

Prediction vs. inference dilemma

MACHINE LEARNING FOR BUSINESS



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Inference vs. prediction dilemma

Inference or causal models:

- The goal is to understand the drivers of a business outcome
- Inference focused models are interpretable
- Less accurate than **prediction** models

Prediction:

- The prediction itself is the main goal
- Are not easily interpretable i.e. work like "black-boxes"
- Much more accurate than **inference** models

Start with the business question

- "What are the main **drivers** of fraud?"
 - Inference
- "**How much** conditions X impact heart attack risk?"
 - Inference
- "**Which** transactions are **likely** fraudulent?"
 - Prediction
- "Is the patient **at risk** of having a heart attack?"
 - Prediction

Modeling data structure

| | Transaction data A | Transaction data B | Transaction data C | Transaction data D | | Fraud probability |
|-----------------|--------------------|--------------------|--------------------|--------------------|--|-------------------|
| Transaction 1 | | | | | | |
| Transaction 2 | | | | | | |
| Transaction 3 | | | | | | |
| Transaction ... | | | | | | |
| Transaction N | | | | | | |

Target variable

Transaction 1
Transaction 2
Transaction 3
Transaction ...
Transaction N

| Transaction data A | Transaction data B | Transaction data C | Transaction data D |
|--------------------|--------------------|--------------------|--------------------|
| | | | |
| | | | |
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| | | | |
| | | | |

Target variable

| Fraud probability |
|-------------------|
| |
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Input features

Data about transactions that the business collected
(input features)

| | Transaction data A | Transaction data B | Transaction data C | Transaction data D |
|-----------------|--------------------|--------------------|--------------------|--------------------|
| Transaction 1 | | | | |
| Transaction 2 | | | | |
| Transaction 3 | | | | |
| Transaction ... | | | | |
| Transaction N | | | | |

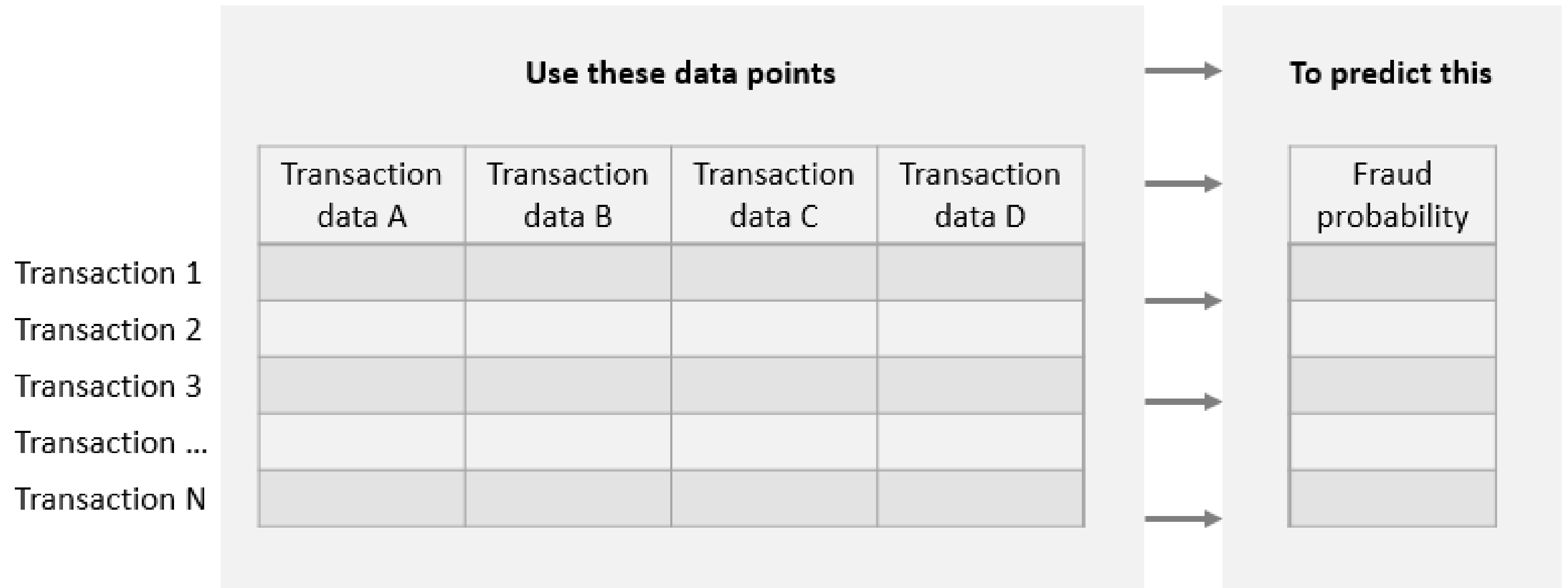
Target variable

| Fraud probability |
|-------------------|
| |
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Using input features

