Feature Engineering with Featuretools

November 16, 2023

Perform Deep Feature Synthesis to discover potential new features for the design of Star Schemas.

[1]:
```
import pandas as pd
import featuretools as ft
import woodwork

# Filter unimportant warning generated by featuretools
import warnings
warnings.filterwarnings('ignore')
```

[2]:
```
# Display utilities
from IPython.display import display_svg
```

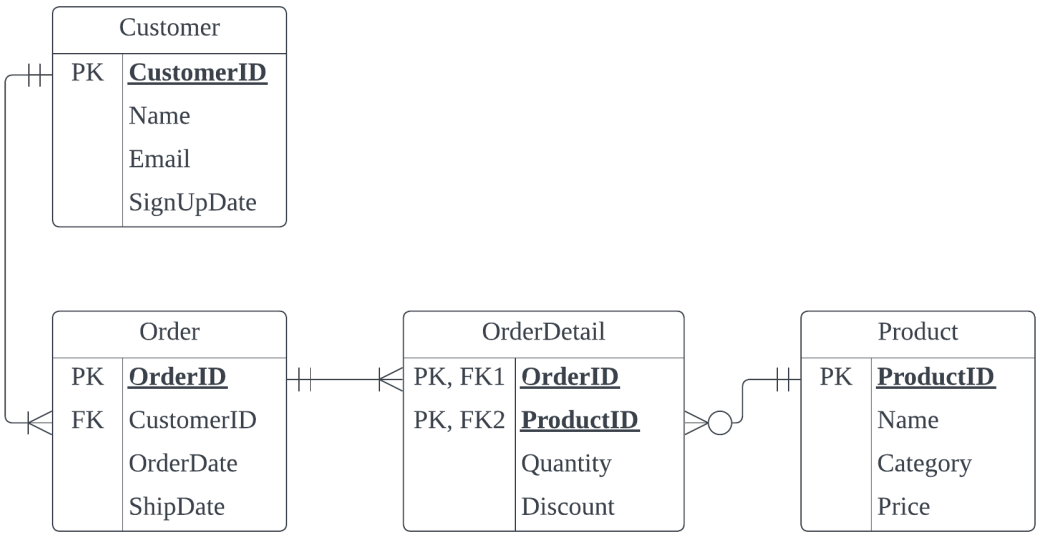
1 Prepare datasets

You are provided with an e-commerce dataset comprising several entities:

1. `Customers`: CustomerID, Name, Email, SignUpDate
2. `Products`: ProductID, Name, Category, Price
3. `Orders`: OrderID, CustomerID, OrderDate, ShipDate
4. `OrderDetails`: OrderID, ProductID, Quantity, Discount

Business Rules:

1. One `customer` can place one or many `orders`; One `order` is placed by one and only one `customer`.
2. One `order` contains one or many `products`; One `product` belongs to zero or many `orders`.



Entity relationship diagram based on the given business rules

Notes: `OrderDetail` acts as the bridge table between `Order` to `Product` tables to create a many-to-many relationship.

1.1 Generate mock-up datasets

[3]:
```
# Define sample data for Customers
customers_data = {
    "CustomerID": [101, 102, 103, 104, 105],
    "Name": ["John Doe", "Jane Smith", "Mike Jordan", "Anna Frank", "Sarah␣
 ↪Connor"],
    "Email": ["john.doe@example.com", "jane.smith@example.com", "mike.
 ↪jordan@example.com", "anna.frank@example.com", "sarah.connor@example.com"],
    "SignUpDate": ["2023-01-10", "2023-01-15", "2023-01-20", "2023-01-25",␣
 ↪"2023-01-30"]
}

# Define sample data for Products
products_data = {
    "ProductID": [201, 202, 203, 204, 205],
    "Name": ["Laptop", "Tablet", "Smartphone", "Earrings", "T-Shirt"],
    "Category": ["Electronics", "Electronics", "Electronics", "Accessories",␣
 ↪"Clothing"],
    "Price": [1000, 500, 800, 100, 50]
}

# Define sample data for Orders
```

```
orders_data = {
    "OrderID": [301, 302, 303, 304, 305],
    "CustomerID": [101, 102, 103, 104, 105],
    "OrderDate": ["2023-02-01", "2023-02-05", "2023-02-10", "2023-02-15",␣
 ↪"2023-02-20"],
    "ShipDate": ["2023-02-03", "2023-02-07", "2023-02-12", "2023-02-19",␣
 ↪"2023-02-25"]
}

# Define sample data for OrderDetails
order_details_data = {
    "OrderID": [301, 302, 303, 304, 304, 305, 305, 305],
    "ProductID": [201, 202, 203, 204, 205, 205, 204, 201],
    "Quantity": [1, 2, 1, 1, 3, 1, 2, 1],
    "Discount": [0, 0.1, 0, 0, 0.2, 0, 0, 0.3]
}

# Create DataFrames
customers_df = pd.DataFrame(customers_data)
products_df = pd.DataFrame(products_data)
orders_df = pd.DataFrame(orders_data)
order_details_df = pd.DataFrame(order_details_data)

# Adding a surrogate key to order_details table (to be used as an index in the␣
 ↪entity)
order_details_df["OrderDetailID"] = order_details_df["OrderID"].astype(str) +␣
 ↪"_" + order_details_df["ProductID"].astype(str)
```

[4]:
```
customers_df
```

[4]:

	CustomerID	Name	Email	SignUpDate
0	101	John Doe	john.doe@example.com	2023-01-10
1	102	Jane Smith	jane.smith@example.com	2023-01-15
2	103	Mike Jordan	mike.jordan@example.com	2023-01-20
3	104	Anna Frank	anna.frank@example.com	2023-01-25
4	105	Sarah Connor	sarah.connor@example.com	2023-01-30

[5]:
```
products_df
```

[5]:

	ProductID	Name	Category	Price
0	201	Laptop	Electronics	1000
1	202	Tablet	Electronics	500
2	203	Smartphone	Electronics	800
3	204	Earrings	Accessories	100
4	205	T-Shirt	Clothing	50

