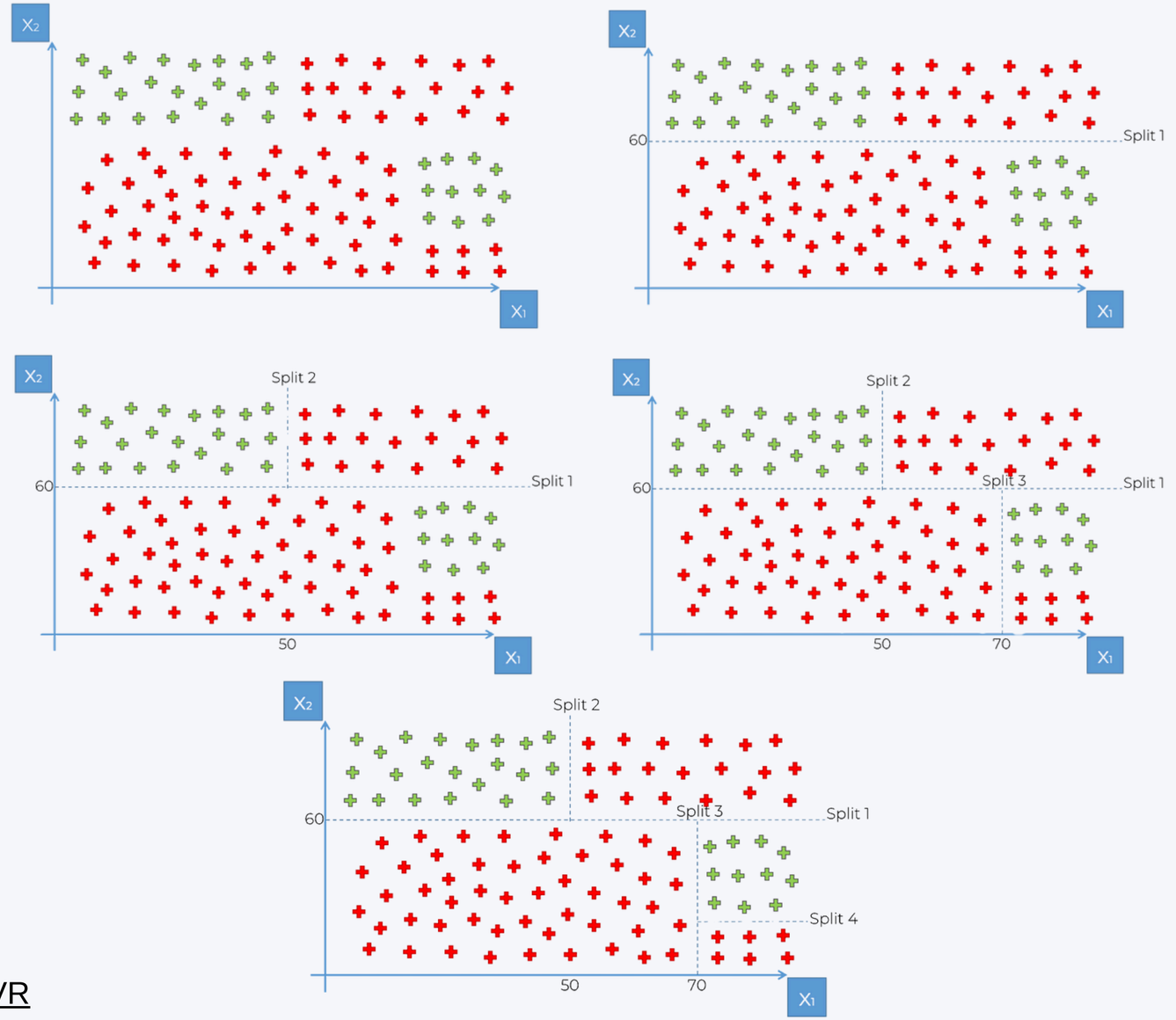
Explanation of Decision Tree Classification:

- The images illustrate how a decision tree classifier works by recursively splitting the data into smaller regions.
- Each split is made based on a feature that best separates the classes (red and green points).
- The first split (Split 1) separates based on $X_2 > 60$, dividing the data into two main groups.
- The second split (Split 2) further divides one of these groups based on $X_1 < 50$.
- Additional splits (Split 3, Split 4) continue until pure or nearly pure regions are formed.



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Decision Tree Classification

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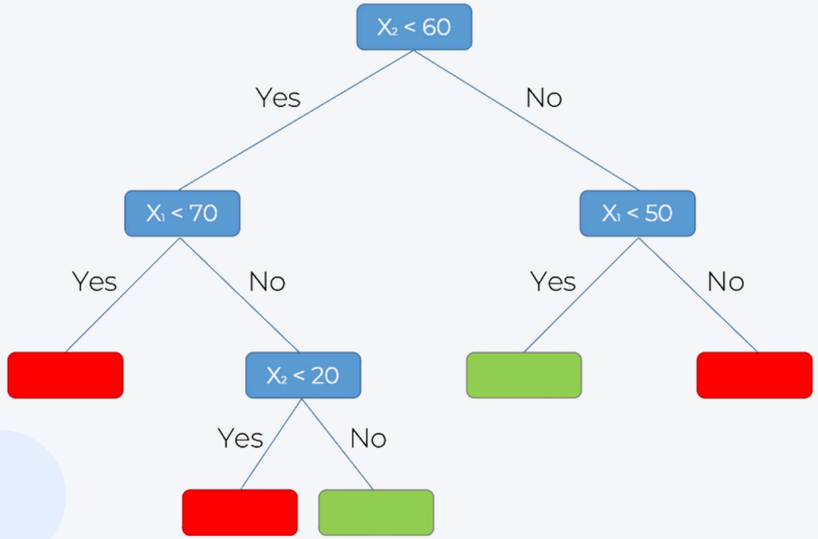
Explanation of Decision Tree Classification:

The tree chooses splits based on feature values that maximize class separation. This is done using:

- **Gini Impurity (default in CART trees):**
  - Measures how mixed a group is.
  - A lower Gini value means a purer split.

$$Gini = 1 - \sum P(i)^2$$



- **Entropy & Information Gain**
  - Entropy measures uncertainty in data:

$$Entropy = -\sum P(i) \log_2 P(i)$$

- **Information Gain calculates how much uncertainty is reduced by a split:**
  - The split that maximizes Information Gain is chosen.

$$IG = Entropy_{parent} - \sum \left(\frac{|Subset|}{|Parent|} \times Entropy_{subset} \right)$$

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Hands-On Code

Decision Tree Classification

Random Forest Classification

Random Forest Classification

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How does Random Forest do Classification?

Ensemble Learning

- **STEP 1:** Pick at random **K** data points from the Training set.
- **STEP 2:** Build the Decision Tree associated to these **K** data points.
- **STEP 3:** Choose the number **Ntree** of trees you want to build and repeat STEPS 1 & 2
- **STEP 4:** For a new data point, make each one of your **Ntree** trees predict the category to which the data points belongs, and assign the new data point to the category that wins the majority vote.

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Random Forest Classification