| | Use these data points | | | | |
|-----------------|-----------------------|--------------------|--------------------|--------------------|-------------------|
| | Transaction data A | Transaction data B | Transaction data C | Transaction data D | Fraud probability |
| Transaction 1 | | | | | |
| Transaction 2 | | | | | |
| Transaction 3 | | | | | |
| Transaction ... | | | | | |
| Transaction N | | | | | |

Predicting target variable



Inference model focus

Which of these affect the fraud probability the most?

| | Transaction data A | Transaction data B | Transaction data C | Transaction data D |
|-----------------|--------------------|--------------------|--------------------|--------------------|
| Transaction 1 | | | | |
| Transaction 2 | | | | |
| Transaction 3 | | | | |
| Transaction ... | | | | |
| Transaction N | | | | |

| Fraud probability |
|-------------------|
| |
| |
| |
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Prediction model focus

Transaction 1
Transaction 2
Transaction 3
Transaction ...
Transaction N

| Transaction data A | Transaction data B | Transaction data C | Transaction data D |
|--------------------|--------------------|--------------------|--------------------|
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |

Get the most accurate probability
this is fraud

| |
|-------------------|
| Fraud probability |
| |
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| |
| |

Let's practice!

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Inference (causal) models

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What is causality?

- Identify causal relationship of how much certain actions affect an outcome of interest
- Answers the "why?" questions
- Optimizes for model interpretability vs. performance
- Models try to detect patterns in observed data (observational) and draw causal conclusions

Experiments vs. observations

- Experiments are designed and causal conclusions are guaranteed e.g. in A/B tests
- When experiments are impossible (unethical, too expensive, both) - the models are used (also called observational studies) to calculate effect of certain inputs on desired outcomes
- Experiments are **always** preferred over observational studies whenever possible

Best practices

1. Do experiments wherever you can
2. If running experiments all the time is too expensive, run them periodically (quarterly, annually) and use it as benchmark
3. If there are no way to run any experiments, build a causal model. This will require an advanced methodology

Inference model example

| | Last month spend | Recency in days | Average cart value | Store visits per year | | Next month spend |
|--------------|------------------|-----------------|--------------------|-----------------------|--|------------------|
| Customer 1 | 845 USD | 20 | 340 USD | 32 | | 585 USD |
| Customer 2 | 205 USD | 1 | 100 USD | 25 | | 150 USD |
| Customer 3 | 0 USD | 55 | 70 USD | 14 | | 20 USD |
| Customer ... | ... | ... | ... | ... | | ... |
| Customer N | 43 | 114.5 | 134 | 61.2 | | 69 USD |

