



PIF
صندوق
الاستثمارات العامة



LEVEL 1: Model Training and Performance Evaluation

Day 3

COURSE OUTLINE

- Feature Engineering
- Feature Selection
- Model Training
- Bias–Variance Trade-Off

Learning Objectives

- Understand the role of feature engineering in improving model performance.
- Apply basic techniques for handling missing values, outliers, and scaling.
- Select important features using filter, wrapper, and embedded methods.
- Train machine learning models and evaluate their performance.
- Identify underfitting vs overfitting using the bias–variance trade-off.

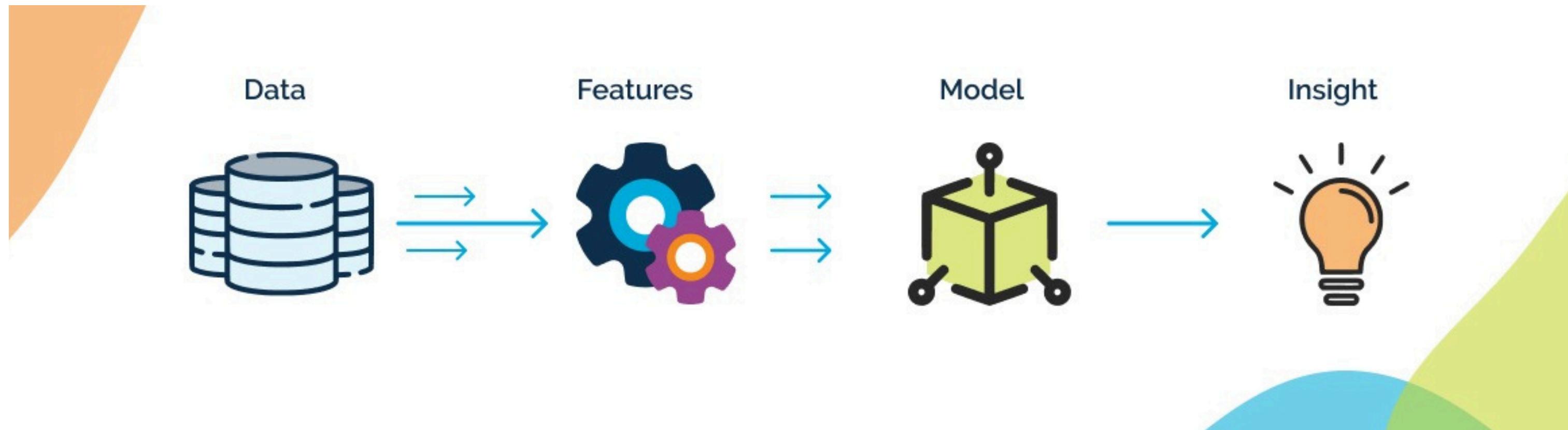
Feature Engineering

What is a
Feature



Feature Engineering

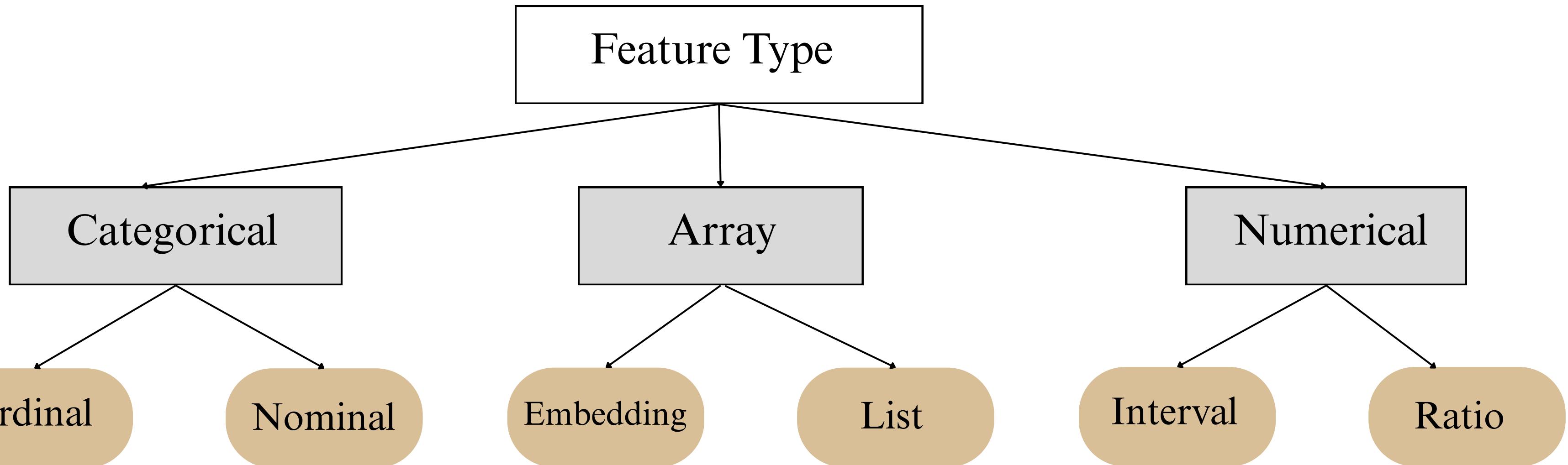
- A feature is a measurable attribute of the data that a machine learning model uses to learn patterns and make predictions.



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Feature Engineering



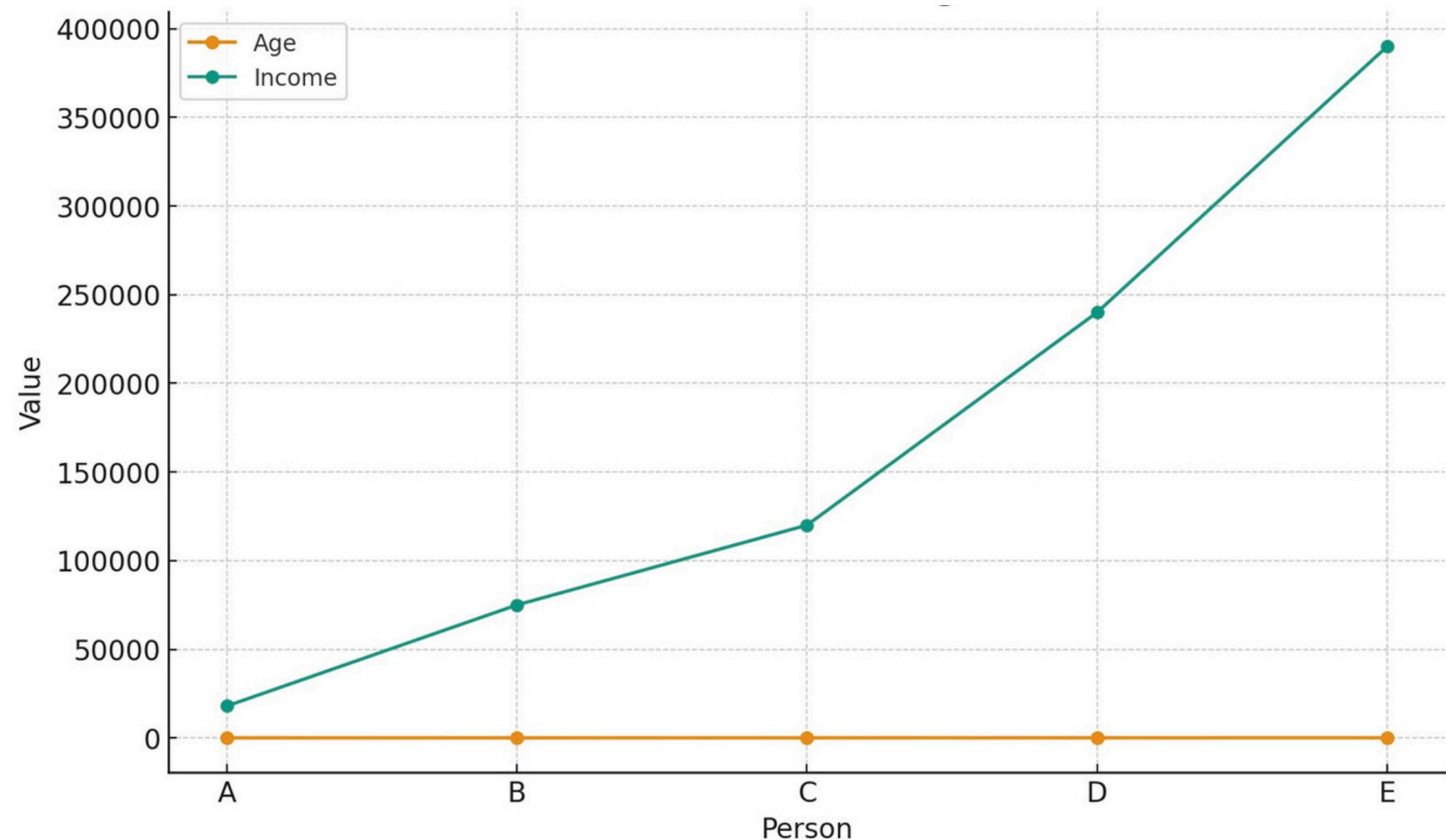
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Feature Engineering

- Features come in different scales.

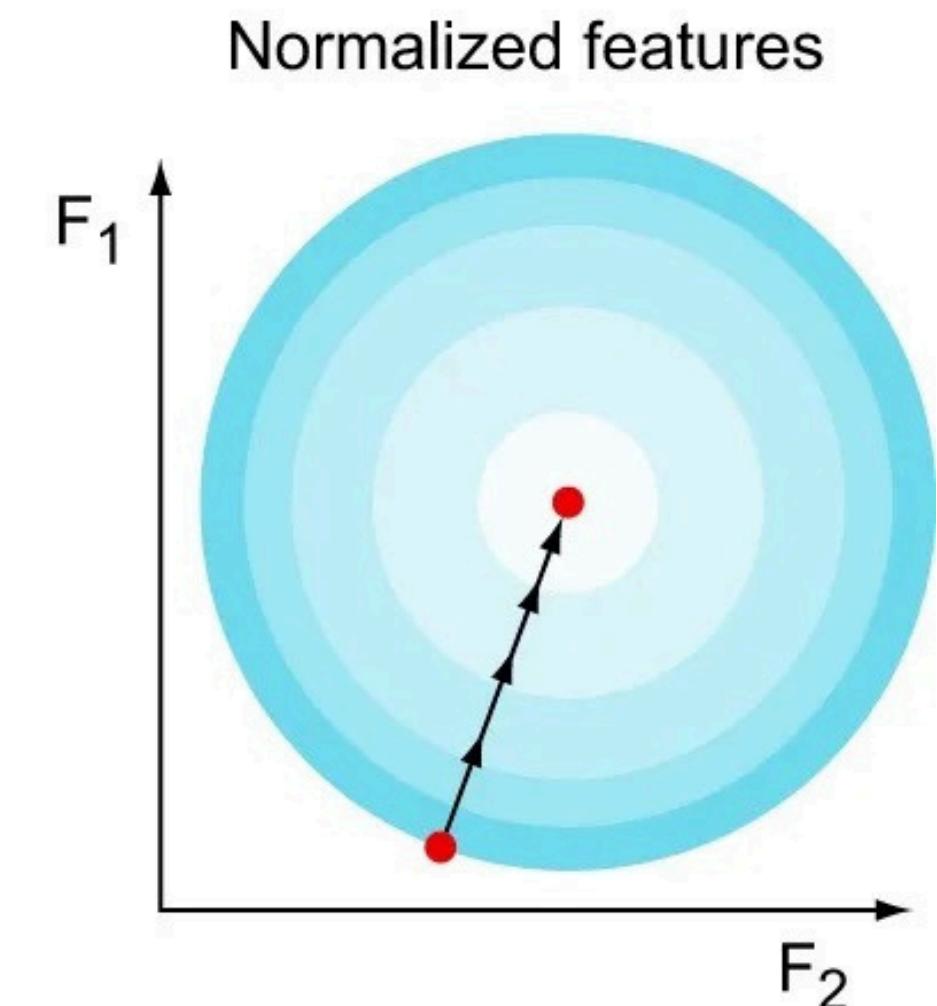
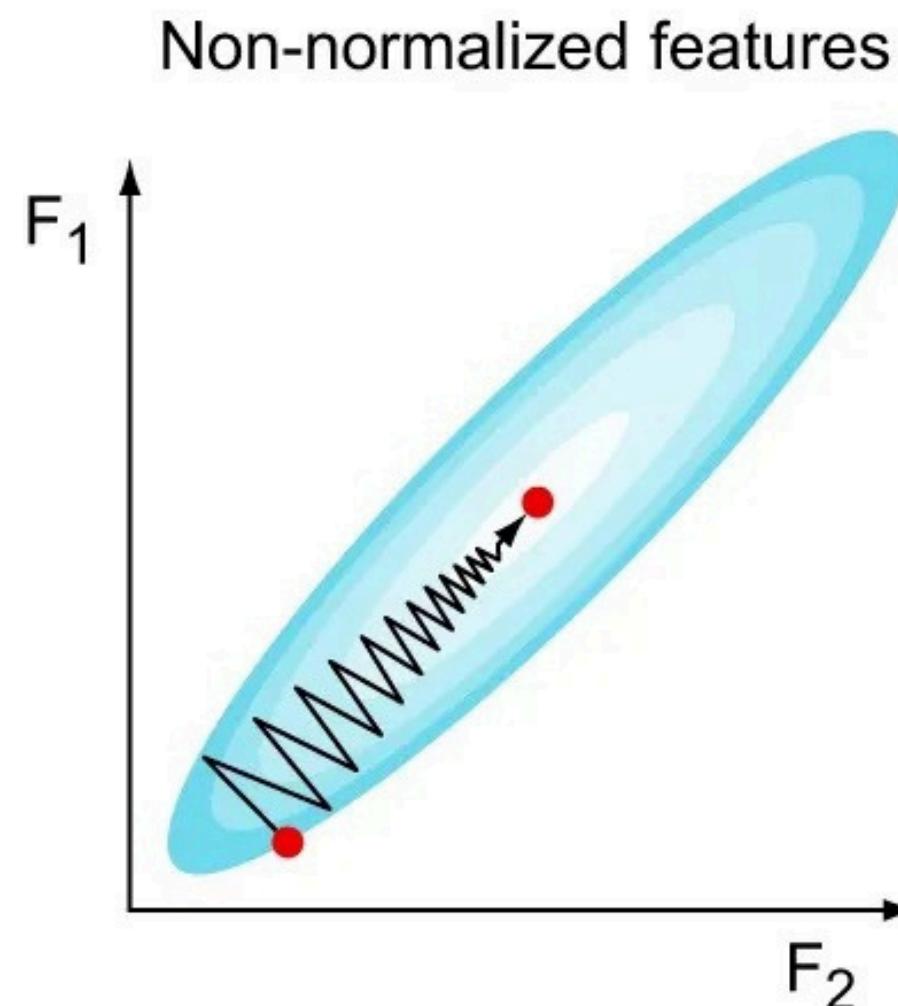
Person	Age	Income
A	22	18,000
B	30	75,000
C	41	120,000
D	55	240,000
E	63	390,000



Feature Engineering

- Features come in different scales.

