Anomaly Detection Algorithm: Building and Evaluating

Overview

In building an anomaly detection algorithm, we aim to identify anomalies in a dataset. The algorithm is based on the Gaussian distribution and involves the following steps:

Step 1: Choose Features

1. **Training Set (x1 through xm):**
   - Each example x has n features.
   - Example: In aircraft engine manufacturing, features could include heat and vibrations.

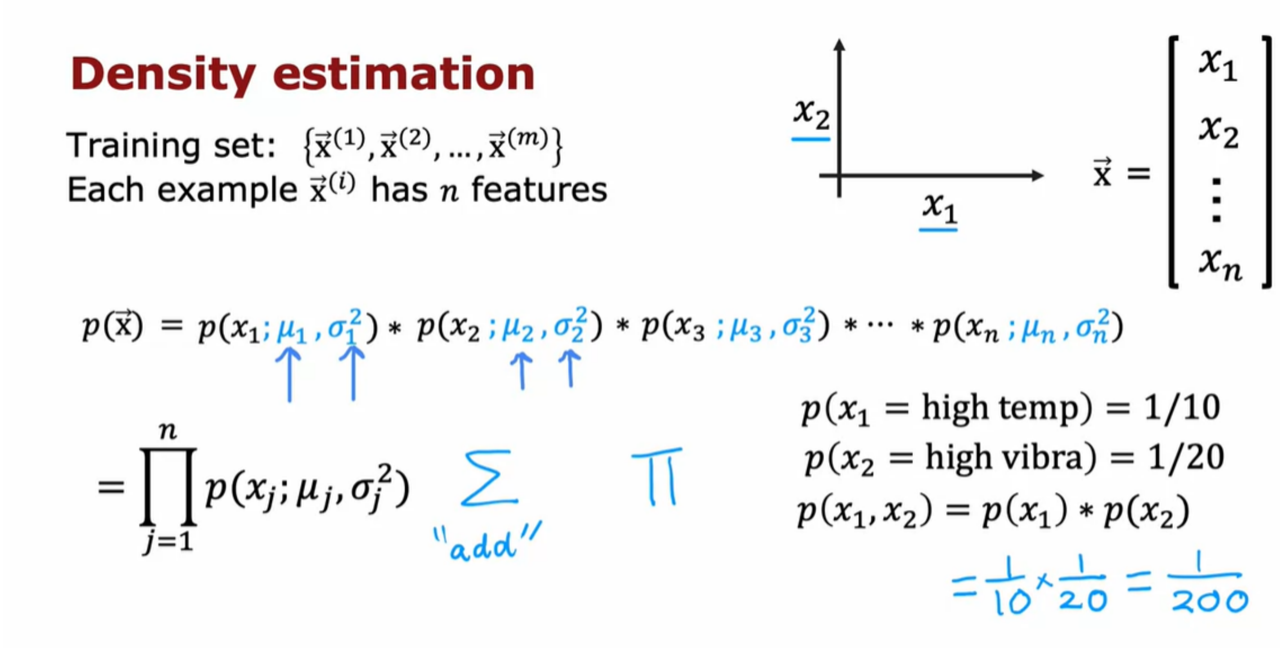
Step 2: Density Estimation

2. **Model for $p(x)$:**
   - Assume features are statistically independent (though the algorithm can work even if they aren't).
   - Probability $p(x)$ modeled as the product of individual feature probabilities:

$$p(x) = \prod_{j=1}^{n} p(x_j)$$

   - Each feature x_j is modeled by a Gaussian distribution:

$$p(x_j) = \frac{1}{\sqrt{2\pi}\sigma_j} e^{-\frac{(x_j - \mu_j)^2}{2\sigma_j^2}}$$



Step 3: Parameter Estimation

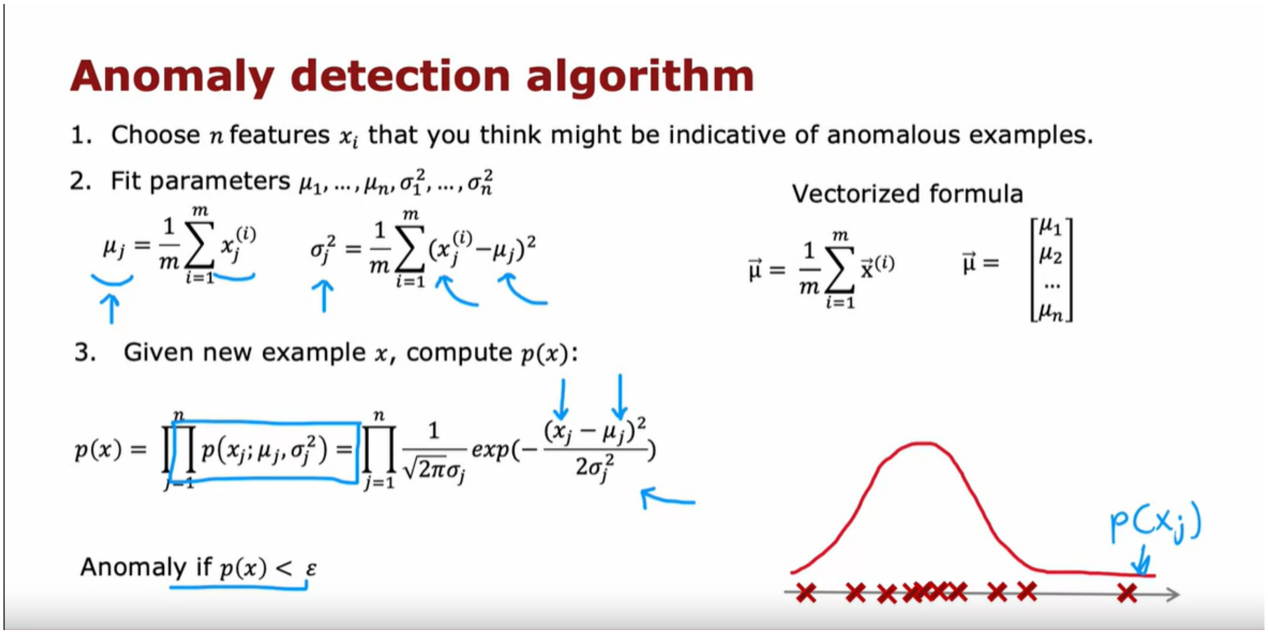
3. **Estimate Parameters (μ_j, σ_j^2):**
   - μ_j is the average of feature x_j over all examples.
   - σ_j^2 is the average squared difference between x_j and μ_j.