[6]:
```
orders_df
```

[6]:

	OrderID	CustomerID	OrderDate	ShipDate
0	301	101	2023-02-01	2023-02-03
1	302	102	2023-02-05	2023-02-07
2	303	103	2023-02-10	2023-02-12
3	304	104	2023-02-15	2023-02-19
4	305	105	2023-02-20	2023-02-25

[7]:
```
order_details_df
```

[7]:

	OrderID	ProductID	Quantity	Discount	OrderDetailID
0	301	201	1	0.0	301_201
1	302	202	2	0.1	302_202
2	303	203	1	0.0	303_203
3	304	204	1	0.0	304_204
4	304	205	3	0.2	304_205
5	305	205	1	0.0	305_205
6	305	204	2	0.0	305_204
7	305	201	1	0.3	305_201

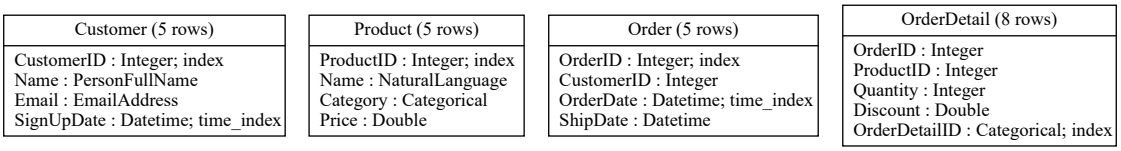
2 Define Entities & EntitySet

[8]:
```
es = ft.EntitySet(id="order_data")

es.add_dataframe(
    dataframe_name="Customer",
    dataframe=customers_df,
    index="CustomerID",
    time_index="SignUpDate",
    logical_types={
        "CustomerID": woodwork.logical_types.Integer,
        "Name": woodwork.logical_types.PersonFullName,
        "Email": woodwork.logical_types.EmailAddress,
        "SignUpDate": woodwork.logical_types.Datetime,
    },
)

es.add_dataframe(
    dataframe_name="Product",
    dataframe=products_df,
    index="ProductID",
    logical_types={
        "ProductID": woodwork.logical_types.Integer,
        "Name": woodwork.logical_types.NaturalLanguage,
        "Category": woodwork.logical_types.Categorical,
        "Price": woodwork.logical_types.Double,
    },
)
```

```
es.add_dataframe(
    dataframe_name="Order",
    dataframe=orders_df,
    index="OrderID",
    time_index="OrderDate",
    logical_types={
        "OrderID": woodwork.logical_types.Integer,
        "CustomerID": woodwork.logical_types.Integer,
        "OrderDate": woodwork.logical_types.Datetime,
        "ShipDate": woodwork.logical_types.Datetime,
    },
)

es.add_dataframe(
    dataframe_name="OrderDetail",
    dataframe=order_details_df,
    index="OrderDetailID",
    logical_types={
        "OrderDetailID": woodwork.logical_types.Categorical,
        "OrderID": woodwork.logical_types.Integer,
        "ProductID": woodwork.logical_types.Integer,
        "Quantity": woodwork.logical_types.Integer,
        "Discount": woodwork.logical_types.Double,
    },
)
```

[8]:
```
Entityset: order_data
  DataFrames:
    Customer [Rows: 5, Columns: 4]
    Product [Rows: 5, Columns: 4]
    Order [Rows: 5, Columns: 4]
    OrderDetail [Rows: 8, Columns: 5]
  Relationships:
    No relationships
```

[9]:
```
display_svg(es.plot())
```



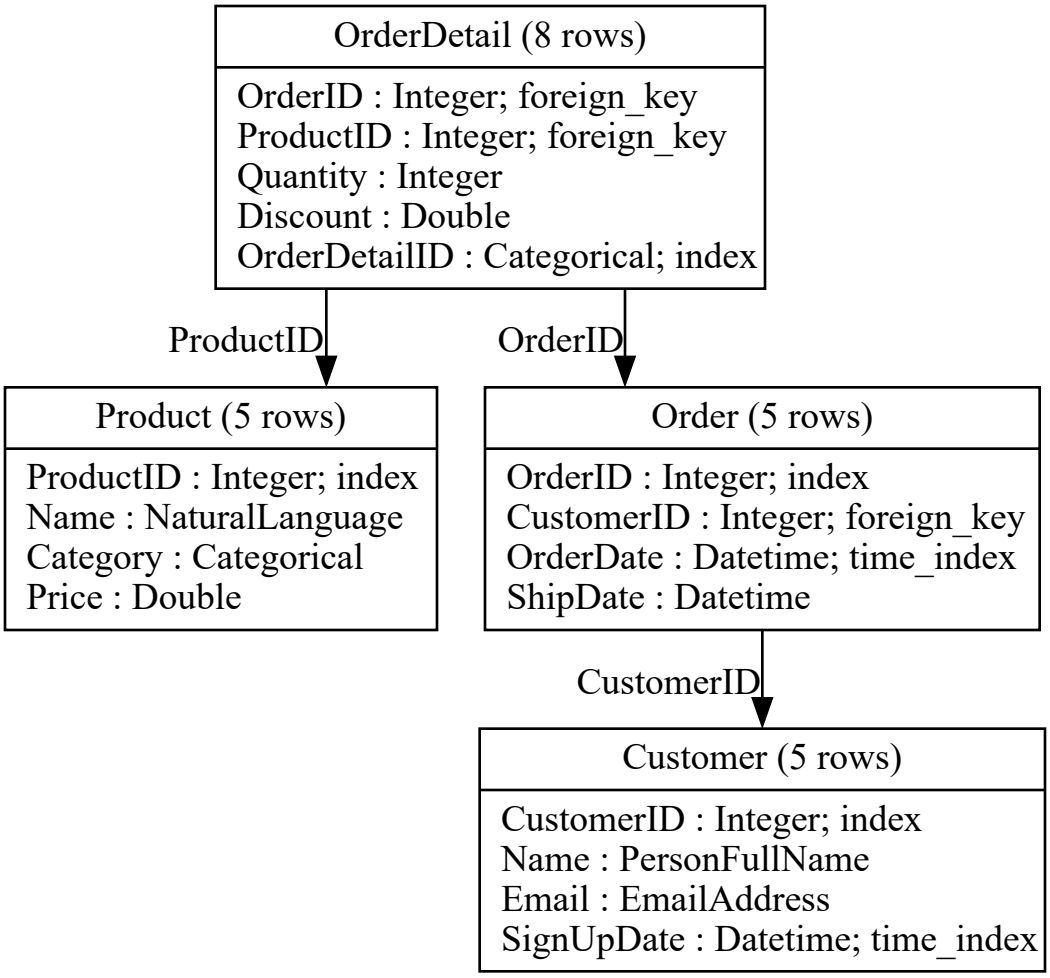
3 Establish relationship between entities