Person	Age	Income
A	22	18,000
B	30	75,000
C	41	120,000
D	55	240,000
E	63	390,000



Feature Engineering

Feature Scaling

Normalization

$$\frac{x - \min}{\max - \min}$$

Standardization

$$\frac{x - \mu}{\sigma}$$

Feature Engineering

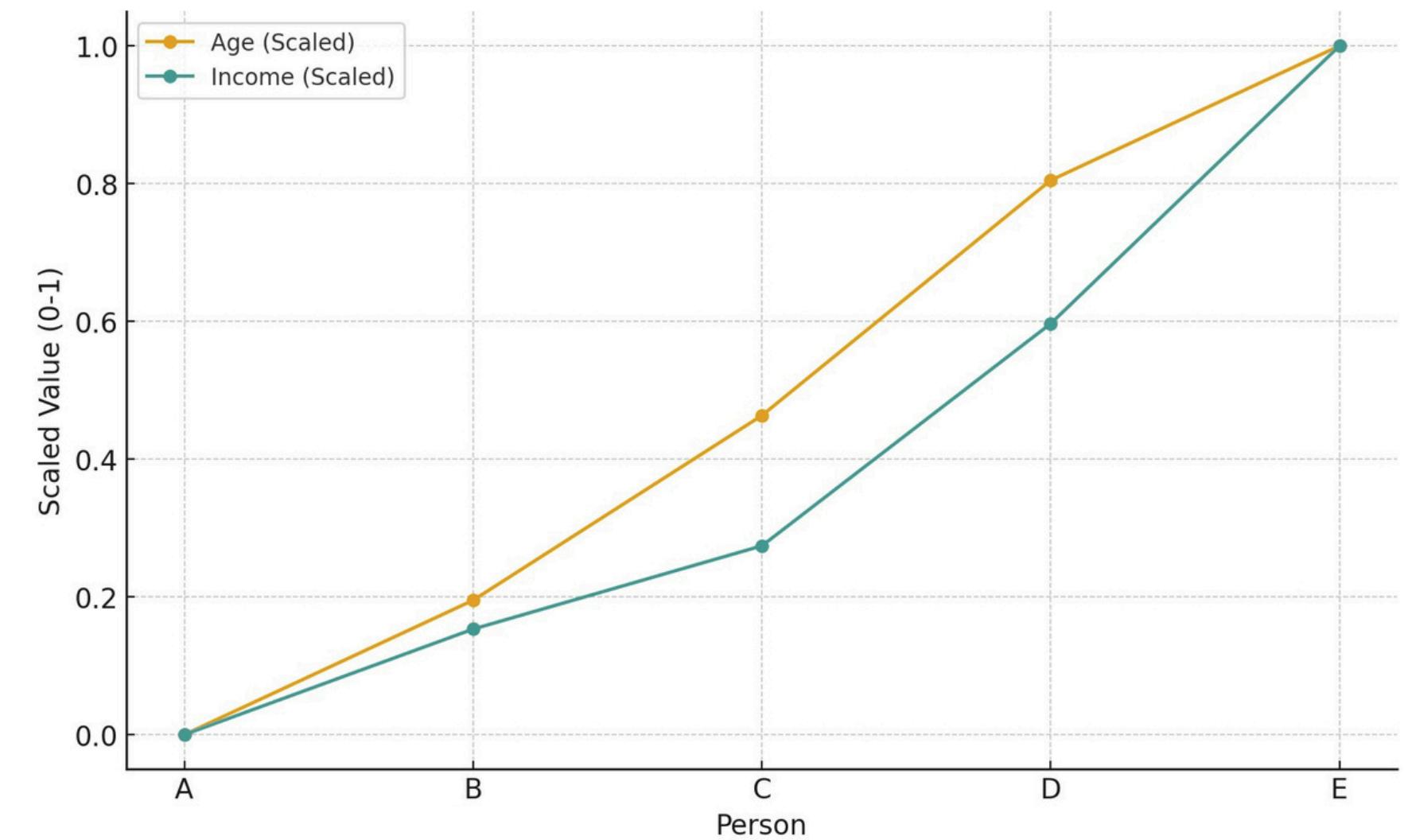
Person	Age	Income
A	0	0
B	0.18	0.15
C	0.38	0.28
D	0.66	0.61
E	0.86	1

$$\frac{x - \min}{\max - \min}$$

Feature Engineering

Person	Age	Income
A	0	0
B	0.18	0.15
C	0.38	0.28
D	0.66	0.61
E	0.86	1

$$\frac{x - \min}{\max - \min}$$



Feature Engineering

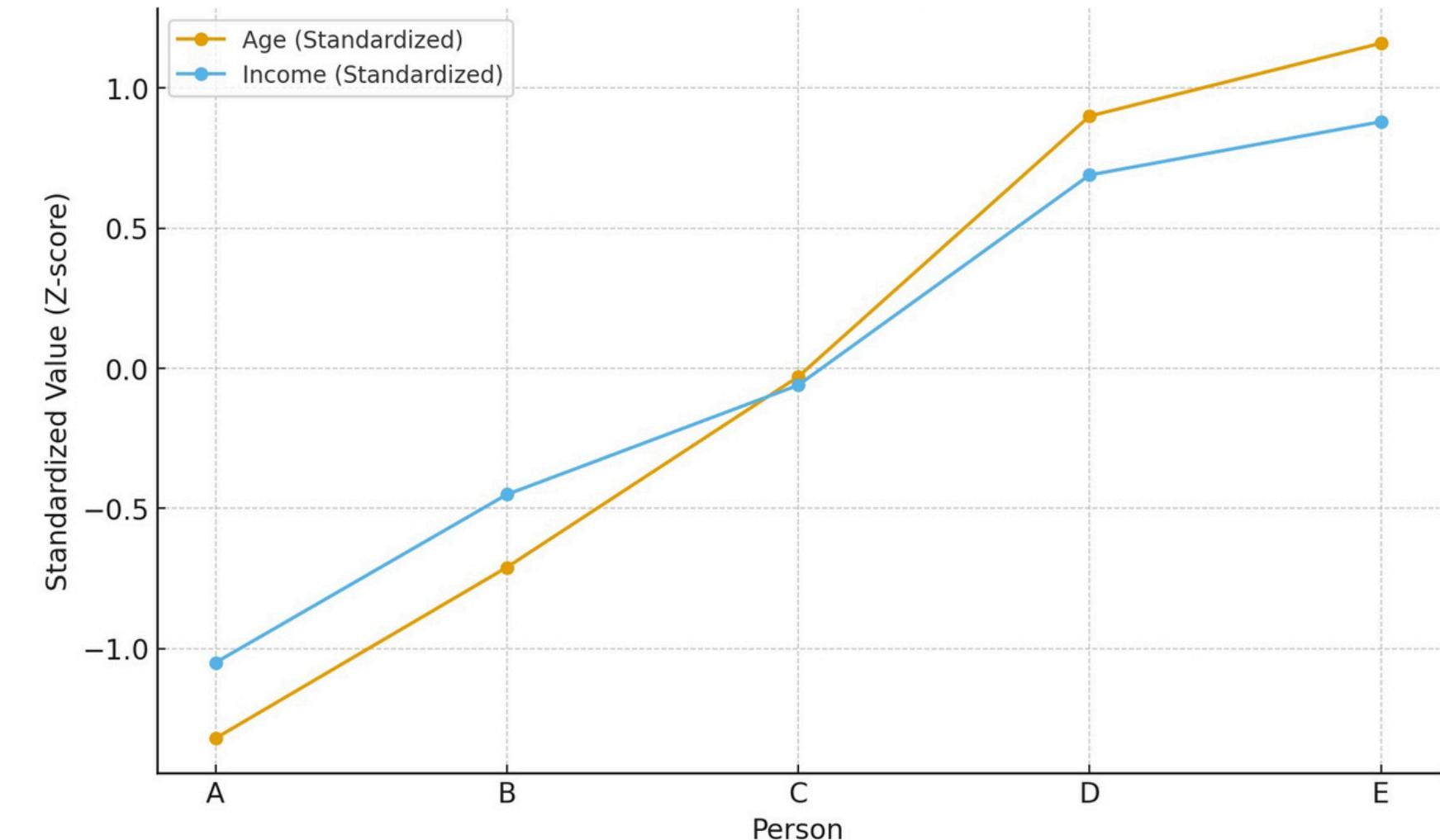
Person	Age	Income
A	-1.32	-1.05
B	-0.71	-0.45
C	-0.03	-0.06
D	0.9	0.69
E	1.16	0.88

$$\frac{x - \mu}{\sigma}$$

Feature Engineering

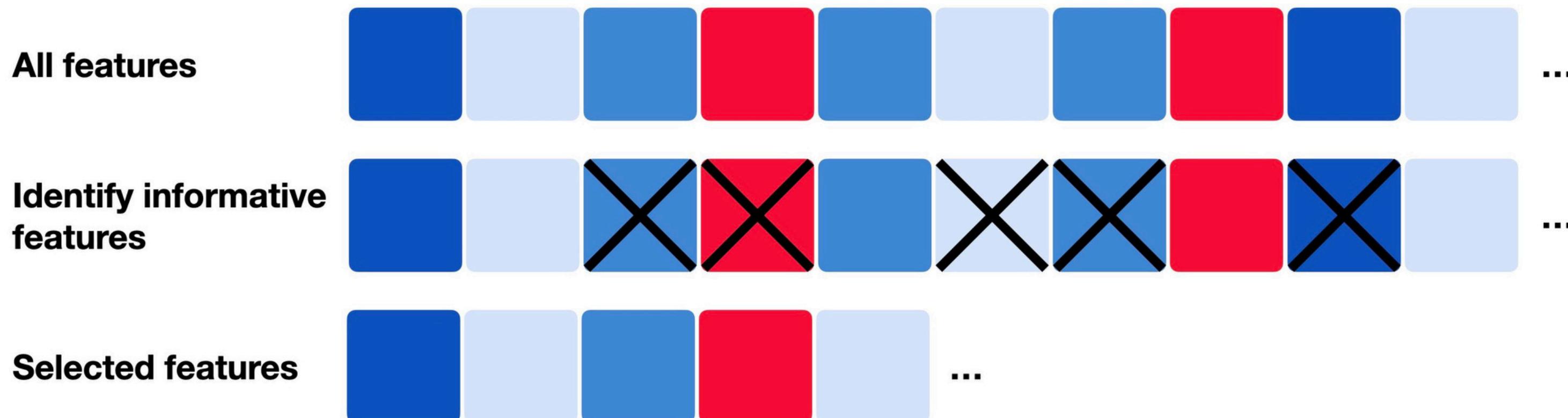
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$$\frac{x - \mu}{\sigma}$$



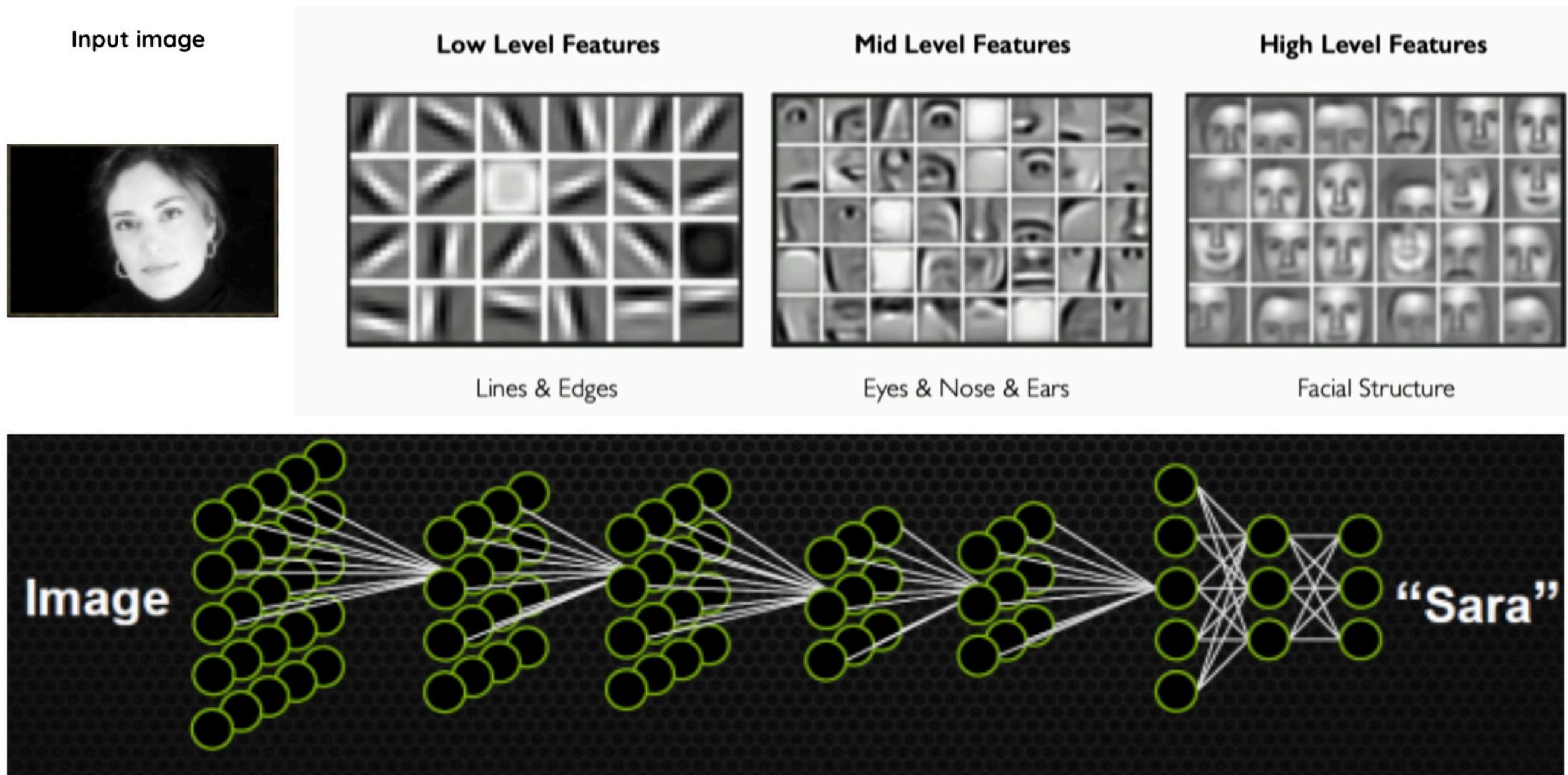
Feature Engineering

- Not all features contribute meaningfully to model performance.



Feature Engineering

- In deep learning, features are learned automatically from raw data.



Model Training

Model Training

- Home Prices Dataset

Size (m ²)	Price (SAR)
120	950,000
180	1,350,000
140	980,000
220	1,850,000
160	1,200,000
200	1,700,000
95	720,000
250	2,300,000
130	1,020,000
175	1,450,000

- The goal of machine learning is to perform well on unseen data.

Model Training

- Home Prices Dataset

Size (m ²)	Price (SAR)
120	950,000
180	1,350,000
140	980,000
220	1,850,000
160	1,200,000
200	1,700,000
95	720,000
250	2,300,000
130	1,020,000
175	1,450,000

- Dataset size= 100



Train

Model Training

- Home Prices Dataset

Size (m ²)	Price (SAR)
120	950,000
180	1,350,000
140	980,000
220	1,850,000
160	1,200,000
200	1,700,000
95	720,000
250	2,300,000
130	1,020,000
175	1,450,000

{

Train set

}

Test set

Model Training

- Home Prices Dataset

Size (m ²)	Price (SAR)
120	950,000
180	1,350,000
140	980,000
220	1,850,000
160	1,200,000
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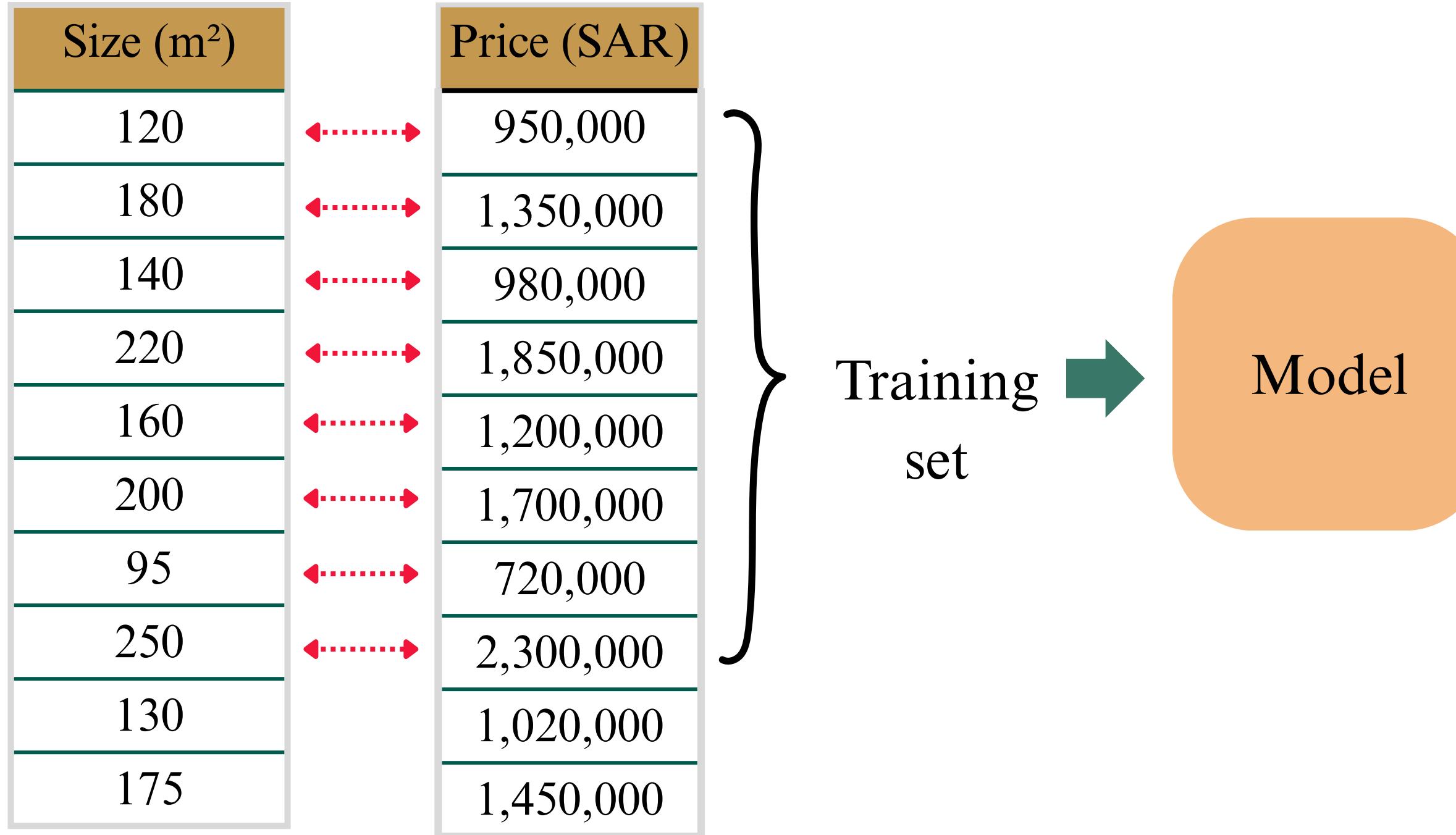
Train set