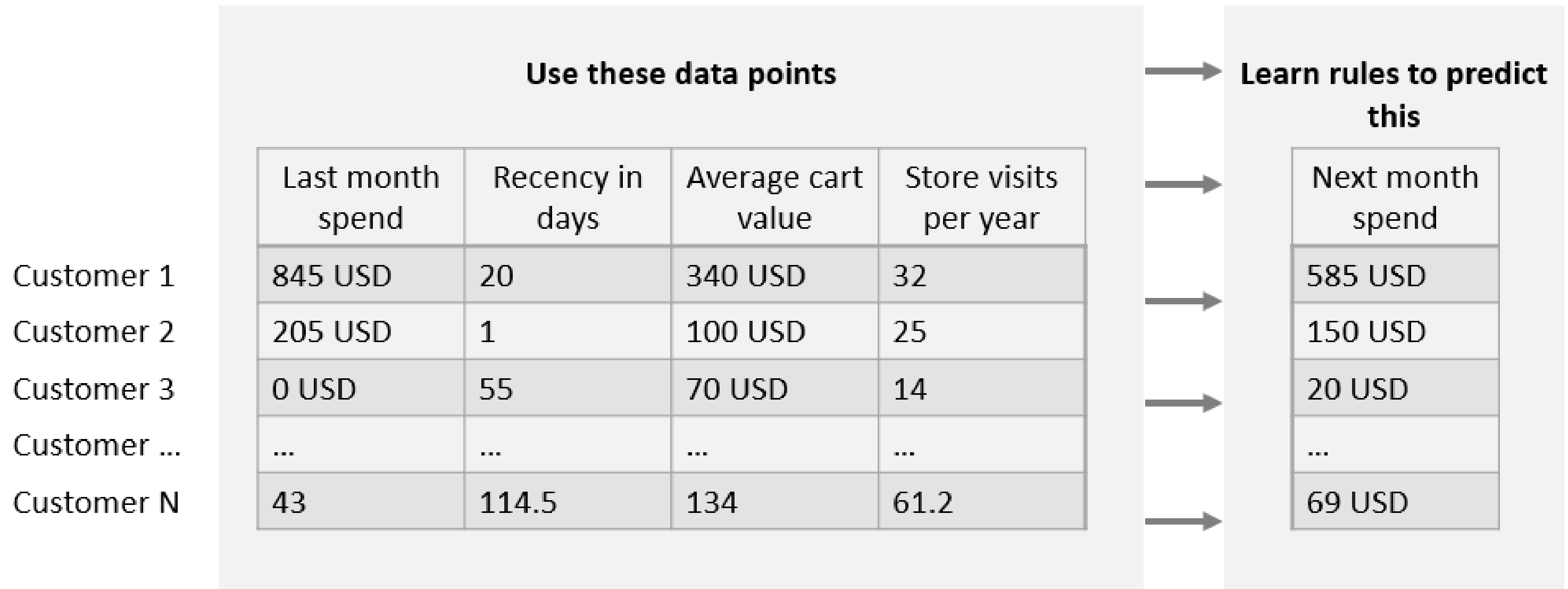
Inference - training

Use these data points

| | Last month spend | Recency in days | Average cart value | Store visits per year |
|--------------|------------------|-----------------|--------------------|-----------------------|
| Customer 1 | 845 USD | 20 | 340 USD | 32 |
| Customer 2 | 205 USD | 1 | 100 USD | 25 |
| Customer 3 | 0 USD | 55 | 70 USD | 14 |
| Customer ... | ... | ... | ... | ... |
| Customer N | 43 | 114.5 | 134 | 61.2 |

| Next month spend |
|------------------|
| 585 USD |
| 150 USD |
| 20 USD |
| ... |
| 69 USD |

Inference - learning



Inference - regression coefficients


Coefficients

| Last month spend | Recency in days | Average cart value | Store visits per year |
|------------------|-----------------|--------------------|-----------------------|
| 0.58 | -0.03 | 0.28 | 0.18 |

Inference - interpretation

Coefficients

| Last month spend | Recency in days | Average cart value | Store visits per year |
|------------------|-----------------|--------------------|-----------------------|
| 0.58 | -0.03 | 0.28 | 0.18 |



How much 1 incremental USD spent in the last month results in predicted next month spend.
Here, the customers who on average spent 1 USD **more** in the last month, will spend 0.58 USD more in the next month compared to customers with 1 USD **less** last month.

Let's practice!

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Prediction models (supervised learning)

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Supervised vs. Unsupervised

Supervised models

Predicting **class/type** of an outcome (e.g. subscription cancellation, fraud, purchase) - **CLASSIFICATION**

Predicting **quantity** of an outcome (e.g. dollars spent, hours played) - **REGRESSION**

Unsupervised models

Clustering - grouping observations into similar groups or clusters (e.g. customer or market segmentation)

Supervised learning types

Classification - Target variable is categorical (discrete) (class of outcome) (**classification**)

- Will the customer cancel a service subscription?

- Is this transaction fraudulent?

- What is the profession of this user?

Regression - Target variable is continuous (amount of outcome) (**regression**)

- Number of product purchases next month

- Number of gaming hours next year

- Dollars spent on insurance

Data collection

Machine learning teams should collect all available data to predict desired outcome with the highest degree of accuracy e.g. in case of purchase predictions:

- Customer information

- Purchase history, cancellations, order amount

- Browsing history, logs, errors

- Device details and location

- Product/service usage frequency

- And others...