Recall the business rules and ERD from Section 1.

[10]:
```
es.add_relationships([
    ft.Relationship(es, "Customer", "CustomerID", "Order", "CustomerID"),
    ft.Relationship(es, "Order", "OrderID", "OrderDetail", "OrderID"),
    ft.Relationship(es, "Product", "ProductID", "OrderDetail", "ProductID"),
])
```

[10]:
```
Entityset: order_data
  DataFrames:
    Customer [Rows: 5, Columns: 4]
    Product [Rows: 5, Columns: 4]
    Order [Rows: 5, Columns: 4]
    OrderDetail [Rows: 8, Columns: 5]
  Relationships:
    Order.CustomerID -> Customer.CustomerID
    OrderDetail.OrderID -> Order.OrderID
    OrderDetail.ProductID -> Product.ProductID
```

[11]:
```
display_svg(es.plot())
```



4 Perform Deep Feature Synthesis to discover new features

Exploring possible primitives to apply:

- agg_primitives (default): ["sum", "std", "max", "skew", "min", "mean", "count", "percent_true", "num_unique", "mode"]
- trans_primitives (default): ["day", "year", "month", "weekday", "haversine", "num_words", "num_characters"]

[12]:
```
primitive_list = ft.list_primitives()
primitive_list[primitive_list["type"] == "aggregation"].
↪reset_index(drop=True)[["name", "type", "description"]]
```

[12]:

	name	type	\
0	percent_true	aggregation	
1	time_since_last_true	aggregation	
2	count_outside_range	aggregation	

```
3                           first  aggregation
4                  n_unique_weeks  aggregation
..                            …          …
60                          mean  aggregation
61                           min  aggregation
62          time_since_last_false  aggregation
63                           max  aggregation
64  n_unique_days_of_calendar_year  aggregation

                                          description
0           Determines the percent of `True` values.
1    Calculates the time since the last `True` value.
2   Determines the number of values that fall outs…
3               Determines the first value in a list.
4              Determines the number of unique weeks.
..                                                …
60        Computes the average for a list of values.
61  Calculates the smallest value, ignoring `NaN` …
62  Calculates the time since the last `False` value.
63  Calculates the highest value, ignoring `NaN` v…
64     Determines the number of unique calendar days.

[65 rows x 3 columns]
```

[13]:
```
primitive_list[primitive_list["type"] == "transform"].
↪reset_index(drop=True)[["name", "type", "description"]]
```

[13]:
```
                             name       type  \
0    scalar_subtract_numeric_feature  transform
1                       days_in_month  transform
2                  median_word_length  transform
3          less_than_equal_to_scalar  transform
4                           cum_count  transform
..                                …       …
133                          second  transform
134                 num_characters  transform
135               divide_by_feature  transform
136                            diff  transform
137                             lag  transform

                                           description
0    Subtracts each value in the list from a given …
1    Determines the number of days in the month of …
2                   Determines the median word length.
3    Determines if values are less than or equal to…
4                     Calculates the cumulative count.
..                                                 …
```

```
133        Determines the seconds value of a datetime.
134  Calculates the number of characters in a given…
135        Divides a scalar by each value in the list.
136  Computes the difference between the value in a…
137  Shifts an array of values by a specified numbe…

[138 rows x 3 columns]
```

4.1 Exploring `Customer` table

Drilling down on `Customer` table to find out potential features.

[14]:
```
feature_matrix, feature_defs = ft.dfs(
    entityset=es,
    target_dataframe_name="Customer",
    max_depth=2,
    agg_primitives=["sum", "mean", "count"],
    trans_primitives=None, # default
)
```

Result Performing DFS on `Customer` table doesn't seem to produce any meaningful feature that can be used for the design of data warehouse's star schema...

4.2 Exploring `Product` table

Drilling down on `Product` table to find out potential features.

[15]:
```
feature_matrix, feature_defs = ft.dfs(
    entityset=es,
    target_dataframe_name="Product",
    max_depth=3,
    agg_primitives=["sum", "mean", "count"],
    trans_primitives=None, # default
)
```

Result Same for `Product` table, DFS doesn't discover any useful feature for data warehouse modeling.

4.3 Exploring `Order` table

Drilling down on `Order` table to find out potential features.

Defining a Custom TransformPrimitive:

Custom Transform Primitive	Description
SubtractDatetime	`Order` table contains `ShipDate` and `OrderDate`, a plausible feature would be `DaysToShip`, which is the number of days takes to ship the order once it has been placed. Since Featuretools doesn't provide a transform primitive for subtracting datetime, we'd have to implement a custom transform primitive for it.
MultiplyThreeNumeric	Featuretools only provides a transform primitive known as *MultiplyNumeric* that applies multiplication to 2 list of numbers. In our case, we might need a primitive for multiplication of 3 numbers, i.e., `OrderDetail.Discount * Product.Price * Quantity` to obtain the total discount applied to an specific product.