}

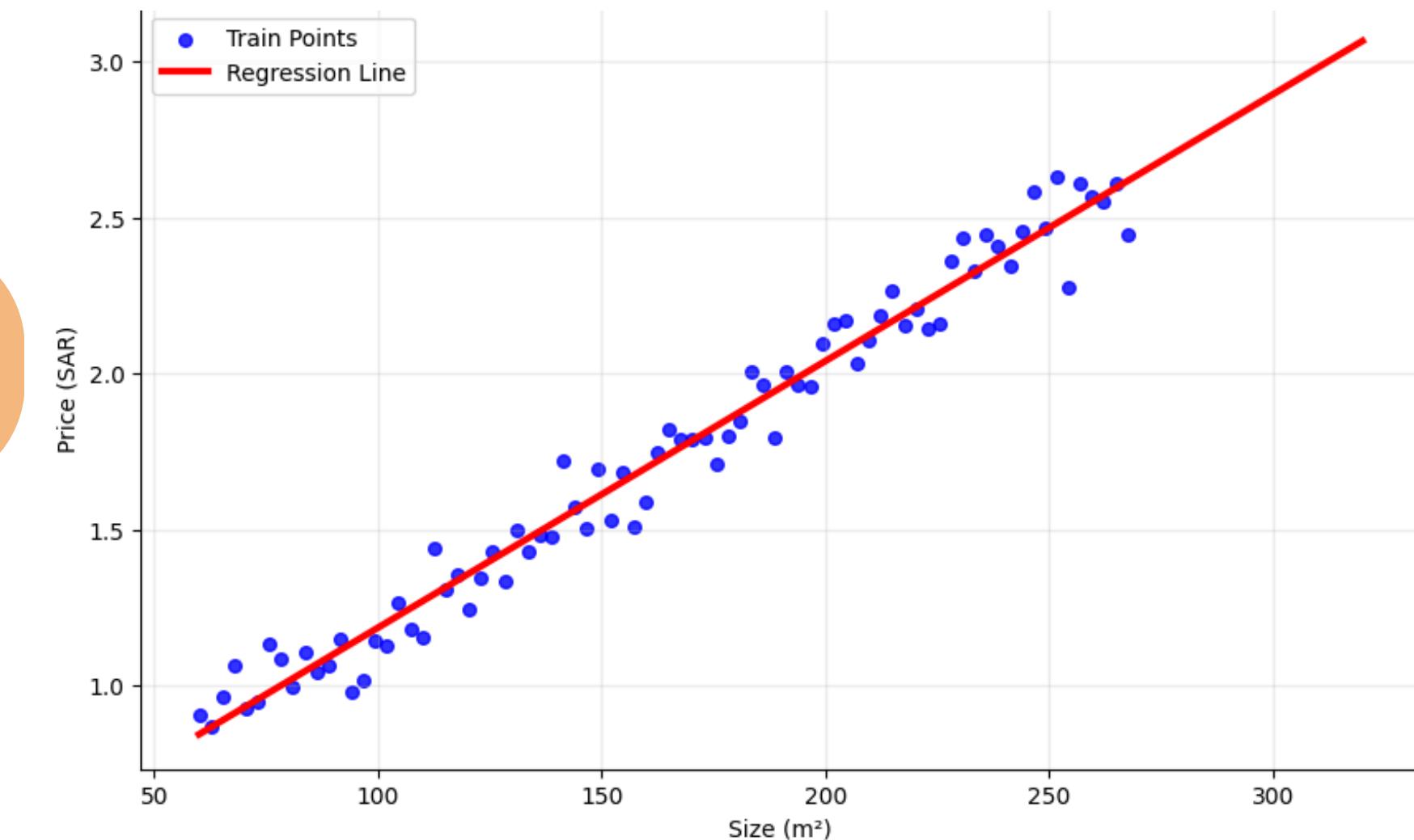
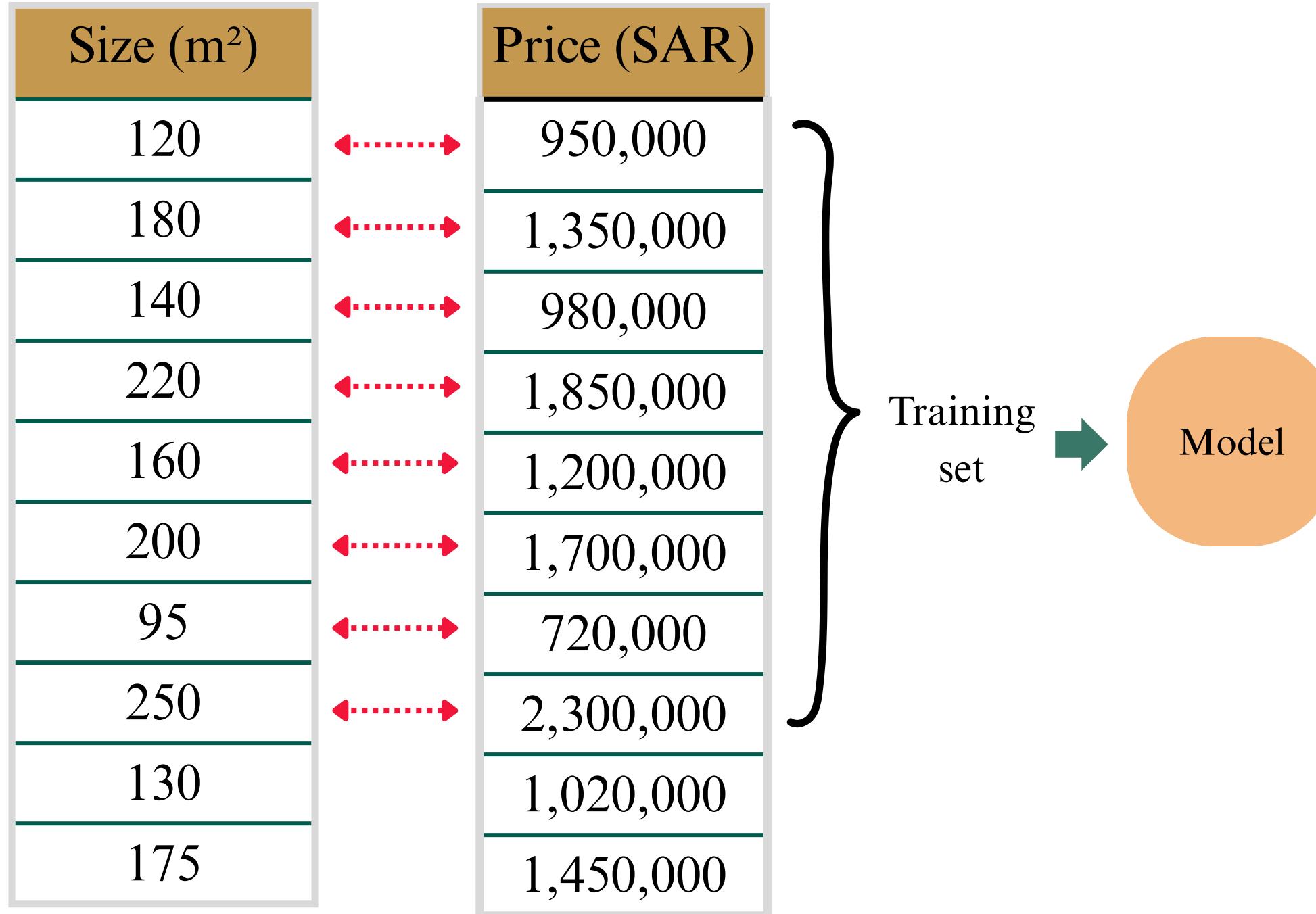
Test set

- The test set evaluates the model on unseen data.

Model Training



Model Training



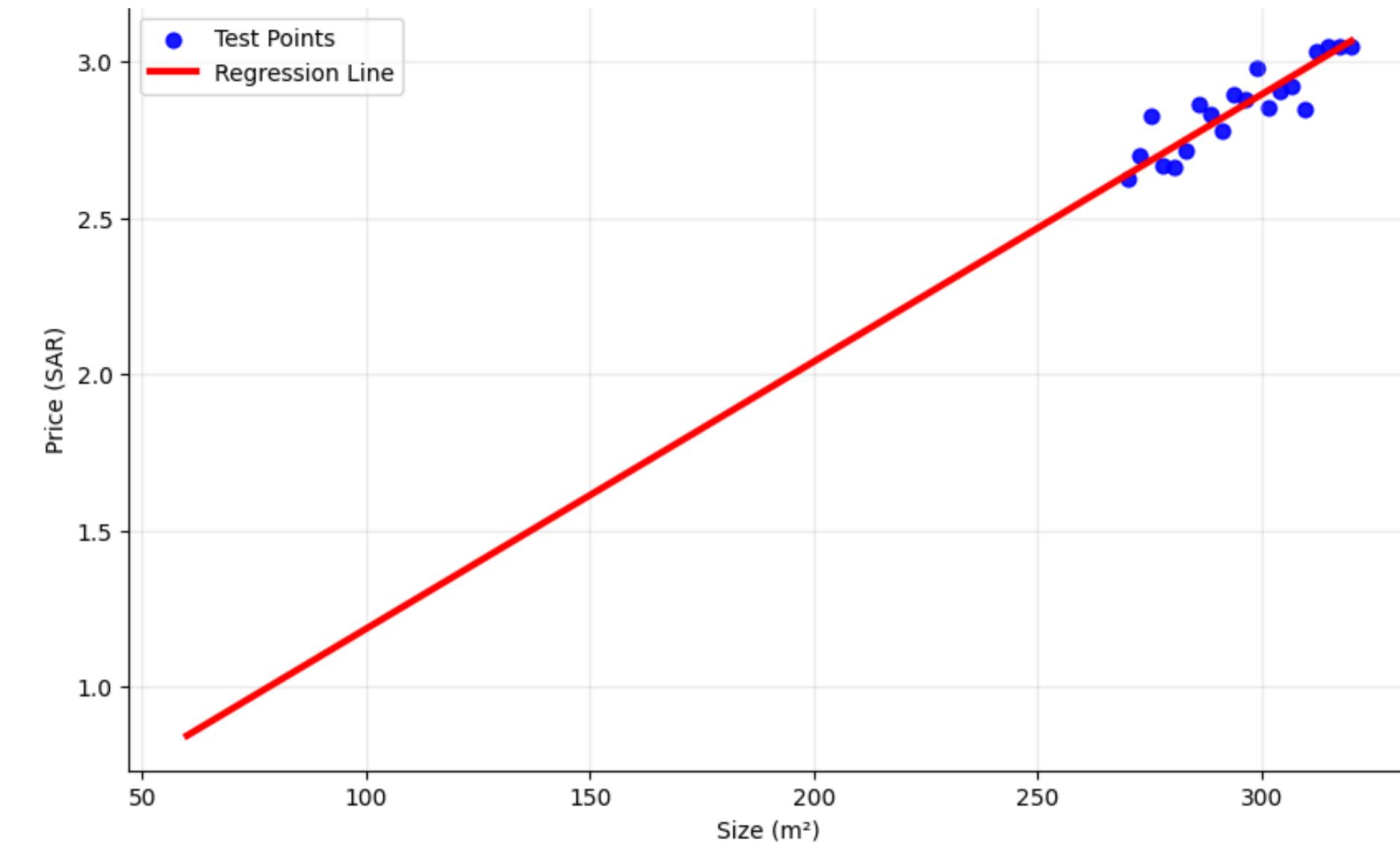
Model Training

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120	950,000
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200	1,700,000
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175	1,450,000