Classification example

| | Past fraud count | Time of transaction | Declined in T-30 days | Amount | Fraud |
|-----------------|------------------|---------------------|-----------------------|----------|-------|
| Transaction 1 | 20 | 3 am | Yes | 5.25 USD | Yes |
| Transaction 2 | 1 | 9 pm | Yes | 19.5 USD | Yes |
| Transaction 3 | 0 | 9.30 am | No | 500 USD | No |
| Transaction ... | | | | | |
| Transaction N | | | | | |

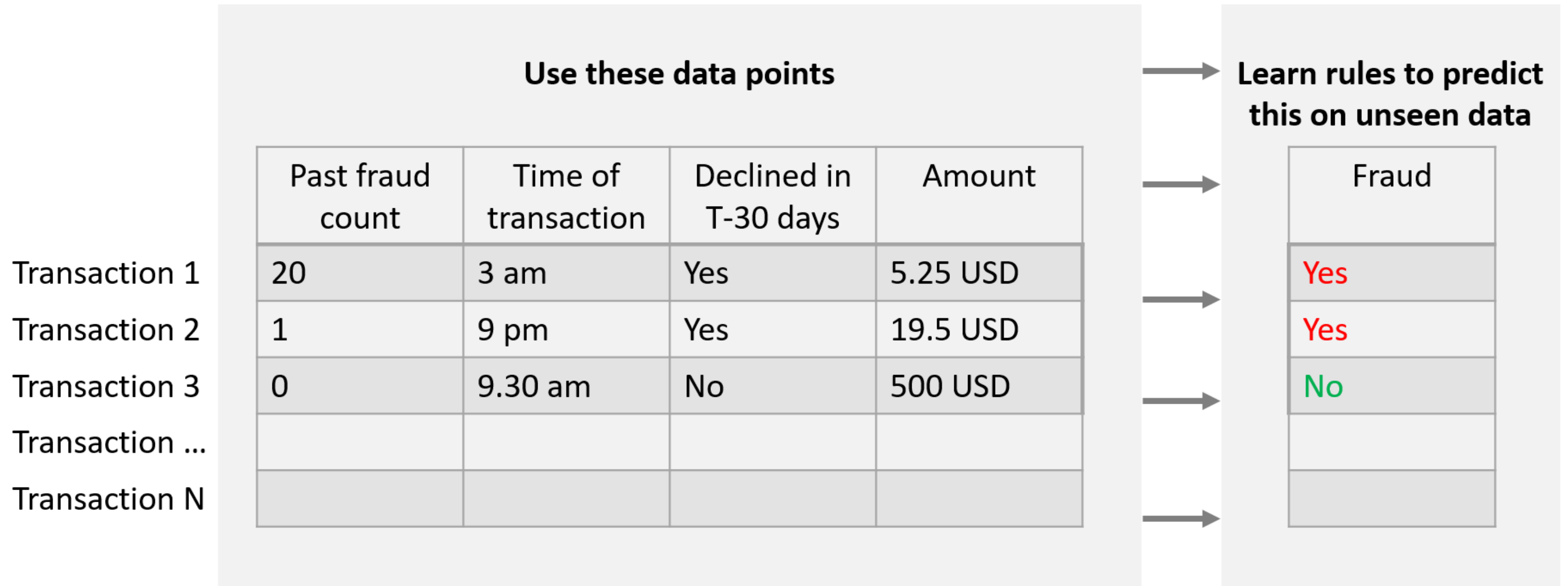
Classification - training

Use these data points

| | Past fraud count | Time of transaction | Declined in T-30 days | Amount |
|-----------------|------------------|---------------------|-----------------------|----------|
| Transaction 1 | 20 | 3 am | Yes | 5.25 USD |
| Transaction 2 | 1 | 9 pm | Yes | 19.5 USD |
| Transaction 3 | 0 | 9.30 am | No | 500 USD |
| Transaction ... | | | | |
| Transaction N | | | | |