[16]:
```
class SubtractDatetime(ft.primitives.TransformPrimitive):
    name = "subtract_datetime"
    input_types = [
        woodwork.column_schema.ColumnSchema(logical_type=woodwork.logical_types.
 ↪Datetime),
        woodwork.column_schema.ColumnSchema(logical_type=woodwork.logical_types.
 ↪Datetime)
    ]
    return_type = woodwork.column_schema.ColumnSchema(semantic_tags={"numeric"})

    def get_function(self):
        def subtract_datetime(datetime1, datetime2):
            delta = (datetime1 - datetime2).dt.days
            return delta
        return subtract_datetime

class MultiplyThreeNumeric(ft.primitives.TransformPrimitive):
    name = "multiply_three_numeric"
    input_types = [
        woodwork.column_schema.ColumnSchema(semantic_tags={"numeric"}),
        woodwork.column_schema.ColumnSchema(semantic_tags={"numeric"}),
        woodwork.column_schema.ColumnSchema(semantic_tags={"numeric"})
    ]
    return_type = woodwork.column_schema.ColumnSchema(semantic_tags={"numeric"})
    commutative = True
```

```
    def __init__(self, commutative=True):
        self.commutative = commutative

    def get_function(self):
        def multiply_three_numeric(numeric1, numeric2, numeric3):
            return numeric1 * numeric2 * numeric3
        return multiply_three_numeric

    def generate_name(self, base_feature_names):
        return "%s * %s * %s" % (base_feature_names[0], base_feature_names[1],␣
 ↪base_feature_names[2])

def get_feature_by_name(feature_defs, feature_name):
    """
    Helper method to obtain feature object by its name
    """
    for feat in feature_defs:
        if feat.get_name() == feature_name:
            return feat
    return None
```

[17]:
```
feature_matrix, feature_defs = ft.dfs(
    entityset=es,
    target_dataframe_name="Order",
    max_depth=3,
    agg_primitives=["sum", "count"],
    trans_primitives=["multiply_numeric", SubtractDatetime,␣
 ↪MultiplyThreeNumeric]
)
```

```
2023-11-16 03:13:51,287 featuretools - WARNING    Attempting to add feature
<Feature: Customer.COUNT(Order) * SUM(OrderDetail.Discount)> which is already
present. This is likely a bug.
2023-11-16 03:13:51,288 featuretools - WARNING    Attempting to add feature
<Feature: Customer.COUNT(Order) * SUM(OrderDetail.Quantity)> which is already
present. This is likely a bug.
2023-11-16 03:13:51,288 featuretools - WARNING    Attempting to add feature
<Feature: Customer.COUNT(OrderDetail) * SUM(OrderDetail.Discount)> which is
already present. This is likely a bug.
2023-11-16 03:13:51,289 featuretools - WARNING    Attempting to add feature
<Feature: Customer.COUNT(OrderDetail) * SUM(OrderDetail.Quantity)> which is
already present. This is likely a bug.
2023-11-16 03:13:51,290 featuretools - WARNING    Attempting to add feature
<Feature: Customer.SUM(OrderDetail.Discount) * SUM(OrderDetail.Quantity)> which
is already present. This is likely a bug.
2023-11-16 03:13:51,290 featuretools - WARNING    Attempting to add feature
<Feature: Customer.COUNT(Order) * SUM(OrderDetail.Discount) *
```

```
SUM(OrderDetail.Quantity)> which is already present. This is likely a bug.
2023-11-16 03:13:51,290 featuretools - WARNING    Attempting to add feature
<Feature: Customer.COUNT(OrderDetail) * SUM(OrderDetail.Discount) *
SUM(OrderDetail.Quantity)> which is already present. This is likely a bug.
```

Result Perform DFS on `Order` table yields the following features that might be useful for data warehouse:

- `SUM(OrderDetail.Quantity)`: total quantity of order items for each order
- `COUNT(OrderDetail)`: total number of unique items in each order
- `SUBTRACT_DATETIME(ShipDate, OrderDate)`: number of days take to ship a product for each order
- `SUM(OrderDetail.Product.Price * Quantity)`: the amount to pay before discount for each order
- `SUM(OrderDetail.Discount * Product.Price * Quantity)`: the discount amount for each order

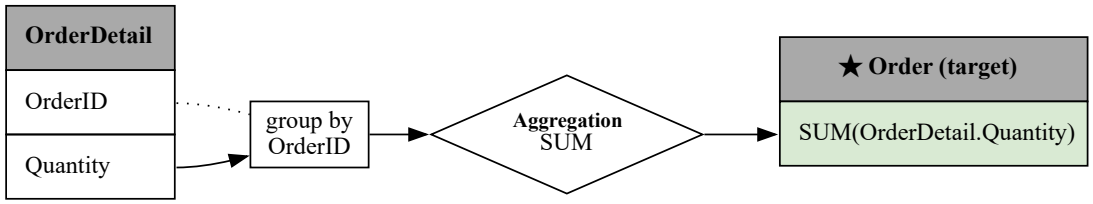
[18]:
```
# Collect the useful features generated
order_results = {
    "OrderTotalQuantity": {
        "feature_name": "SUM(OrderDetail.Quantity)",
        "feature_obj": get_feature_by_name(feature_defs=feature_defs,␣
 ↪feature_name="SUM(OrderDetail.Quantity)")
    },
    "OrderTotalUniqueItems": {
        "feature_name": "COUNT(OrderDetail)",
        "feature_obj": get_feature_by_name(feature_defs=feature_defs,␣
 ↪feature_name="COUNT(OrderDetail)")
    },
    "DaysToShip": {
        "feature_name": "SUBTRACT_DATETIME(ShipDate, OrderDate)",
        "feature_obj": get_feature_by_name(feature_defs=feature_defs,␣
 ↪feature_name="SUBTRACT_DATETIME(ShipDate, OrderDate)")
    },
    "OrderSubtotal": {
        "feature_name": "SUM(OrderDetail.Product.Price * Quantity)",
        "feature_obj": get_feature_by_name(feature_defs=feature_defs,␣
 ↪feature_name="SUM(OrderDetail.Product.Price * Quantity)")
    },
    "OrderDiscountAmount": {
        "feature_name": "SUM(OrderDetail.Discount * Product.Price * Quantity)",
        "feature_obj": get_feature_by_name(feature_defs=feature_defs,␣
 ↪feature_name="SUM(OrderDetail.Discount * Product.Price * Quantity)")
    },
}
```

```
feature_matrix[[order_results[var_name]["feature_name"] for var_name in␣
 ↪order_results]].T
```