Model



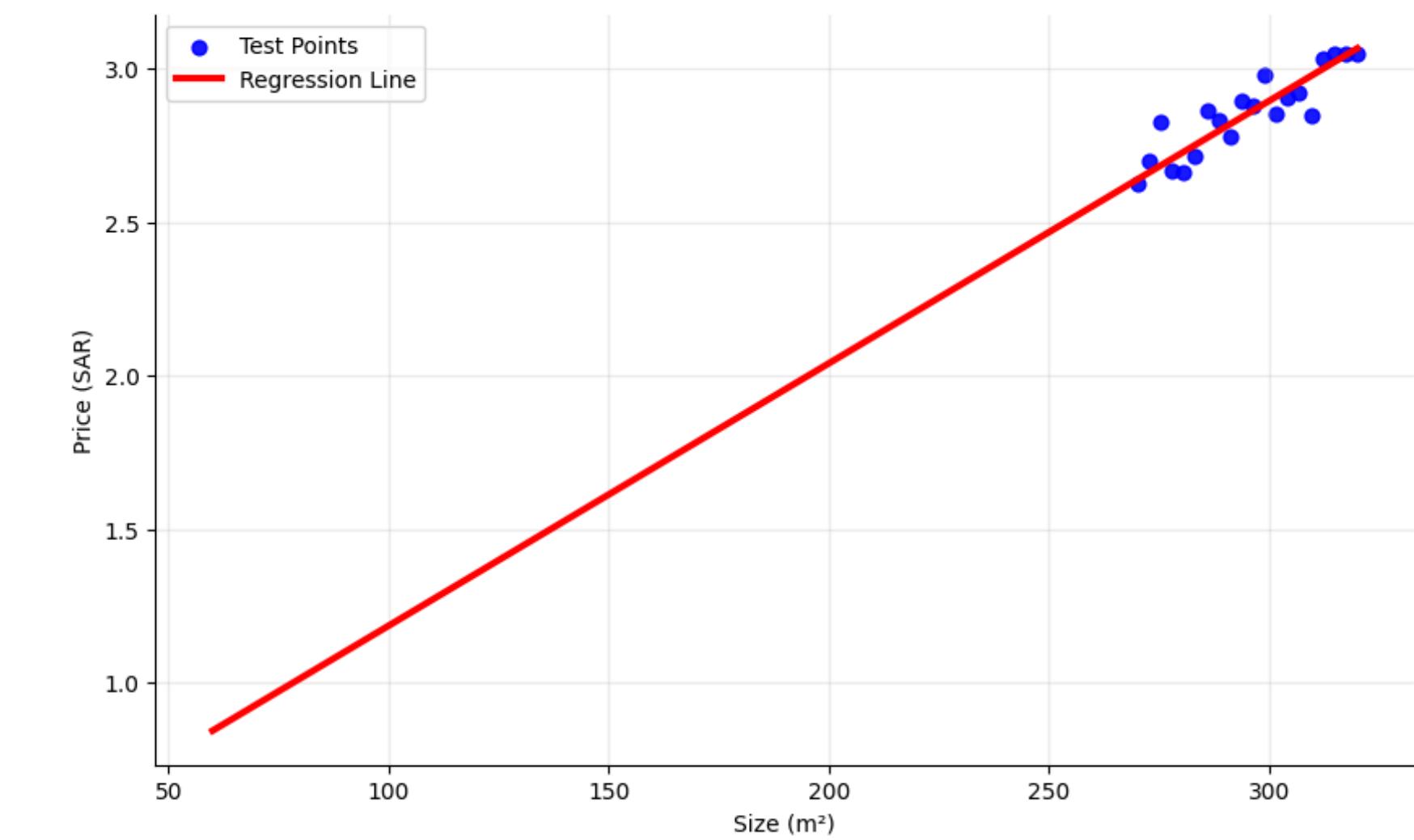
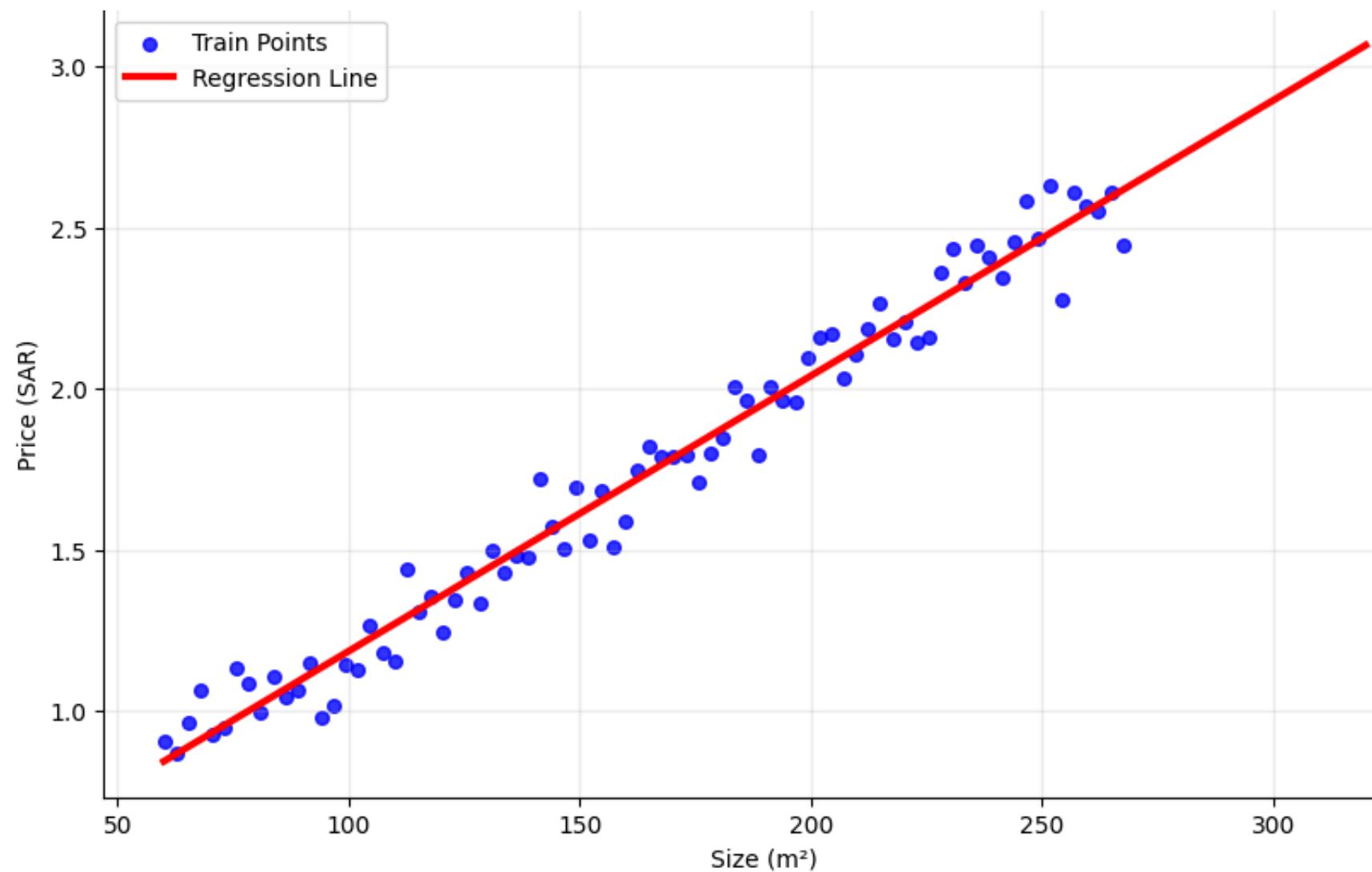
Testing set



Model Training

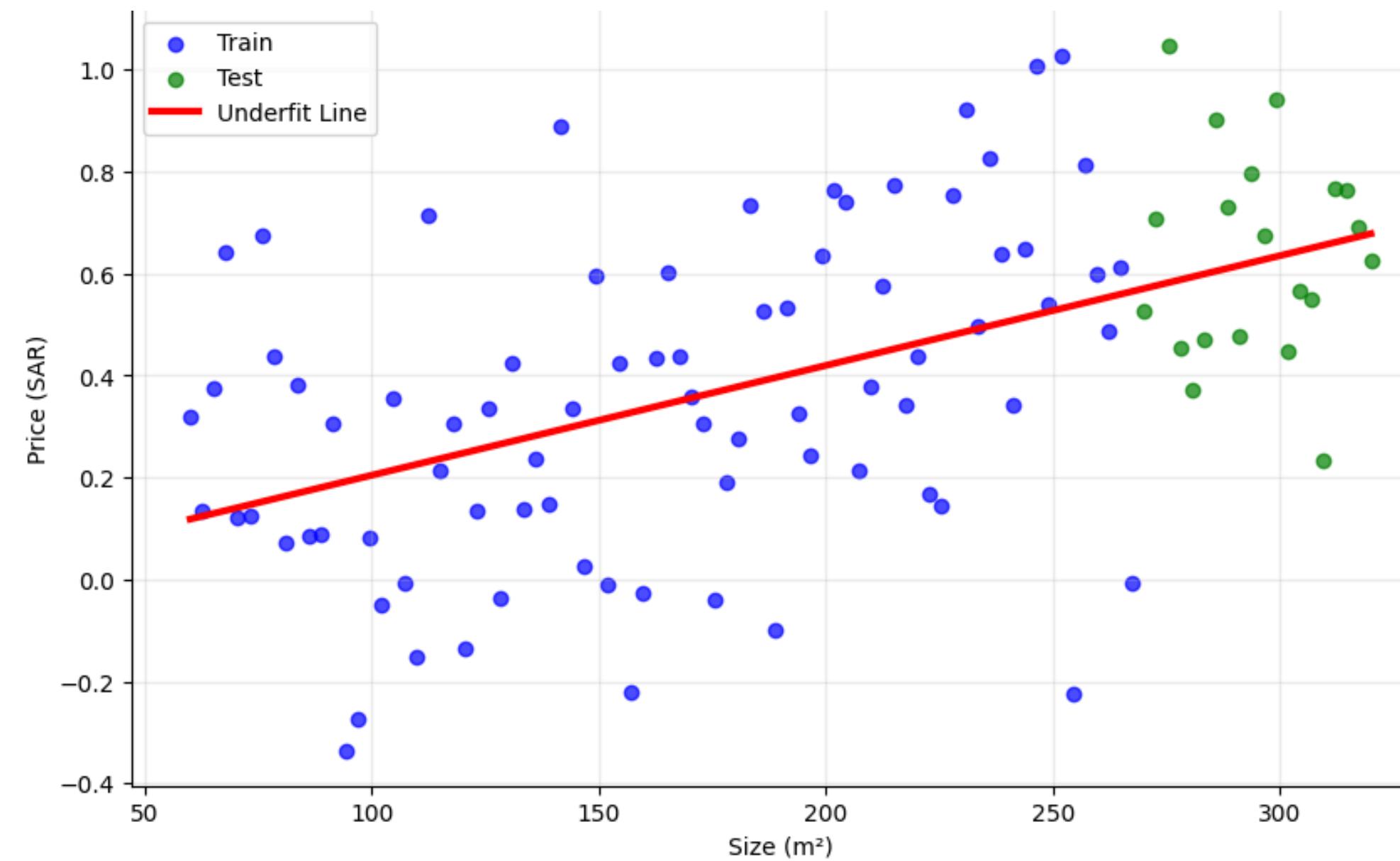
- Model Performance

just fit



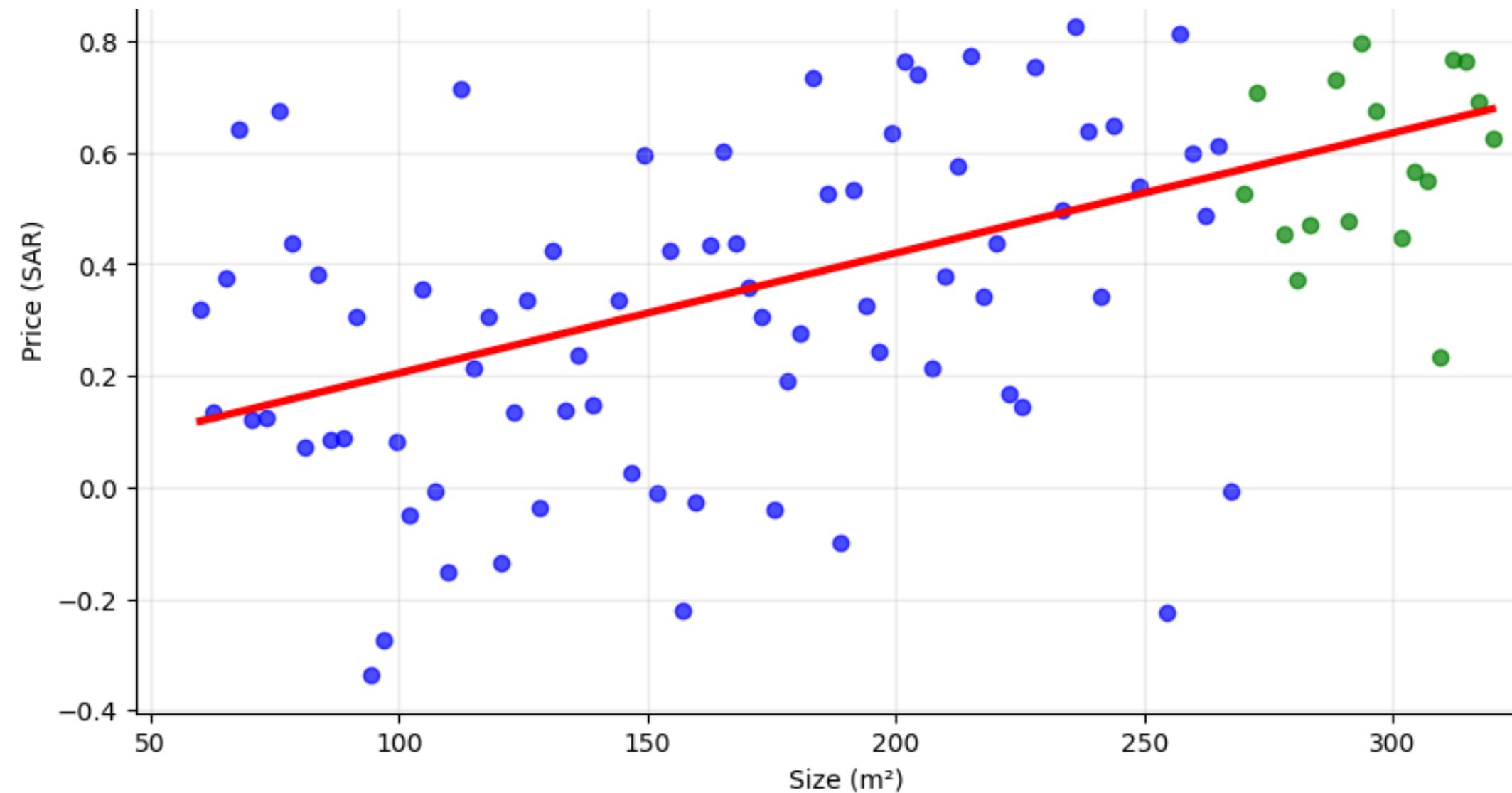
Model Training

Poor train + poor test = ?



Model Training

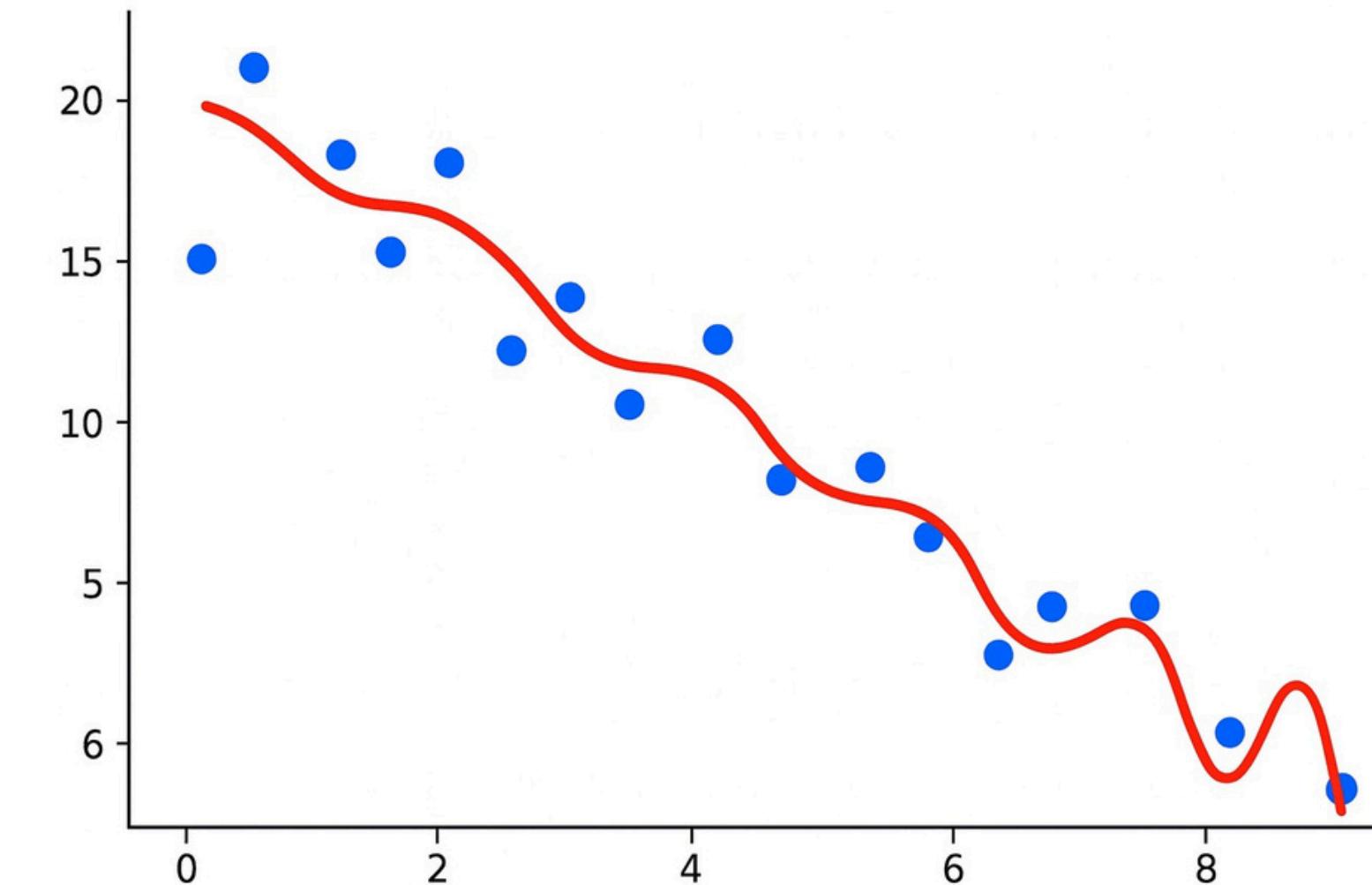
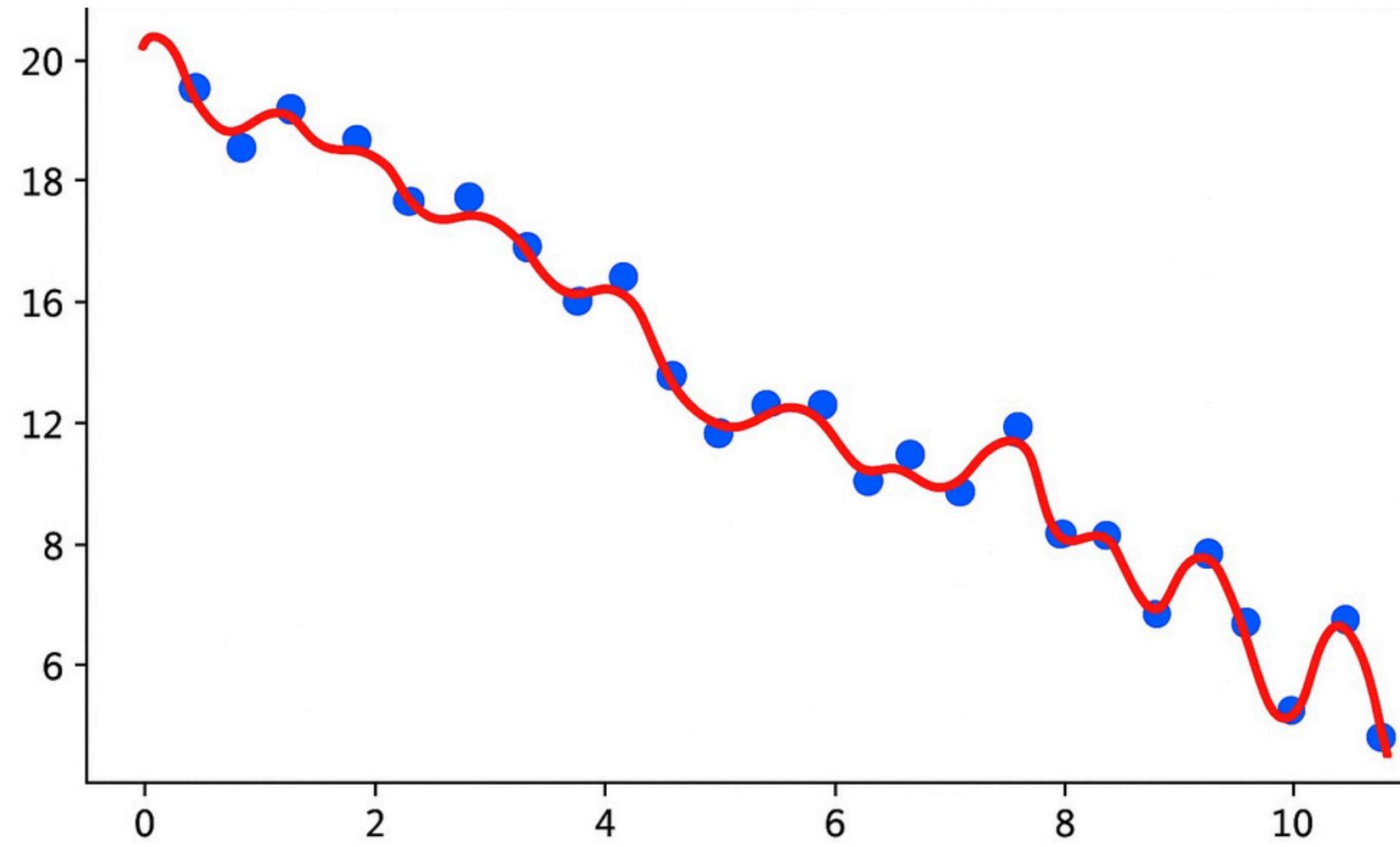
Poor train + poor test = **Underfitting**