| Fraud |
|-------|
| Yes |
| Yes |
| No |
| |
| |

Classification - learning



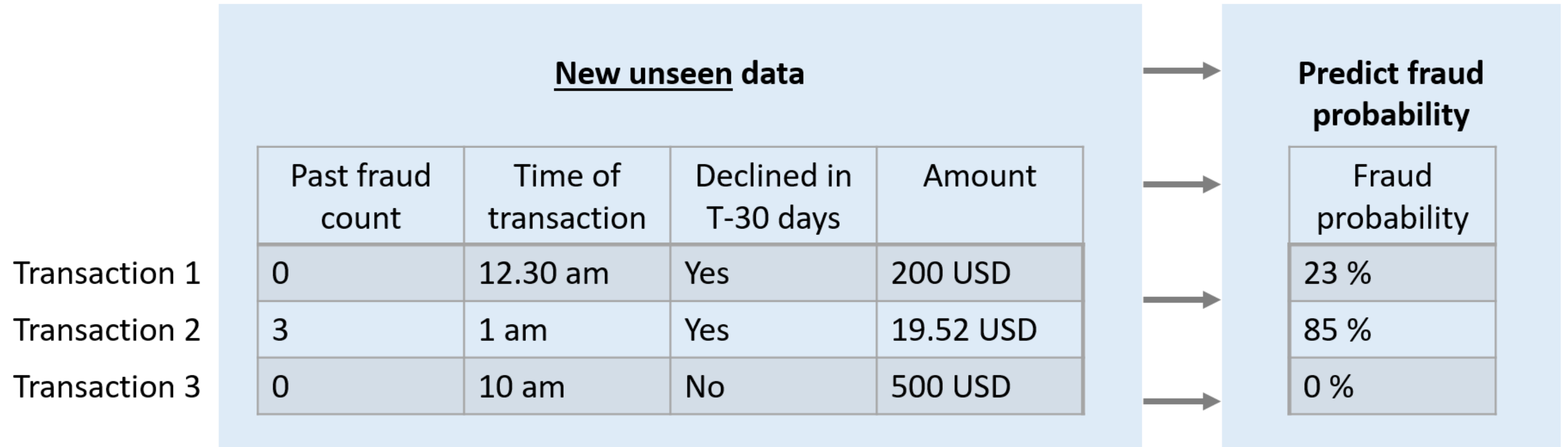
Classification - unseen data

Transaction 1
Transaction 2
Transaction 3

| <u>New unseen data</u> | | | |
|------------------------|---------------------|-----------------------|-----------|
| Past fraud count | Time of transaction | Declined in T-30 days | Amount |
| 0 | 12.30 am | Yes | 200 USD |
| 3 | 1 am | Yes | 19.52 USD |
| 0 | 10 am | No | 500 USD |

| Fraud probability |
|-------------------|
| |
| |
| |

Classification - prediction



Regression example

| | Last month spend | Recency in days | Average cart value | Store visits per year | Next month spend |
|--------------|------------------|-----------------|--------------------|-----------------------|------------------|
| Customer 1 | 845 USD | 20 | 340 USD | 32 | 585 USD |
| Customer 2 | 205 USD | 1 | 100 USD | 25 | 150 USD |
| Customer 3 | 0 USD | 55 | 70 USD | 14 | 20 USD |
| Customer ... | ... | ... | ... | ... | ... |
| Customer N | 43 | 114.5 | 134 | 61.2 | 69 USD |