[18]:
```
OrderID                                              301     302     303  \
SUM(OrderDetail.Quantity)                            1.0     2.0     1.0
COUNT(OrderDetail)                                     1       1       1
SUBTRACT_DATETIME(ShipDate, OrderDate)               2.0     2.0     2.0
SUM(OrderDetail.Product.Price * Quantity)         1000.0  1000.0  800.0
SUM(OrderDetail.Discount * Product.Price * Quan…     0.0   100.0    0.0

OrderID                                              304     305
SUM(OrderDetail.Quantity)                            4.0     4.0
COUNT(OrderDetail)                                     2       3
SUBTRACT_DATETIME(ShipDate, OrderDate)               4.0     5.0
SUM(OrderDetail.Product.Price * Quantity)          250.0  1250.0
SUM(OrderDetail.Discount * Product.Price * Quan…    30.0   300.0
```

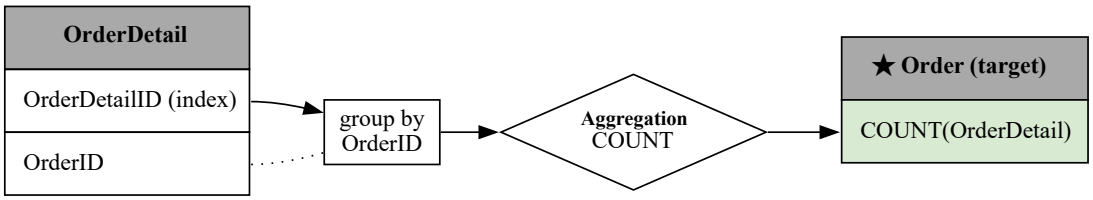
[19]:
```
for i, var_name in enumerate(order_results):
    feat_obj = order_results[var_name]["feature_obj"]
    feat_name = order_results[var_name]["feature_name"]

    print(f"{i+1}. {var_name}")
    display_svg(ft.graph_feature(feat_obj))
    print(f"Feature name\t\t: {feat_name}")
    print(f"Feature description\t: {ft.describe_feature(feat_obj)}")
    print()
```

1. OrderTotalQuantity



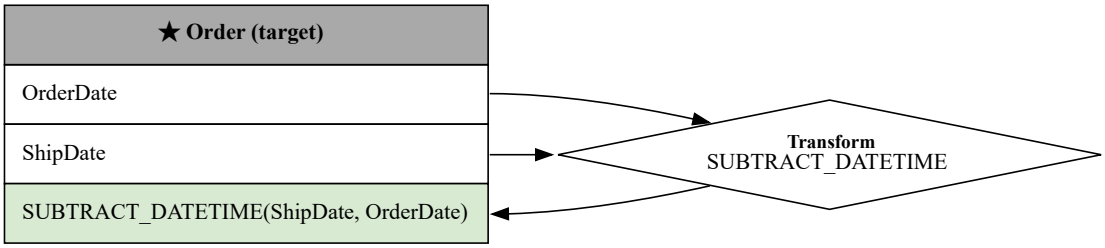

```
Feature name            : SUM(OrderDetail.Quantity)
Feature description     : The sum of the "Quantity" of all instances of
"OrderDetail" for each "OrderID" in "Order".
```

2. OrderTotalUniqueItems



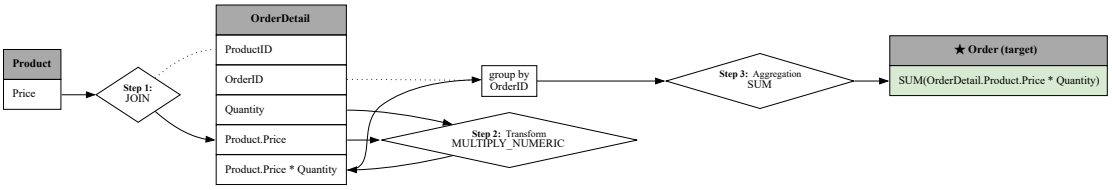
Feature name : COUNT(OrderDetail)
Feature description : The number of all instances of "OrderDetail" for each "OrderID" in "Order".

3. DaysToShip



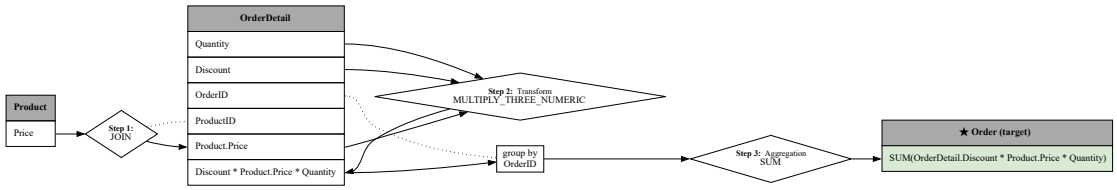
Feature name : SUBTRACT_DATETIME(ShipDate, OrderDate)
Feature description : The result of applying SUBTRACT_DATETIME to the "ShipDate", the "OrderDate".

4. OrderSubtotal



Feature name : SUM(OrderDetail.Product.Price * Quantity)
Feature description : The sum of the product of the "Price" for the instance of "Product" associated with this instance of "OrderDetail" and the "Quantity" of all instances of "OrderDetail" for each "OrderID" in "Order".