Underfitting → **High Bias**

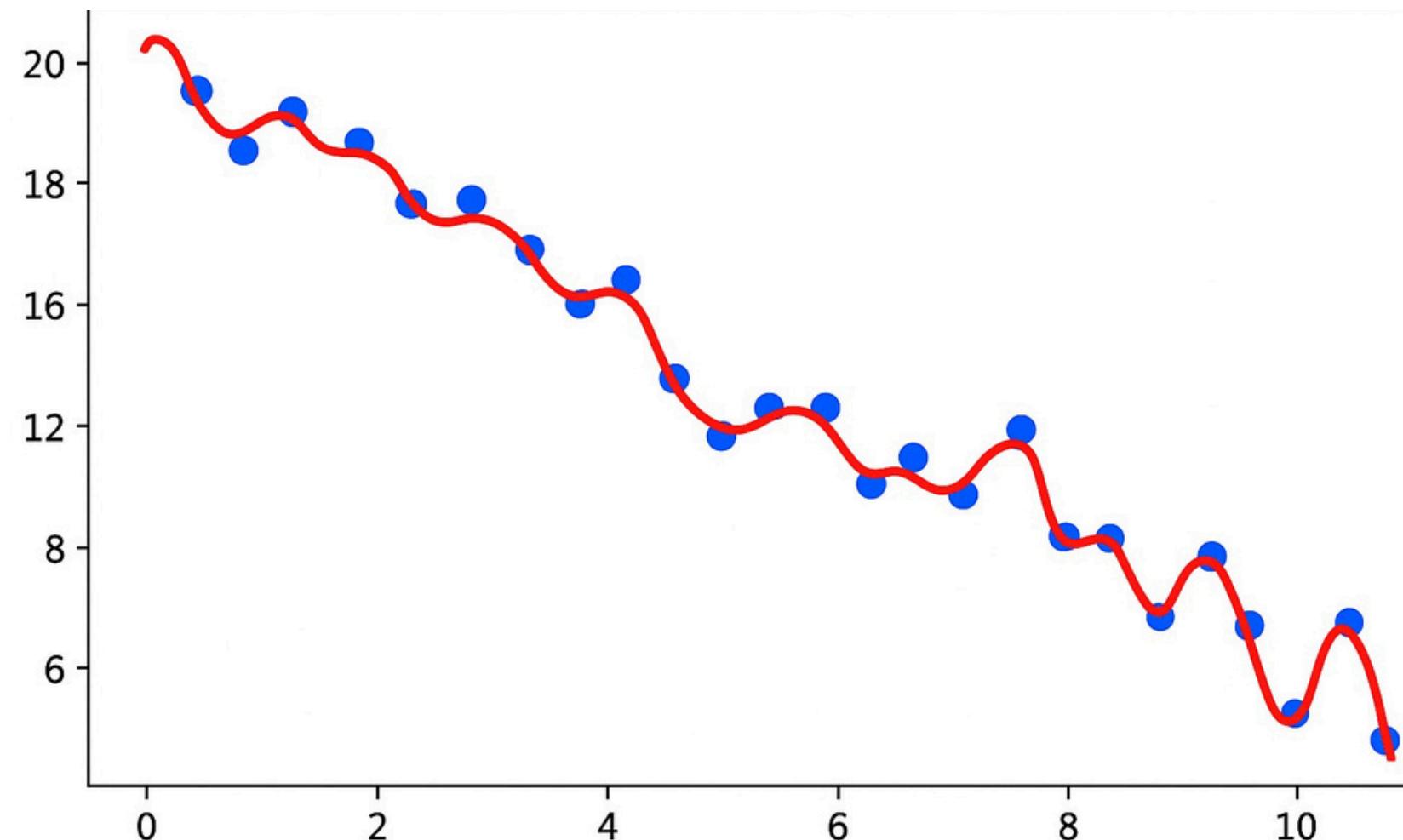
Model Training

Good train + poor test = ?