$$\mu_j = \frac{1}{m} \sum_{i=1}^{m} x_j^{(i)}$$

$$\sigma_j^2 = \frac{1}{m} \sum_{i=1}^{m} (x_j^{(i)} - \mu_j)^2$$

Step 4: Anomaly Detection

4. **Decision Rule:**
   - Given a new example x_{test}:
     - Compute $p(x_{\text{test}})$ using the product of individual feature probabilities.
     - If $p(x_{\text{test}}) < \epsilon$, flag as an anomaly.



Parameter Choices

- **Choosing Features:**
  - Select features believed to indicate anomalous behavior.
- **Choosing ϵ:**
  - ϵ is a threshold to determine when an example is flagged as anomalous.
  - Typically chosen based on cross-validation on a labeled validation set.

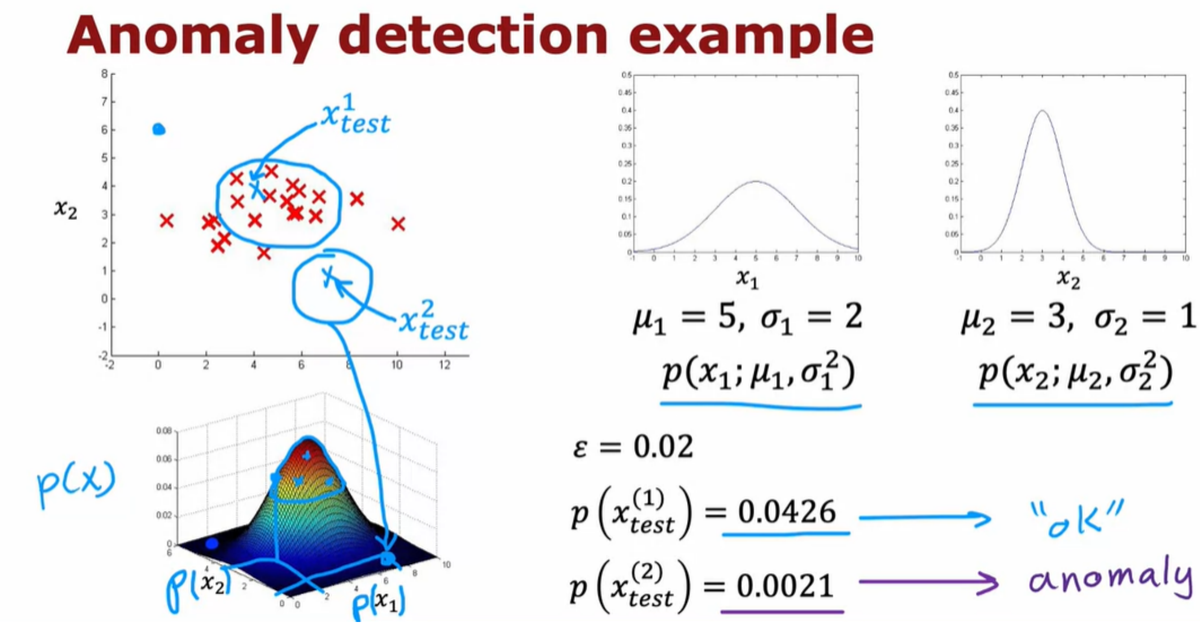
Evaluation

- **How to know if the algorithm is working well?**
  - Use labeled data (with anomalies marked) to evaluate algorithm performance.
  - Metrics:
    - True Positive (TP), False Positive (FP), False Negative (FN), True Negative (TN).
    - Precision, Recall, F1 Score.
    - Adjust ϵ to balance precision and recall based on application requirements.

Example Evaluation

- **Parameters:**
  - $\epsilon = 0.02$
- **Test Examples:**
  - $x_{\text{test}_1}: p(x_{\text{test}_1}) \approx 0.4$ (Not flagged as anomaly)
  - $x_{\text{test}_2}: p(x_{\text{test}_2}) \approx 0.0021$ (Flagged as anomaly)

- **Conclusion:**
  - Algorithm correctly identifies x_{test_2} as an anomaly and ignores x_{test_1}.



Next Steps

In the next video, we'll explore parameter tuning, choosing an appropriate ϵ, and refining the anomaly detection system for optimal performance.