5. OrderDiscountAmount




```
Feature name            : SUM(OrderDetail.Discount * Product.Price * Quantity)
Feature description     : The sum of the result of applying
MULTIPLY_THREE_NUMERIC to the "Discount", the "Price" for the instance of
"Product" associated with this instance of "OrderDetail", the "Quantity" of all
instances of "OrderDetail" for each "OrderID" in "Order".
```

4.3.1 Create deeper features by running DFS on generated features

Based on the initial generated features (e.g., `"OrderSubtotal"` and `"OrderDiscountAmount"`), it's desirable to have a deeper feature that tell the **grand total** of the order by subtracting `"OrderDiscountAmount"` from `"OrderSubtotal"`. Thus, let's try running DFS on the already-generated features for the second time.

[20]:
```
# Create a new df by joining the original orders with the newly generated␣
 ↪features
new_orders_df = pd.merge(
    orders_df,
    feature_matrix[[order_results[var_name]["feature_name"] for var_name in␣
 ↪order_results]].reset_index(),
    left_on="OrderID", right_on="OrderID"
)

# Define new entity set
deeper_order_es = ft.EntitySet("deeper_orders")
deeper_order_es.add_dataframe(dataframe=new_orders_df,␣
 ↪dataframe_name="new_orders", index="OrderID")

display_svg(deeper_order_es.plot())
```

new_orders (5 rows)
OrderID : Integer; index CustomerID : Integer OrderDate : Datetime ShipDate : Datetime SUM(OrderDetail.Quantity) : Double COUNT(OrderDetail) : Integer SUBTRACT_DATETIME(ShipDate, OrderDate) : Double SUM(OrderDetail.Product.Price * Quantity) : Double SUM(OrderDetail.Discount * Product.Price * Quantity) : Double

[21]:
```
deeper_feature_matrix, deeper_feature_defs = ft.dfs(
    entityset=deeper_order_es,
    target_dataframe_name="new_orders",
    trans_primitives=[ft.primitives.SubtractNumeric(commutative=False)]
)
```

Result Perform DFS on the new `Order` table that consists of previously generated features yield the following useful features:

- `SUM(OrderDetail.Product.Price * Quantity) - SUM(OrderDetail.Discount * Product.Price * Quantity)`: the grand total amount to pay after discount

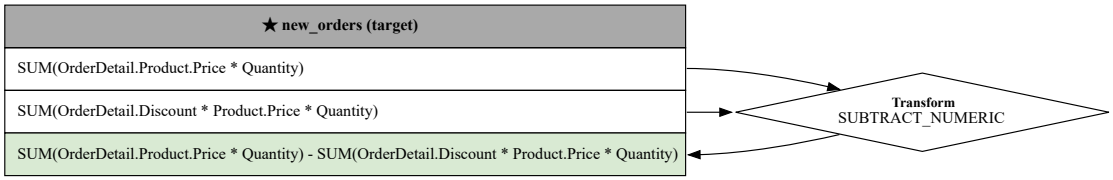
[22]:
```
# Update order_results with the newly generated feature
order_results["OrderGrandTotal"] = {
    "feature_name": "SUM(OrderDetail.Product.Price * Quantity) -␣
 ↪SUM(OrderDetail.Discount * Product.Price * Quantity)",
    "feature_obj": get_feature_by_name(feature_defs=deeper_feature_defs,␣
 ↪feature_name="SUM(OrderDetail.Product.Price * Quantity) - SUM(OrderDetail.
 ↪Discount * Product.Price * Quantity)")
}

deeper_feature_matrix[[order_results["OrderGrandTotal"]["feature_name"]]].T
```

[22]:
```
OrderID                                                 301    302    303  \
SUM(OrderDetail.Product.Price * Quantity) - SUM…  1000.0  900.0  800.0

OrderID                                                 304    305
SUM(OrderDetail.Product.Price * Quantity) - SUM…  220.0  950.0
```

[23]:
```
var_name = "OrderGrandTotal"
feat_name = order_results[var_name]["feature_name"]
```

```
feat_obj = order_results[var_name]["feature_obj"]

print(var_name)
display_svg(ft.graph_feature(feat_obj))
print(f"Feature name\t\t: {feat_name}")
print(f"Feature description\t: {ft.describe_feature(feat_obj)}")
```

```
OrderGrandTotal
```




```
Feature name            : SUM(OrderDetail.Product.Price * Quantity) -
SUM(OrderDetail.Discount * Product.Price * Quantity)
Feature description     : The result of the "SUM(OrderDetail.Product.Price *
Quantity)" minus the "SUM(OrderDetail.Discount * Product.Price * Quantity)".
```

4.4 Exploring `OrderDetail` table

Drilling down on `OrderDetail` table to find out potential features.

[24]:
```
feature_matrix, feature_defs = ft.dfs(
    entityset=es,
    target_dataframe_name="OrderDetail",
    max_depth=3,
    agg_primitives=[],
    trans_primitives=["multiply_numeric", MultiplyThreeNumeric]
)
```

Result Perform DFS on `OrderDetail` table yield the following features that might be useful for data warehouse:

- `Product.Price * Quantity`: the amount to pay before discount for each order detail
- `Discount * Product.Price * Quantity`: the discount amount for each order detail

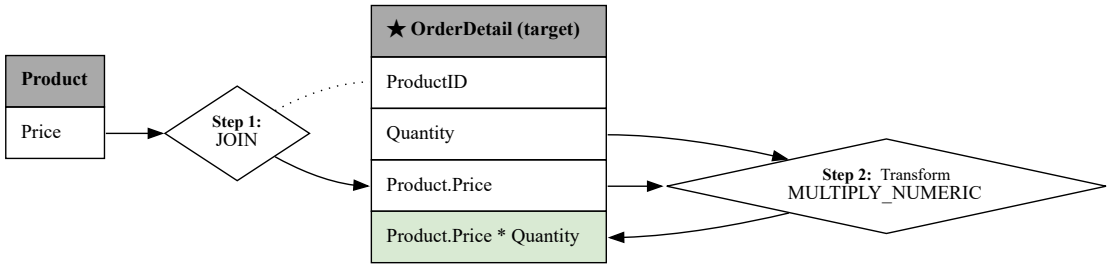
[25]:
```
# Collect the useful features generated
order_detail_results = {
    "OrderDetailSubtotal": {
        "feature_name": "Product.Price * Quantity",
        "feature_obj": get_feature_by_name(feature_defs=feature_defs,␣
 ↪feature_name="Product.Price * Quantity"),
    },
    "OrderDetailDiscountAmount": {
```

```
        "feature_name": "Discount * Product.Price * Quantity",
        "feature_obj": get_feature_by_name(feature_defs=feature_defs,␣
 ↪feature_name="Discount * Product.Price * Quantity"),
    },
}

feature_matrix[[order_detail_results[var_name]["feature_name"] for var_name in␣
 ↪order_detail_results]].T
```