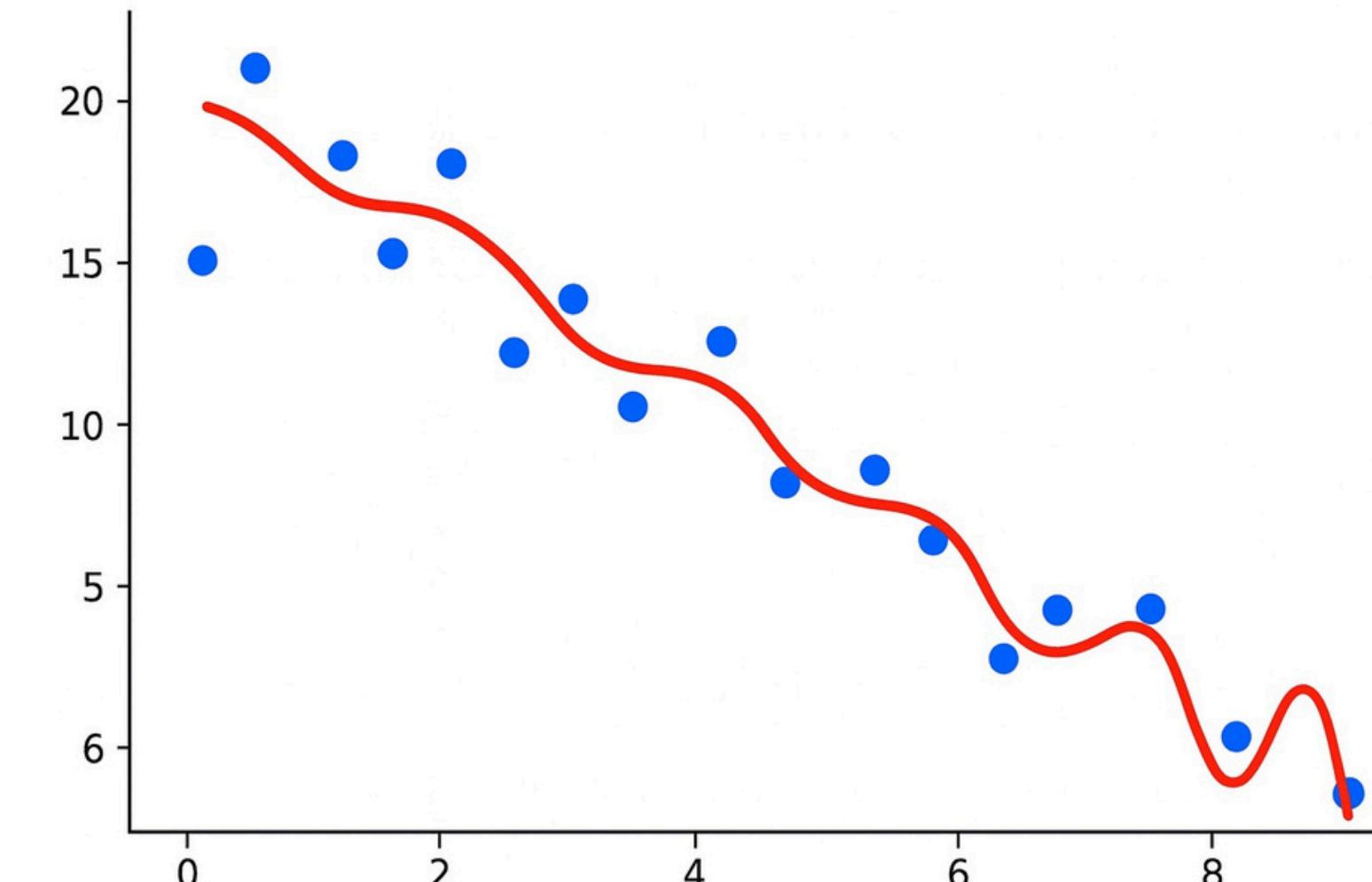


Model Training

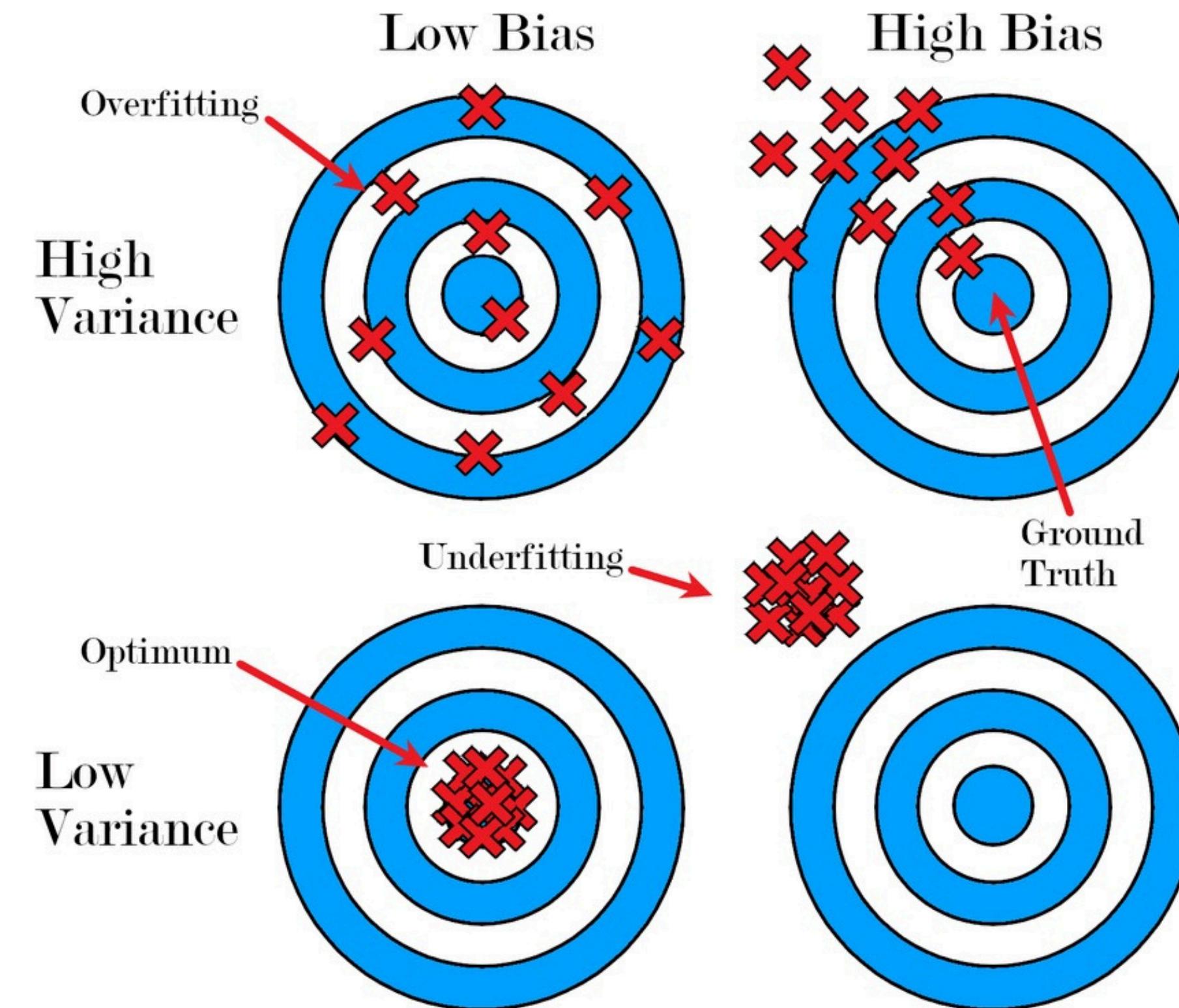
Good train + poor test = Overfitting



Overfitting → High Variance



Model Training



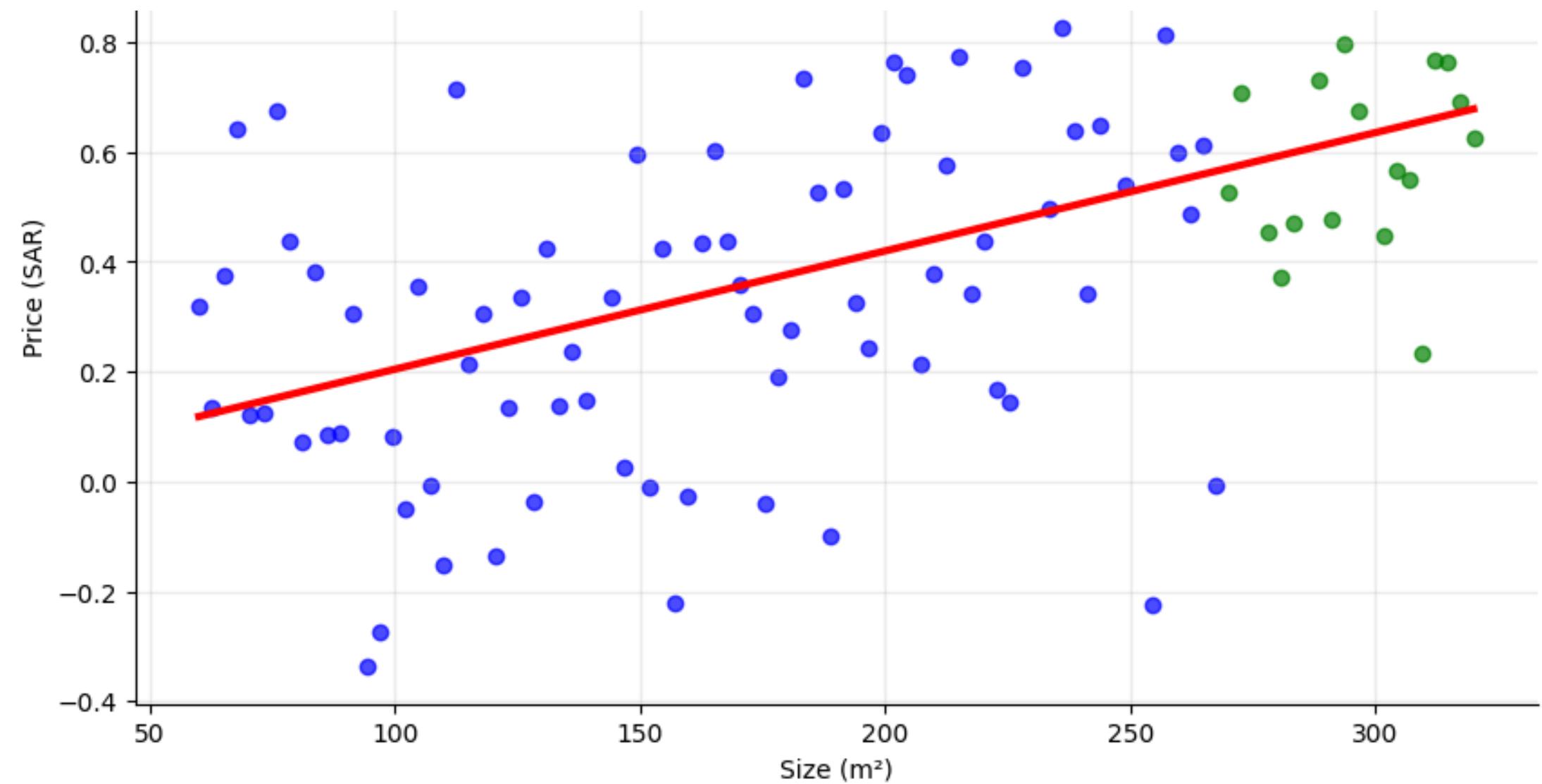
How to Improve a
Model's Performance



Model Training

Poor train + poor test = Underfitting

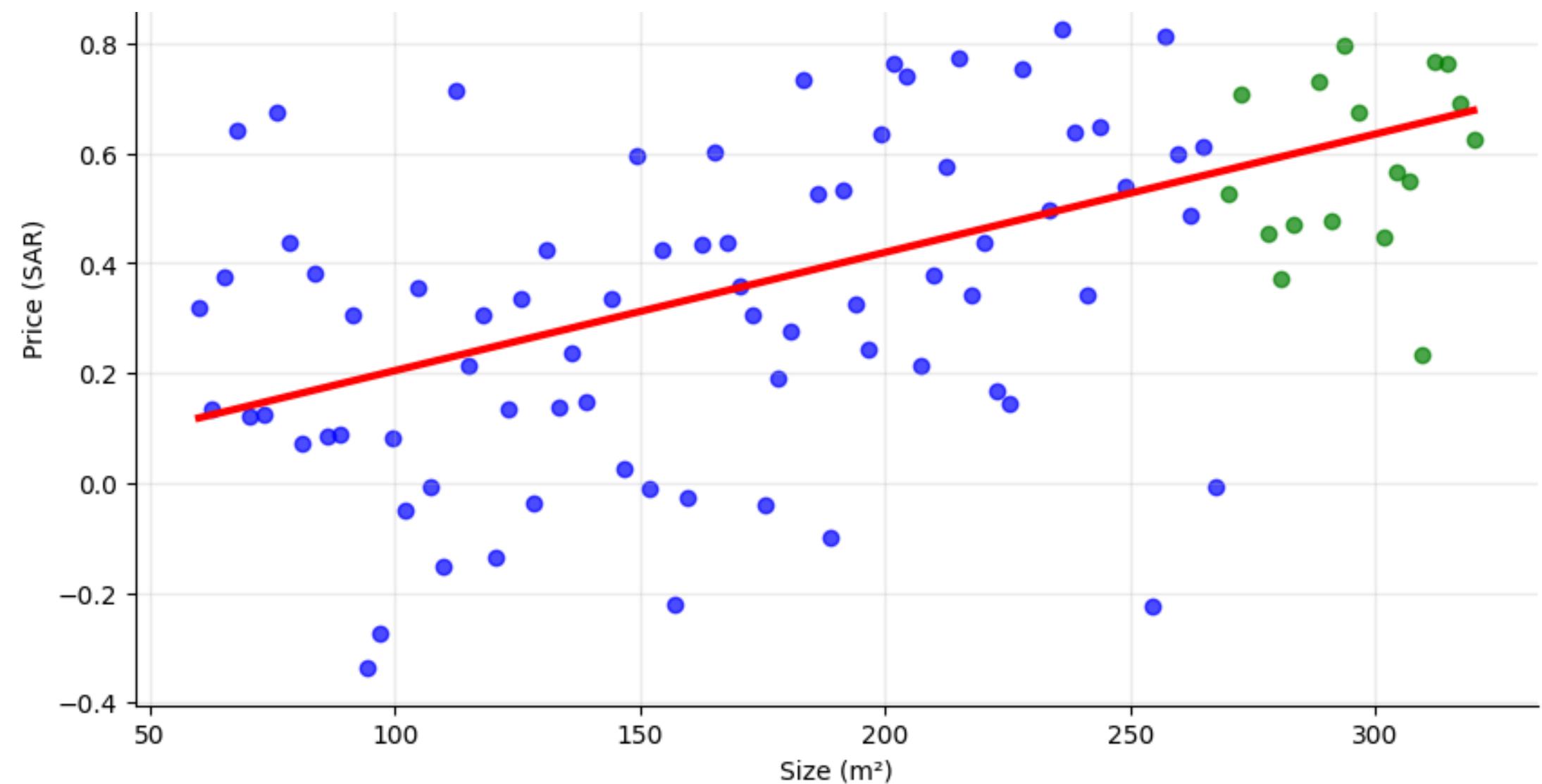
- Add more features



Model Training

Poor train + poor test = Underfitting

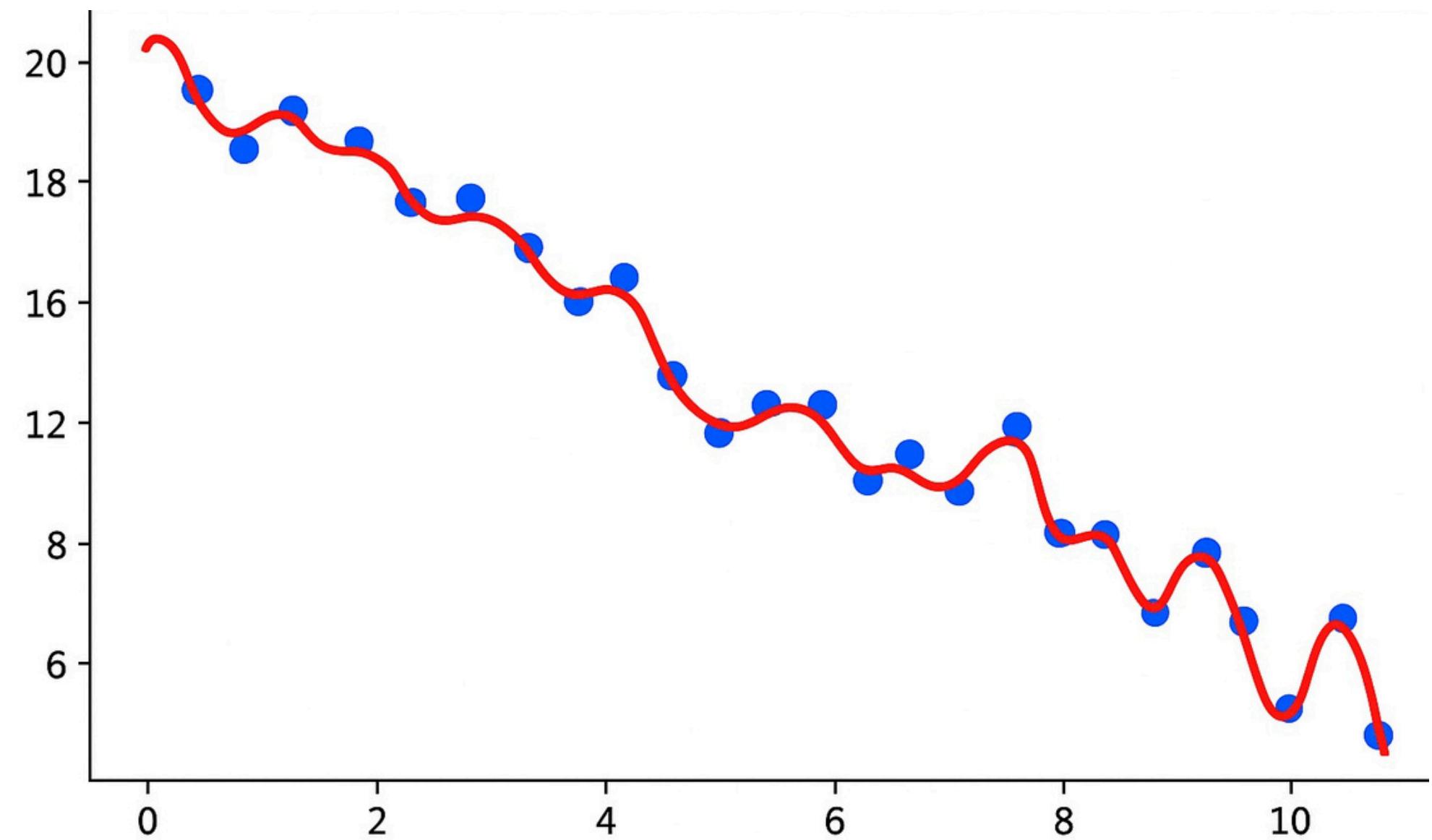
- Add more features
- Add polynomial features



Model Training

Good train + poor test = **Overfitting**

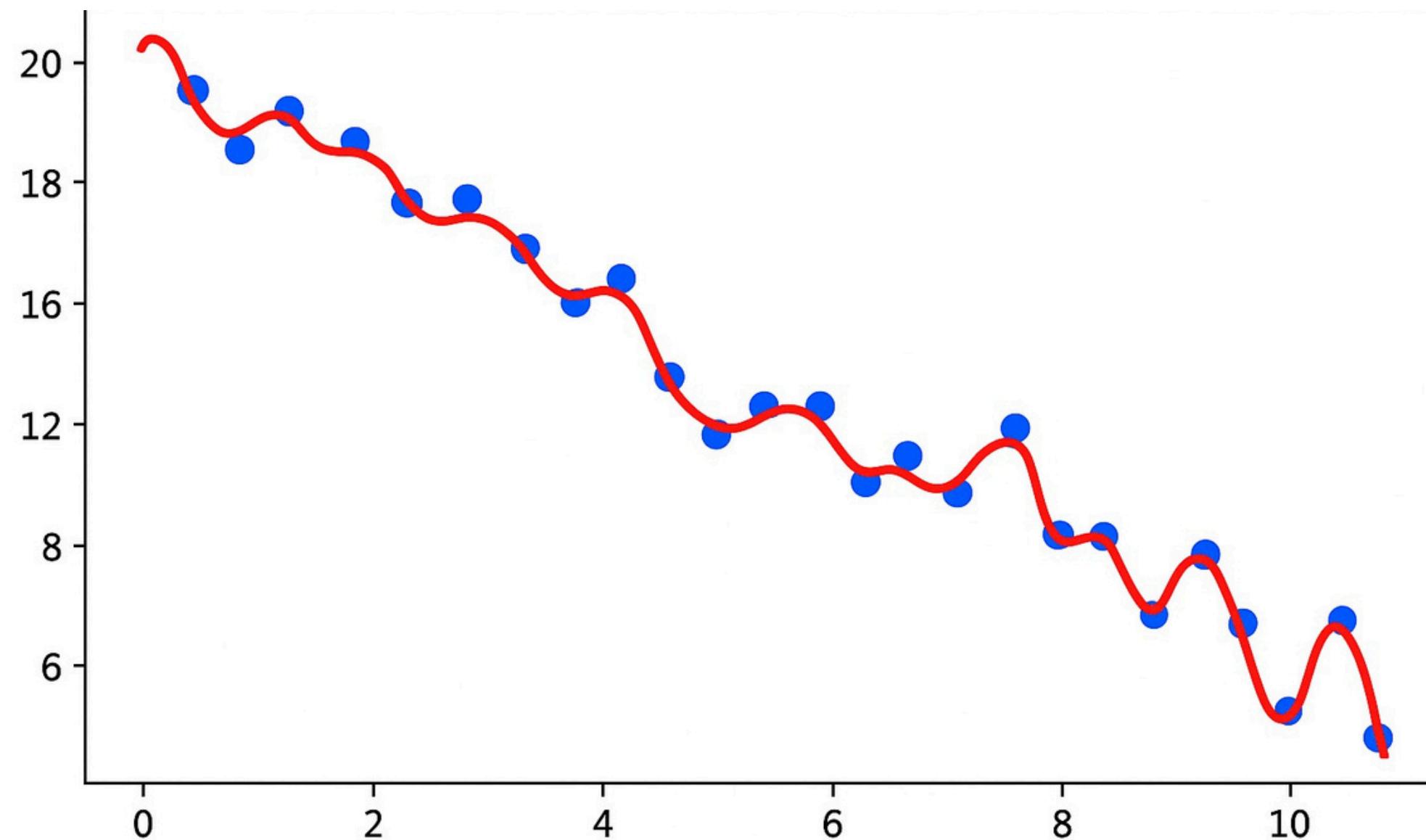
- Add more data



Model Training

Good train + poor test = **Overfitting**

- Add more data
- Feature selection



Model Training

Size (m ²)	Price (SAR)
120	950,000
180	1,350,000
140	980,000
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175	1,450,000



Train

Model Training

Size (m ²)	Price (SAR)
120	950,000
180	1,350,000
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160	1,200,000
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95	720,000
250	2,300,000
130	1,020,000
175	1,450,000

} Training set

} Validation Set



Model Training

Size (m ²)	Price (SAR)
120	950,000
180	1,350,000
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220	1,850,000
160	1,200,000
200	1,700,000
95	720,000
250	2,300,000
130	1,020,000
175	1,450,000

{

Train set

{

Validation Set

{

Test Set



Model Training

Size (m ²)	Price (SAR)
120	950,000
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220	1,850,000
160	1,200,000
200	1,700,000
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250	2,300,000
130	1,020,000
175	1,450,000

Train set

Validation Set

Test Set

- The validation set is used to choose the best model before final testing.

Model Training

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120	950,000
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95	720,000
250	2,300,000
130	1,020,000
175	1,450,000

}

}

}

Train set

Validation Set

Test Set

What if the chosen split doesn't reflect the true
data distribution?