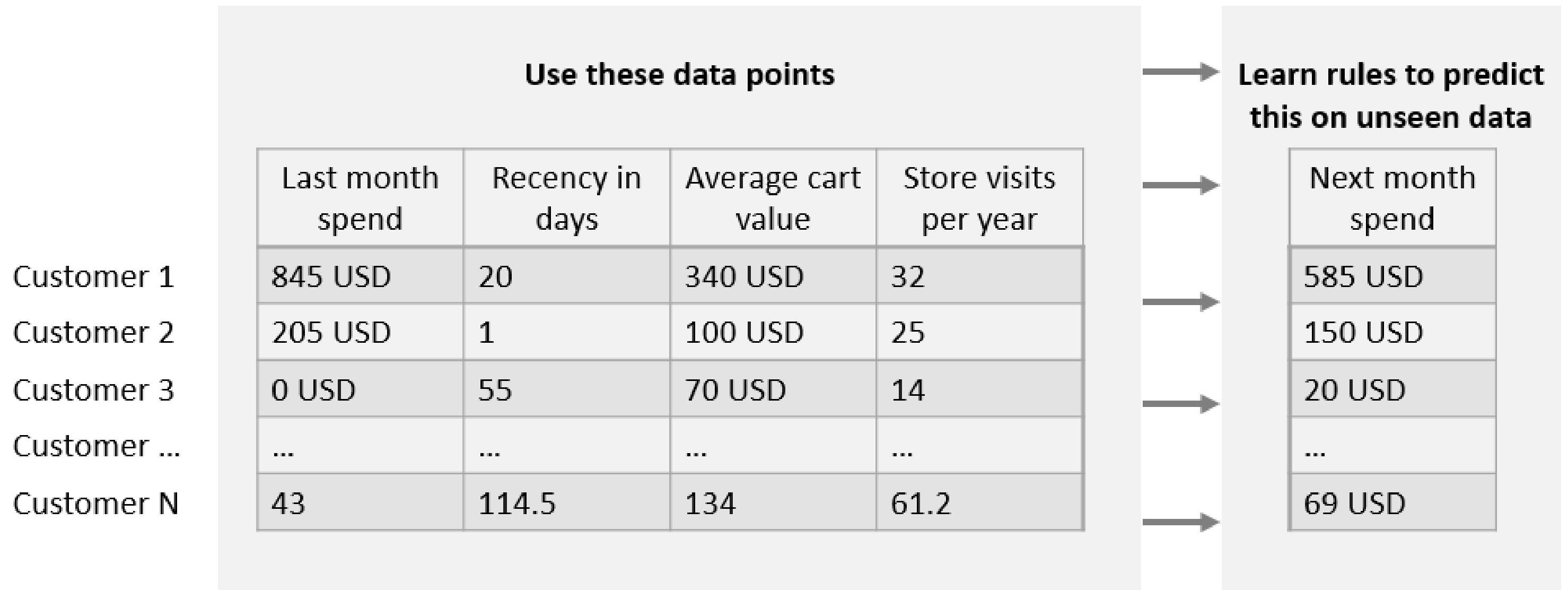
Regression - training

Use these data points

| | Last month spend | Recency in days | Average cart value | Store visits per year |
|--------------|------------------|-----------------|--------------------|-----------------------|
| Customer 1 | 845 USD | 20 | 340 USD | 32 |
| Customer 2 | 205 USD | 1 | 100 USD | 25 |
| Customer 3 | 0 USD | 55 | 70 USD | 14 |
| Customer ... | ... | ... | ... | ... |
| Customer N | 43 | 114.5 | 134 | 61.2 |

| Next month spend |
|------------------|
| 585 USD |
| 150 USD |
| 20 USD |
| ... |
| 69 USD |