[25]:
```
OrderDetailID                          301_201  302_202  303_203  304_204  \
Product.Price * Quantity                1000.0   1000.0    800.0    100.0
Discount * Product.Price * Quantity        0.0    100.0      0.0      0.0

OrderDetailID                          304_205  305_205  305_204  305_201
Product.Price * Quantity                 150.0     50.0    200.0   1000.0
Discount * Product.Price * Quantity       30.0      0.0      0.0    300.0
```

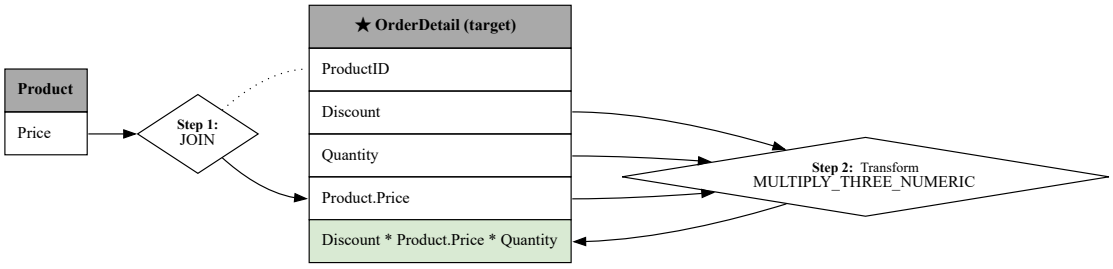
[26]:
```
for i, var_name in enumerate(order_detail_results):
    feat_obj = order_detail_results[var_name]["feature_obj"]
    feat_name = order_detail_results[var_name]["feature_name"]

    print(f"{i+1}. {var_name}")
    display_svg(ft.graph_feature(feat_obj))
    print(f"Feature name\t\t: {feat_name}")
    print(f"Feature description\t: {ft.describe_feature(feat_obj)}")
    print()
```

1. OrderDetailSubtotal




```
Feature name            : Product.Price * Quantity
Feature description     : The product of the "Price" for the instance of
"Product" associated with this instance of "OrderDetail" and the "Quantity".
```

2. OrderDetailDiscountAmount




```
Feature name            : Discount * Product.Price * Quantity
Feature description     : The result of applying MULTIPLY_THREE_NUMERIC to the
"Discount", the "Price" for the instance of "Product" associated with this
instance of "OrderDetail", the "Quantity".
```

4.4.1 Create deeper features by running DFS on generated features

Based on the initial generated features for `OrderDetail` (e.g., `"OrderDetailSubtotal"` and `"OrderDetailDiscountAmount"`), it's desirable to have a deeper feature that tell the **total payable amount** of the order detail by subtracting `"OrderDetailDiscountAmount"` from `"OrderDetailSubtotal"`. Thus, let's try running DFS on the already-generated features for the second time.

[27]:
```
# Create a new df by joining the original orders with the newly generated␣
↪features
new_order_details_df = pd.merge(
    order_details_df,
    feature_matrix[[order_detail_results[var_name]["feature_name"] for var_name␣
↪in order_detail_results]].reset_index(),
    left_on="OrderDetailID", right_on="OrderDetailID"
)

deeper_order_detail_es = ft.EntitySet("deeper_order_details")
deeper_order_detail_es.add_dataframe(dataframe=new_order_details_df,␣
↪dataframe_name="new_order_details", index="OrderDetailID")

display_svg(deeper_order_detail_es.plot())
```

new_order_details (8 rows)
OrderID : Integer ProductID : Integer Quantity : Integer Discount : Double OrderDetailID : Categorical; index Product.Price * Quantity : Double Discount * Product.Price * Quantity : Double

[28]:
```
deeper_feature_matrix, deeper_feature_defs = ft.dfs(
    entityset=deeper_order_detail_es,
    target_dataframe_name="new_order_details",
    trans_primitives=[ft.primitives.SubtractNumeric(commutative=False)]
)
```

Result Perform DFS on the new `OrderDetail` table that consists of previously generated features yield the following useful features:

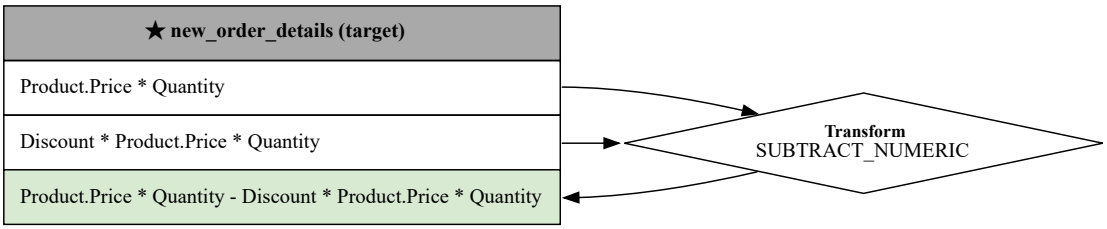
- `Product.Price * Quantity - Discount * Product.Price * Quantity`: the total amount to pay after discount for each order detail

[29]:
```
# Update order_detail_results with the newly generated feature
order_detail_results["OrderDetailPayableAmount"] = {
    "feature_name": "Product.Price * Quantity - Discount * Product.Price *␣
 ↪Quantity",
    "feature_obj": get_feature_by_name(feature_defs=deeper_feature_defs,␣
 ↪feature_name="Product.Price * Quantity - Discount * Product.Price *␣
 ↪Quantity")
}

deeper_feature_matrix[[order_detail_results["OrderDetailPayableAmount"]["feature_name"]]].
 ↪T
```