Model Training

Size (m ²)	Price (SAR)
120	950,000
180	1,350,000
140	980,000
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130	1,020,000
175	1,450,000

}

Train set

{

Validation Set

{

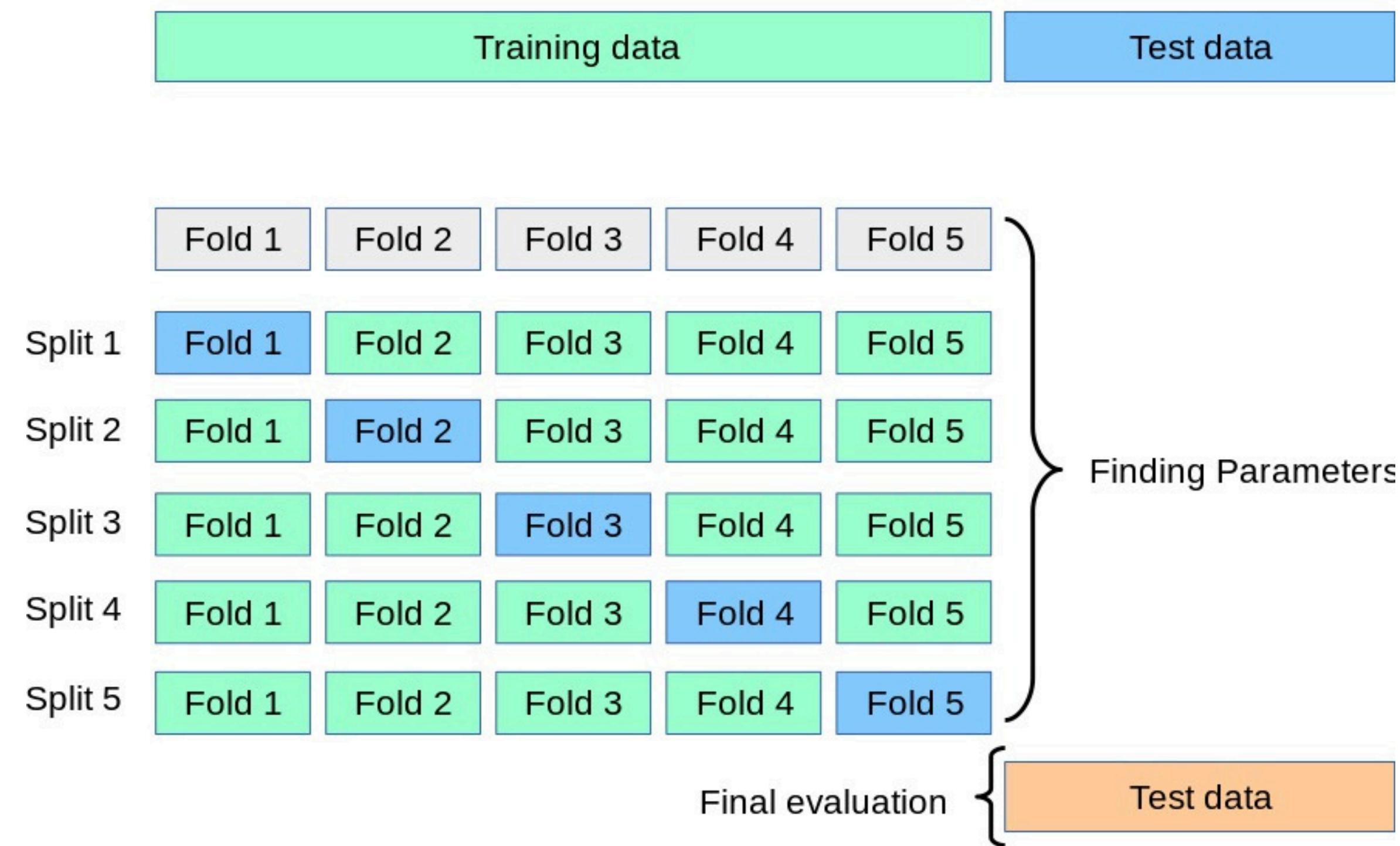
Test Set

What if the chosen split doesn't reflect the true data distribution?

A single validation split may not represent the whole dataset fairly.

Model Training

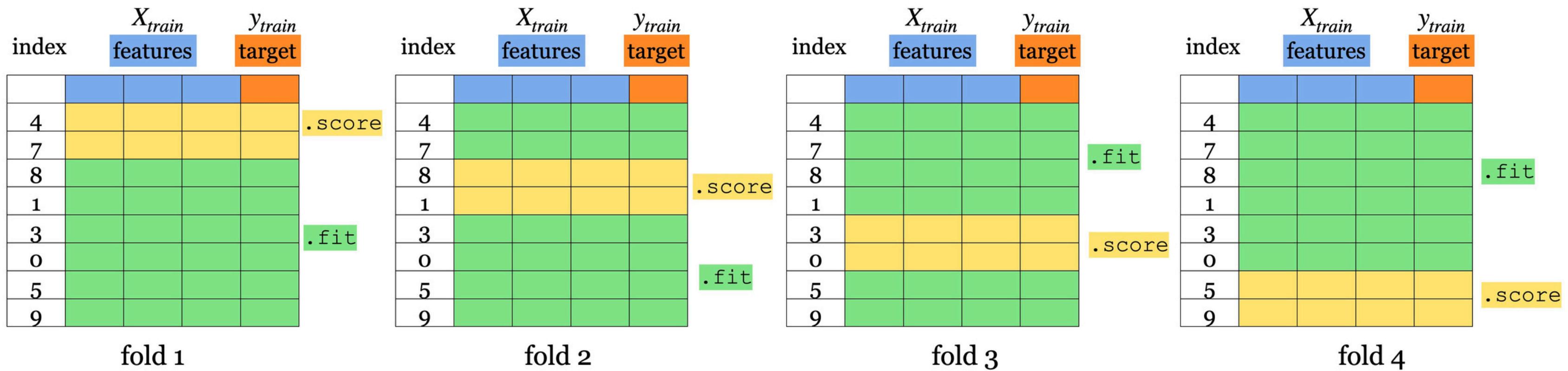
- Cross validation



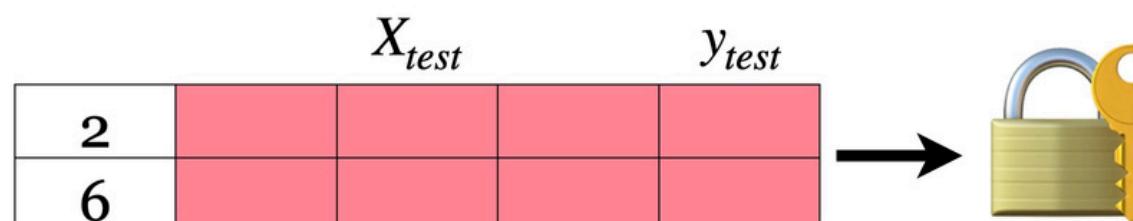
Model Training

- Cross validation

4-fold cross-validation



test split is still in the locked chest



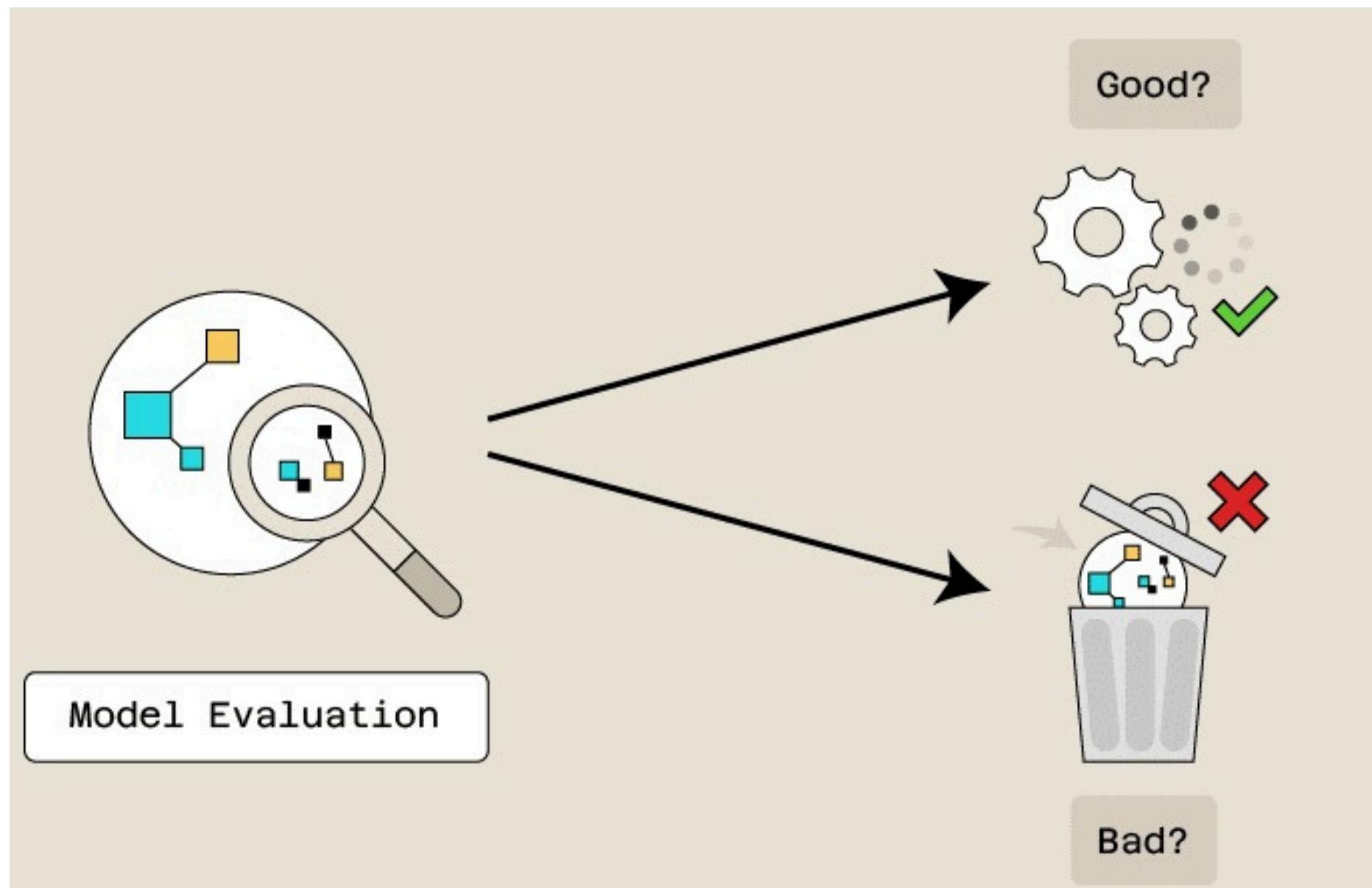
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Model Evaluation

Model Evaluation

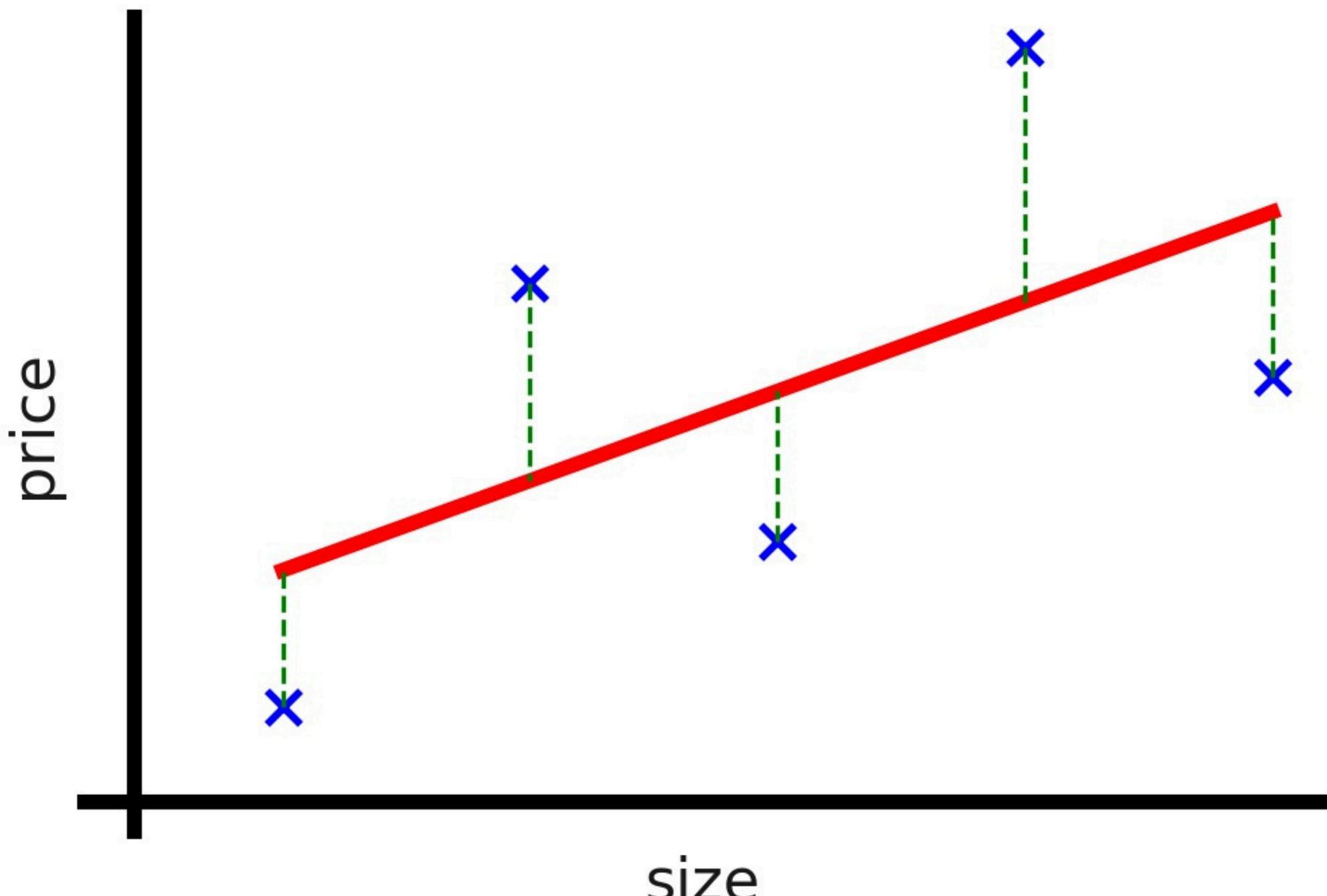
- Evaluation metrics assess how effectively a trained model performs on new, unseen data.



Model Evaluation

- Regression models

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120	950,000
180	1,350,000
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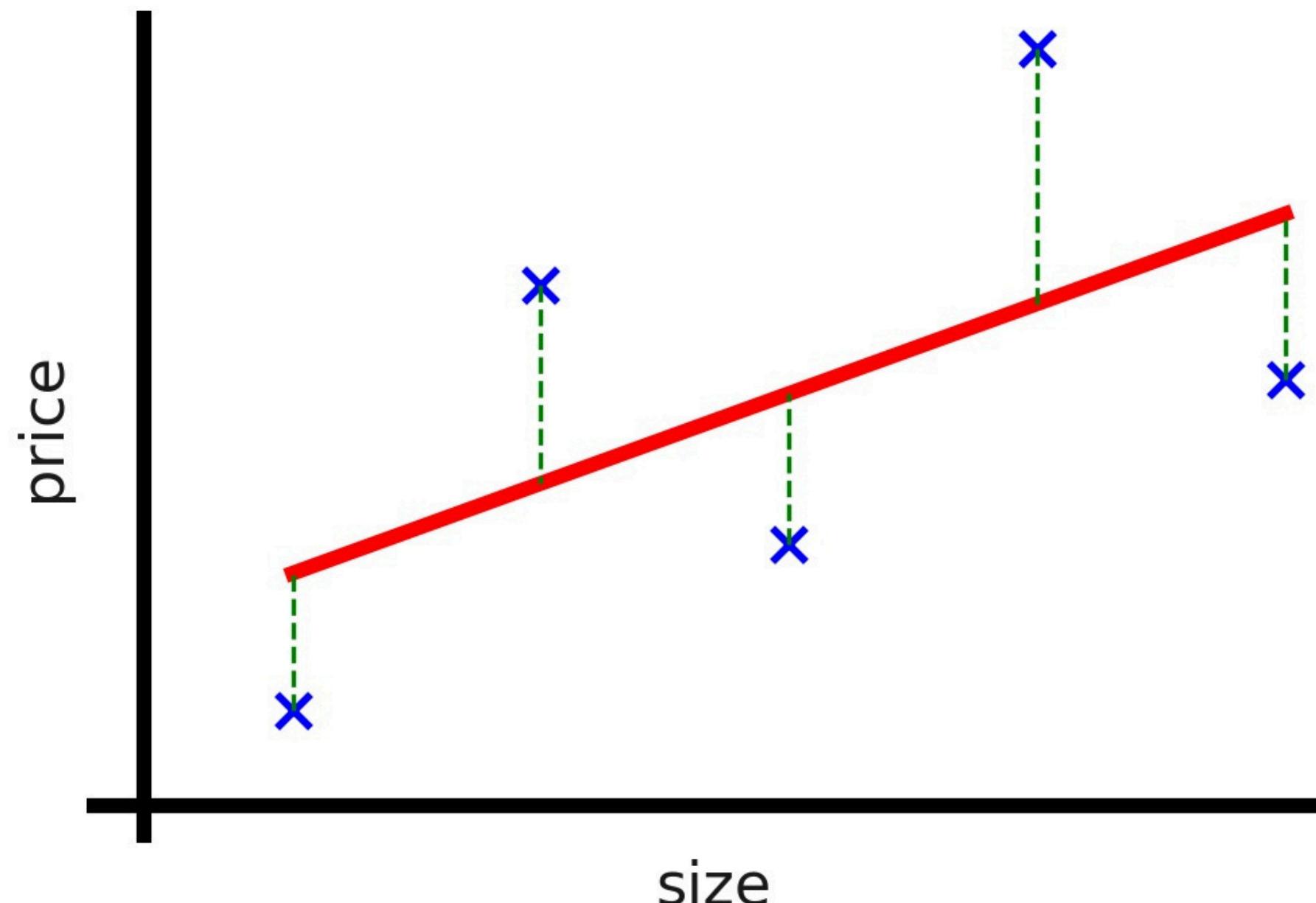