Regression - learning



Regression - unseen data

Customer 1

Customer 2

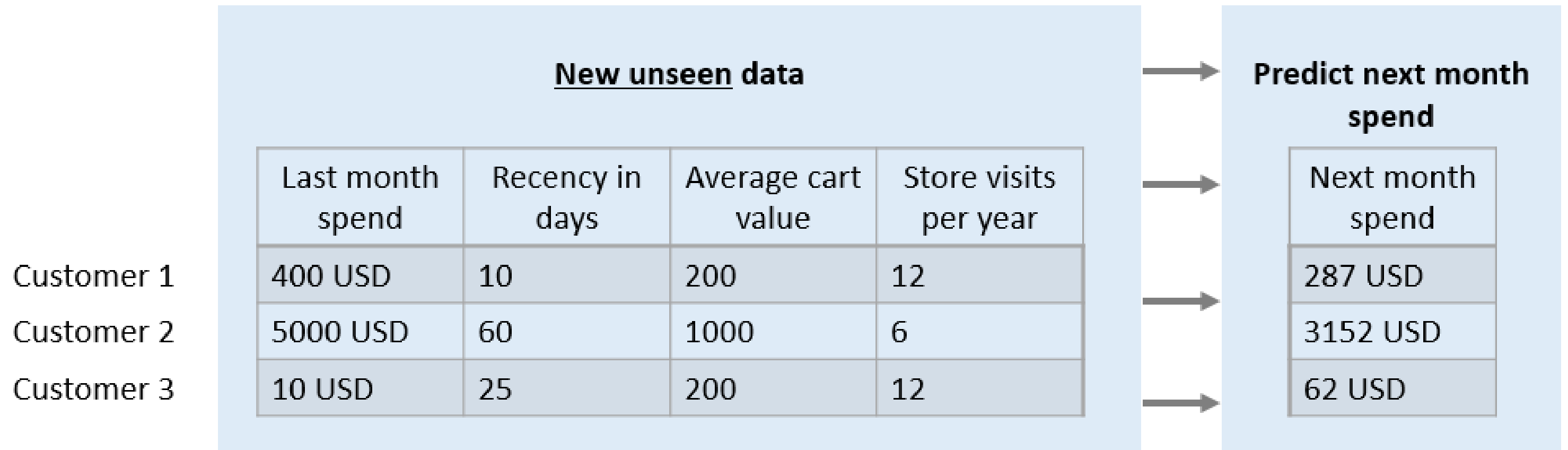
Customer 3

New unseen data

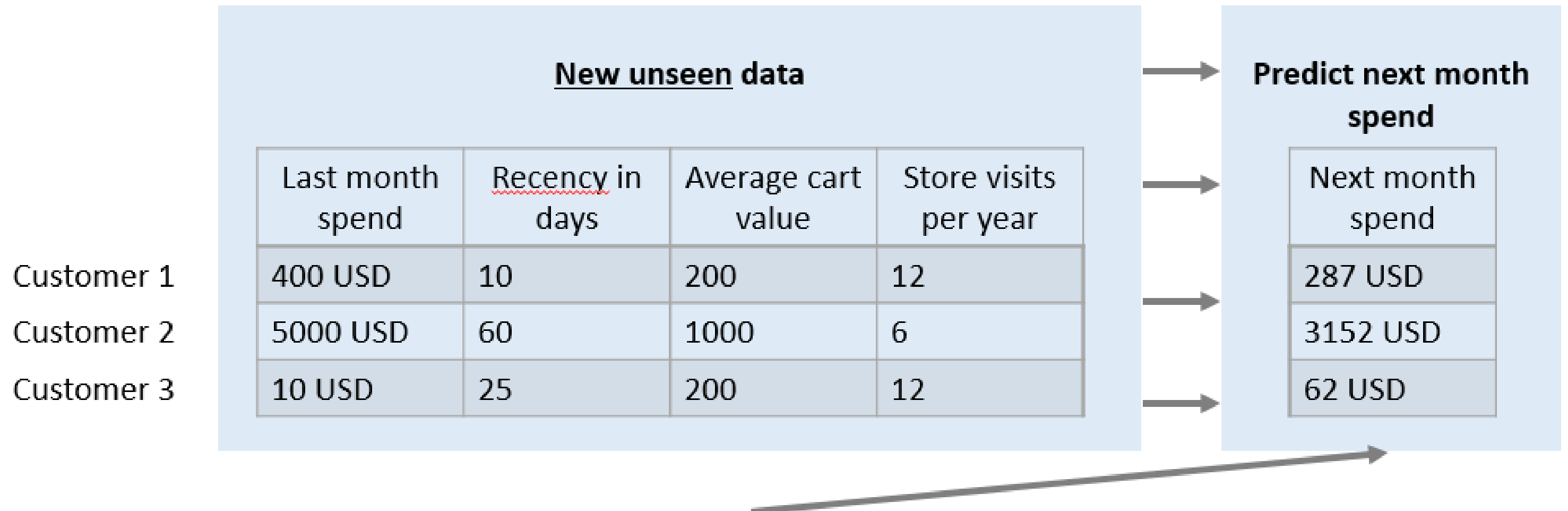
| Last month spend | Recency in days | Average cart value | Store visits per year |
|------------------|-----------------|--------------------|-----------------------|
| 400 USD | 10 | 200 | 12 |
| 5000 USD | 60 | 1000 | 6 |
| 10 USD | 25 | 200 | 12 |

| |
|------------------|
| Next month spend |
| |
| |
| |

Regression - prediction



Regression - actual prediction



These are **real** predictions based from a linear regression model!

Let's practice!

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Prediction models (unsupervised learning)

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What is unsupervised machine learning?

Unsupervised models

Clustering - grouping observations into similar groups or clusters (e.g. customer or market segmentation)

Anomaly detection - detecting which observations fall out of the discovered "regular pattern" and use it as an input in supervised learning or a business input

Recommender engines - e.g. recommending products or services to customers based on their similarity to other customers e.g. Netflix movie recommendations

Clustering example - segmentation

| | Annual spend | Recency in days | Store visits per year |
|--------------|--------------|-----------------|-----------------------|
| Customer 1 | 8450 USD | 20 | 32 |
| Customer 2 | 2050 USD | 1 | 25 |
| Customer 3 | 450 USD | 55 | 14 |
| Customer ... | ... | ... | ... |
| Customer N | 628 USD | 114.5 | 61.2 |

Segmentation - data

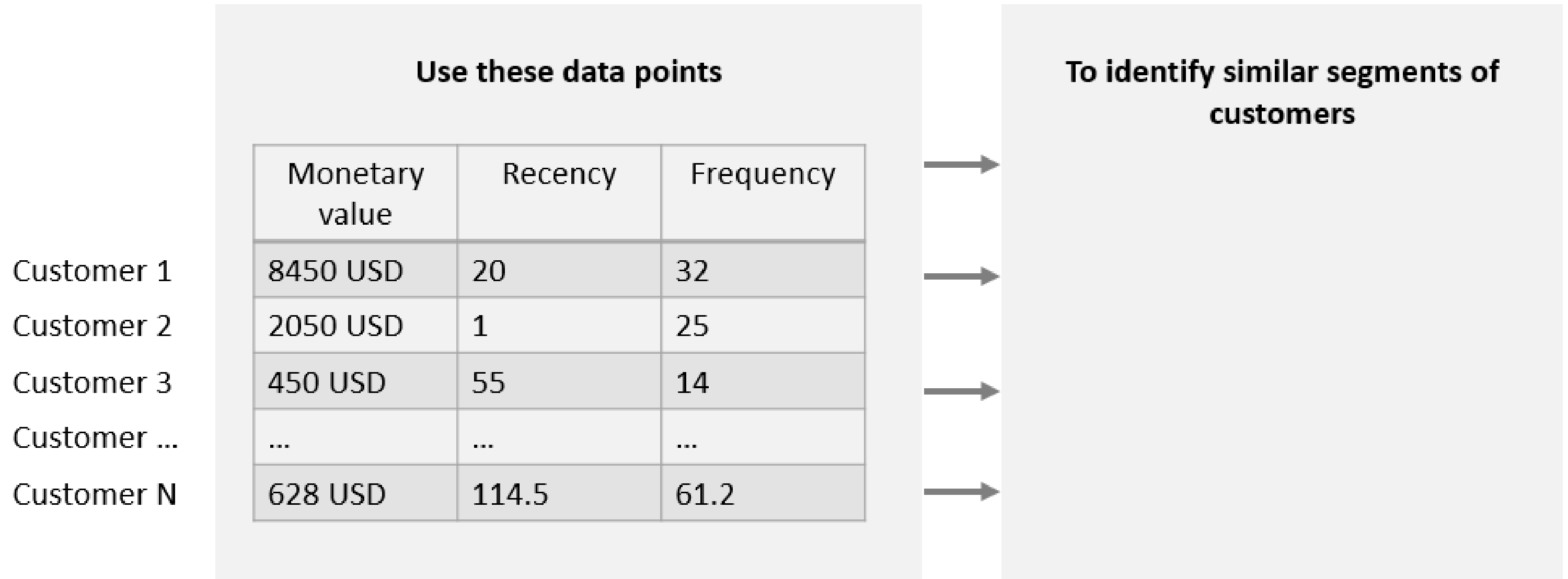
| | Monetary value | Recency | Frequency |
|--------------|-------------------|---------|-----------|
| Customer 1 | 8450 USD | 20 | 32 |
| Customer 2 | 2050 USD | 1 | 25 |
| Customer 3 | 450 USD | 55 | 14 |
| Customer ... | ... | ... | ... |
| Customer N | 628 USD | 114.5 | 61.2 |

Segmentation - training

Use these data points

| | Monetary value | Recency | Frequency |
|--------------|----------------|---------|-----------|
| Customer 1 | 8450 USD | 20 | 32 |
| Customer 2 | 2050 USD | 1 | 25 |
| Customer 3 | 450 USD | 55 | 14 |
| Customer ... | ... | ... | ... |
| Customer N | 628 USD | 114.5 | 61.2 |

Segmentation - discover



Segmentation - analyze

Customer 1
Customer 2
Customer 3
Customer ...
Customer N

Use these data points

| Monetary value | Recency | Frequency |
|----------------|---------|-----------|
| 8450 USD | 20 | 32 |
| 2050 USD | 1 | 25 |
| 450 USD | 55 | 14 |
| ... | ... | ... |
| 628 USD | 114.5 | 61.2 |



To identify similar segments of customers

1
2
3

| Monetary value | Recency | Frequency |
|----------------|---------|-----------|
| 4788 | 76 | 74 |
| 8872 | 21 | 34 |
| 1312 | 29 | 21 |

Let's practice!

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