Model Evaluation

- Regression models

Size (m ²)	Price (SAR)
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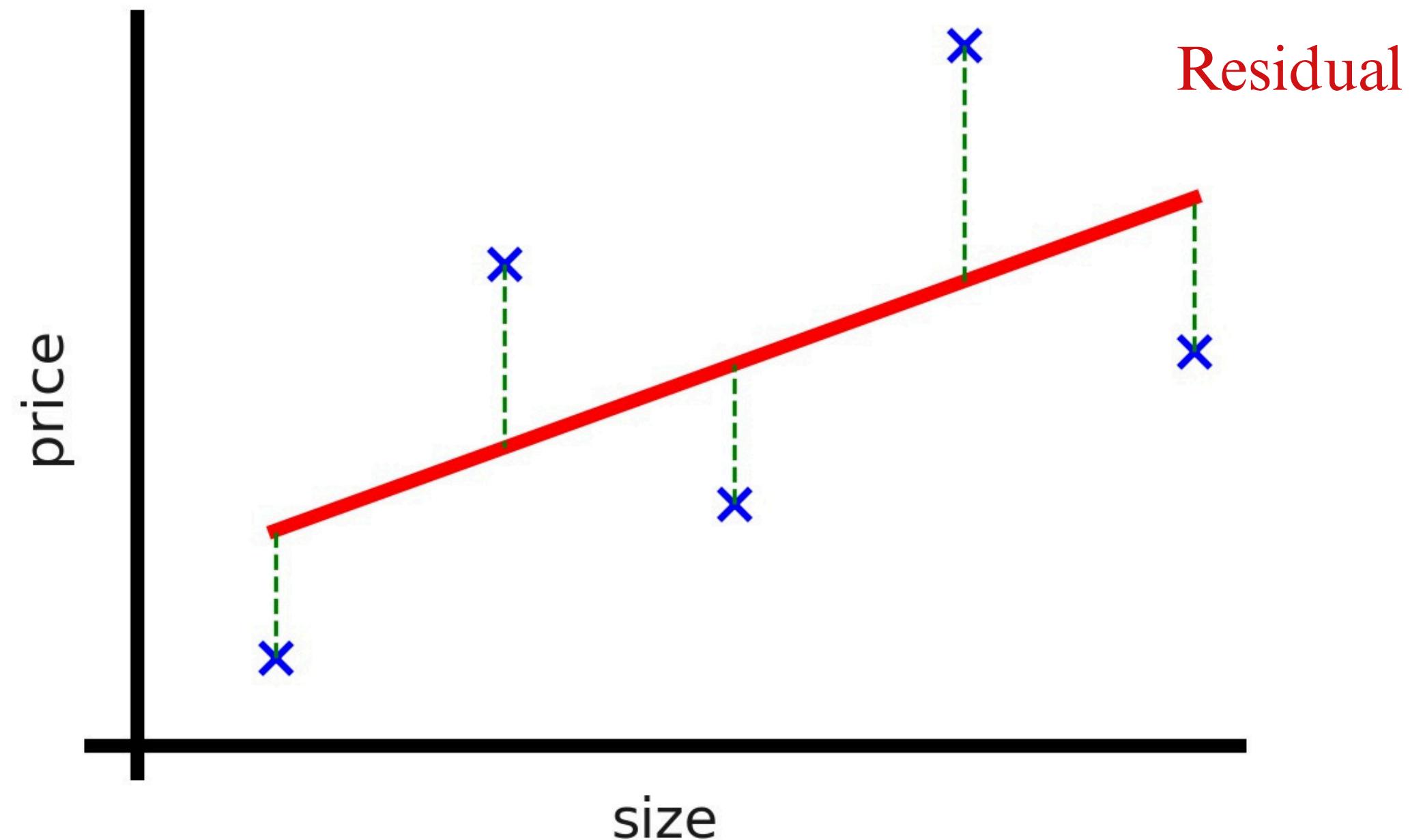
- The distance between the actual data point and the regression line



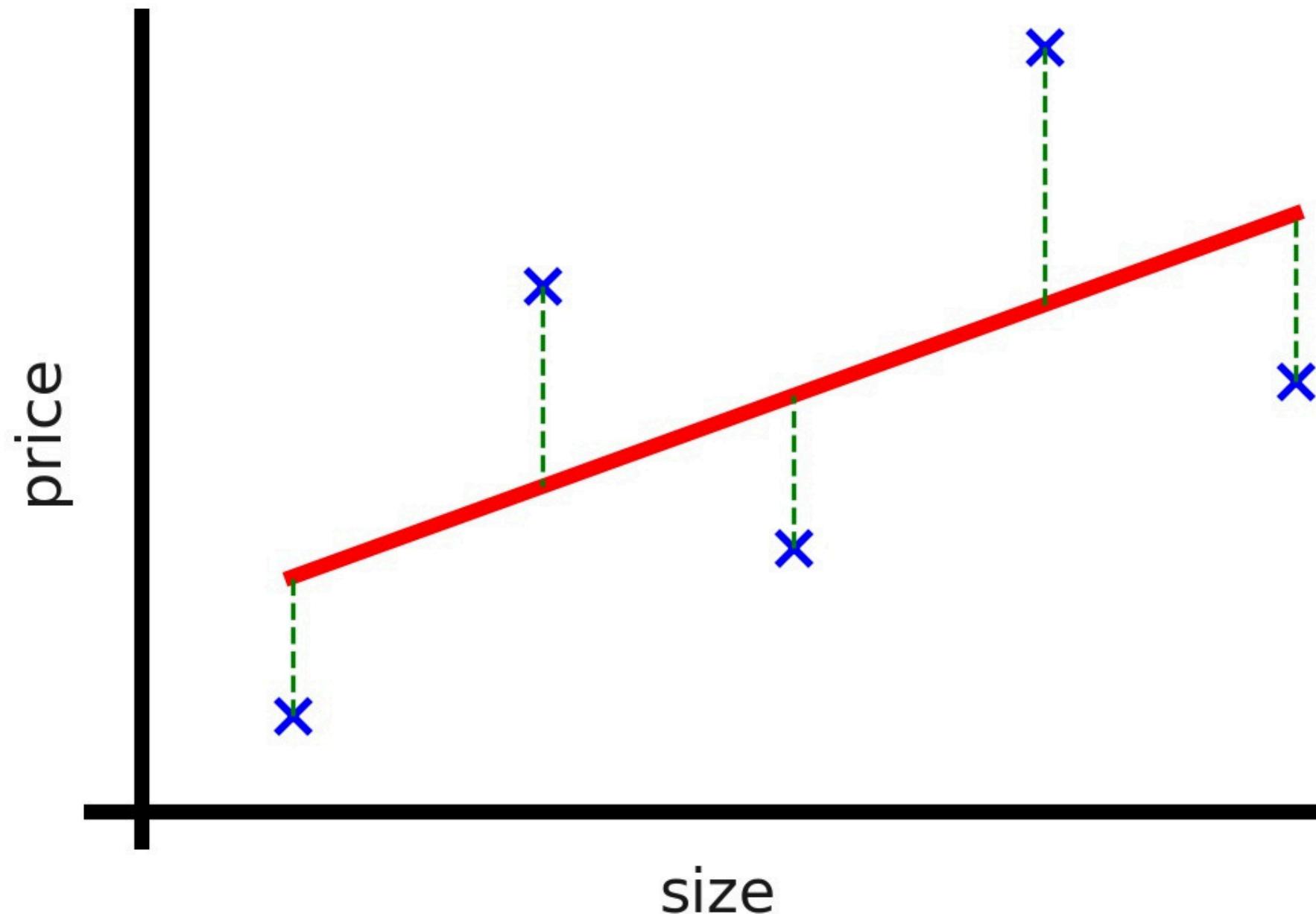
Model Evaluation

- Regression models
- The distance between the actual data point and the regression line

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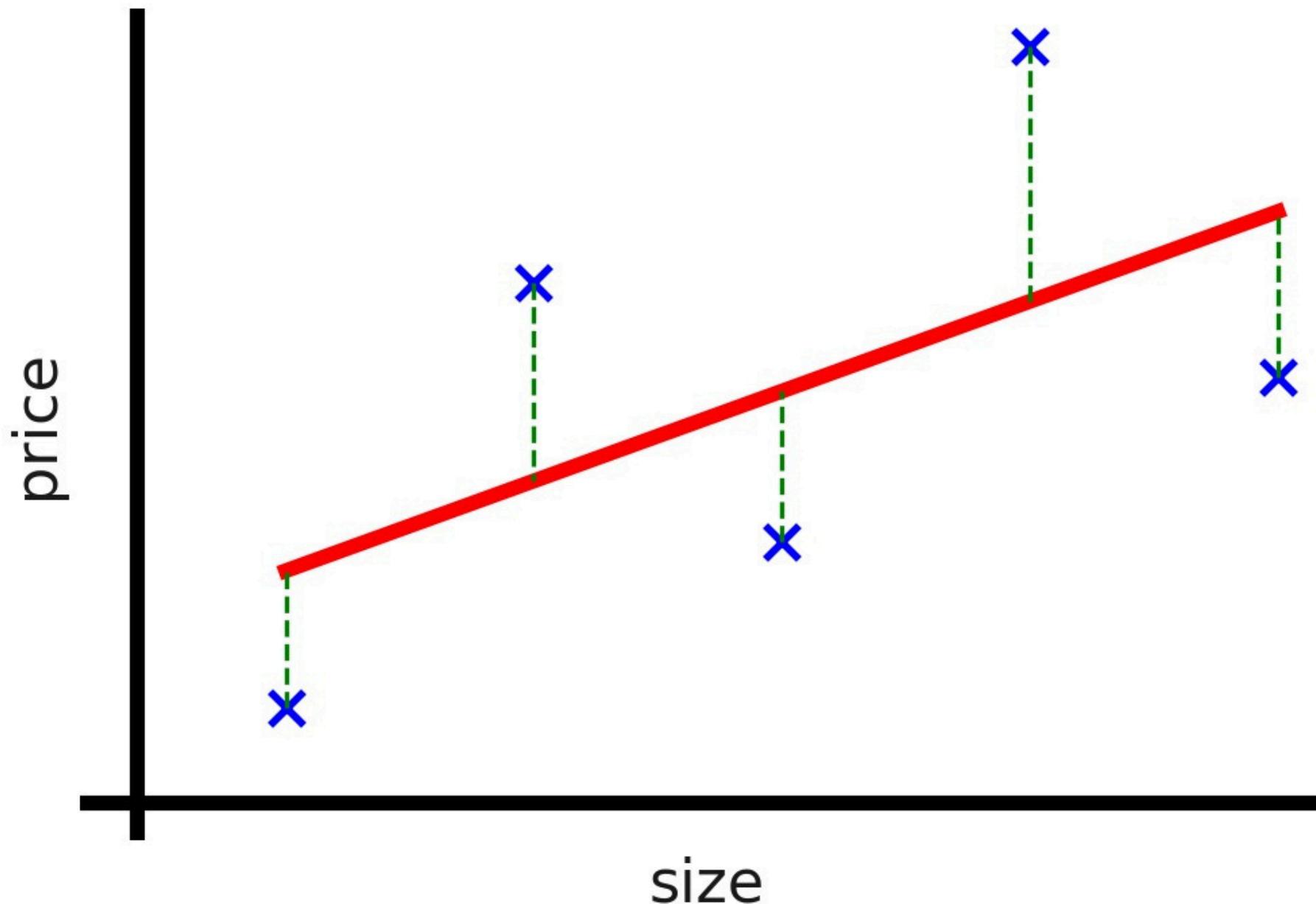


Model Evaluation



Mean Squared Error
↓
Actual value – Predicted value

Model Evaluation



Mean Squared Error

Actual value – Predicted value

$$\text{MSE} = \frac{1}{n} \sum_{i=1}^n (y_i - \hat{y}_i)^2$$

Model Evaluation

- Classification models

Size (m ²)	Customer Segment
120	Economy
180	Mid
140	Economy
220	Luxury
160	Mid
200	Luxury
95	Economy
250	Luxury
130	Mid
175	Mid

Actual=

Economy

Model Evaluation

- Classification models

Size (m ²)	Customer Segment
120	Economy
180	Mid
140	Economy
220	Luxury
160	Mid
200	Luxury
95	Economy
250	Luxury
130	Mid
175	Mid

Actual=

Economy

Predicted=

Economy



Model Evaluation

- Classification models

Size (m ²)	Customer Segment
120	Economy
180	Mid
140	Economy
220	Luxury
160	Mid
200	Luxury
95	Economy
250	Luxury
130	Mid
175	Mid

Actual=

Economy



Predicted=

Luxury

Model Evaluation

- Classification models

Size (m ²)	Customer Segment
120	Economy
180	Mid
140	Economy
220	Luxury
160	Mid
200	Luxury
95	Economy
250	Luxury
130	Mid
175	Mid

Actual=

Economy



Predicted=

Economy

Actual=

Economy



Predicted=

Luxury

Accuercy=

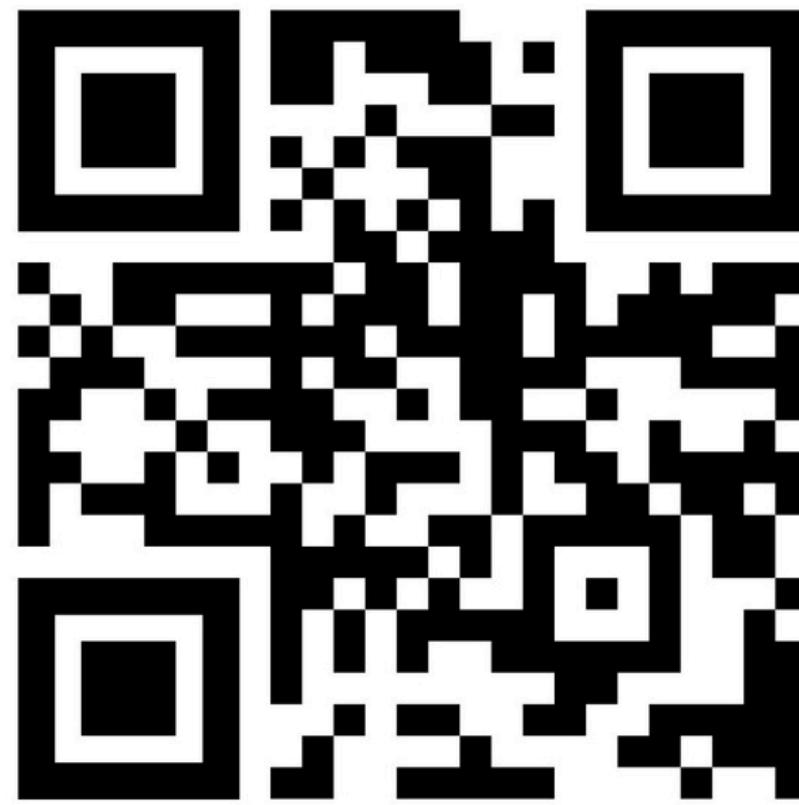
Correct Predictions

Total Predictions

Model Training and Evaluation

Hands-On Activity

Hands-On Activity



- Train a classification model and evaluate its performance.
- Analyze the results and try to improve your model.

Teachable Machine Date Fruit Image Dataset



Thank You