[29]:
```
OrderDetailID                                  301_201  302_202  303_203  \
Product.Price * Quantity - Discount * Product.P…  1000.0    900.0    800.0

OrderDetailID                                  304_204  304_205  305_205  \
Product.Price * Quantity - Discount * Product.P…   100.0    120.0     50.0

OrderDetailID                                  305_204  305_201
Product.Price * Quantity - Discount * Product.P…   200.0    700.0
```

[30]:
```
var_name = "OrderDetailPayableAmount"
feat_name = order_detail_results[var_name]["feature_name"]
feat_obj = order_detail_results[var_name]["feature_obj"]

print(var_name)
display_svg(ft.graph_feature(feat_obj))
print(f"Feature name\t\t: {feat_name}")
print(f"Feature description\t: {ft.describe_feature(feat_obj)}")
```

```
OrderDetailPayableAmount
```




```
Feature name            : Product.Price * Quantity - Discount * Product.Price *
Quantity
Feature description     : The result of the "Product.Price * Quantity" minus the
"Discount * Product.Price * Quantity".
```

4.5 Getting the derivatives of `date`

A simple date attribute can be decomposed into multiple sub-attributes (e.g., `"day"`, `"weekday"`, `"week"`, `"quarter"`, `"month"`, `"year"`).

[31]:
```
feature_matrix, feature_defs = ft.dfs(
    entityset=es,
    target_dataframe_name="Order",
    agg_primitives=[],
    trans_primitives=["day", "weekday", "week", "quarter", "month", "year"]
)
```

Result Applying transformation on date (e.g., `OrderDate`) yields these:

- `DAY(OrderDate)`: Extracts the day of the month from the `OrderDate`.
- `WEEKDAY(OrderDate)`: Determines the day of the week (Monday is 0 and Sunday is 6) for the `OrderDate`.
- `WEEK(OrderDate)`: Identifies the week number of the year for the `OrderDate`.
- `QUARTER(OrderDate)`: Determines the quarter of the year for the `OrderDate`.
- `MONTH(OrderDate)`: Extracts the month from the `OrderDate`.
- `YEAR(OrderDate)`: Extracts the year from the `OrderDate`.

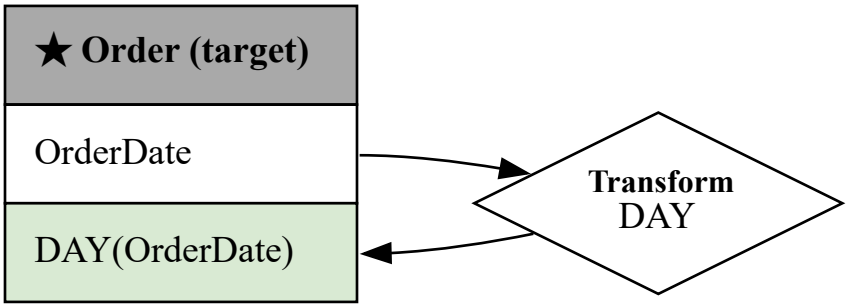
[32]:
```
# Collect the useful features generated
date_attr_name = "OrderDate" # ShipDate

date_results = {
    "day": {
        "feature_name": f"DAY({date_attr_name})",
        "feature_obj": get_feature_by_name(feature_defs=feature_defs,␣
 ↪feature_name=f"DAY({date_attr_name})"),
    },
    "weekday": {
        "feature_name": f"WEEKDAY({date_attr_name})",
        "feature_obj": get_feature_by_name(feature_defs=feature_defs,␣
 ↪feature_name=f"WEEKDAY({date_attr_name})"),
    },
    "week": {
        "feature_name": f"WEEK({date_attr_name})",
        "feature_obj": get_feature_by_name(feature_defs=feature_defs,␣
 ↪feature_name=f"WEEK({date_attr_name})"),
    },
    "month": {
        "feature_name": f"MONTH({date_attr_name})",
        "feature_obj": get_feature_by_name(feature_defs=feature_defs,␣
 ↪feature_name=f"MONTH({date_attr_name})"),
    },
    "quarter": {
        "feature_name": f"QUARTER({date_attr_name})",
        "feature_obj": get_feature_by_name(feature_defs=feature_defs,␣
 ↪feature_name=f"QUARTER({date_attr_name})"),
    },
    "year": {
        "feature_name": f"YEAR({date_attr_name})",
        "feature_obj": get_feature_by_name(feature_defs=feature_defs,␣
 ↪feature_name=f"YEAR({date_attr_name})"),
    },
}

feature_matrix[[date_results[var_name]["feature_name"] for var_name in␣
 ↪date_results]].T
```

[32]:

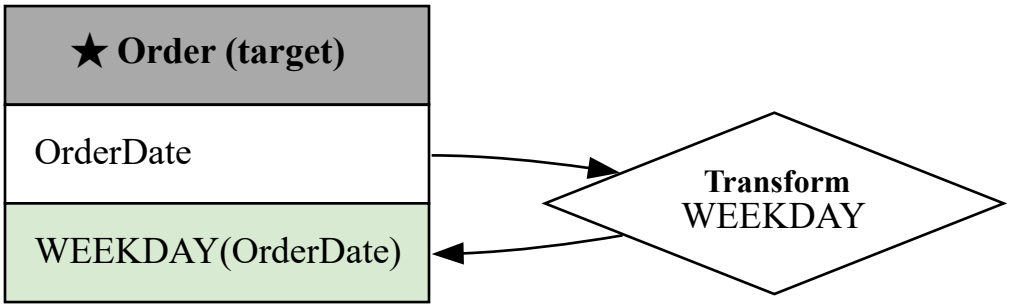
OrderID	301	302	303	304	305
DAY(OrderDate)	1	5	10	15	20
WEEKDAY(OrderDate)	2	6	4	2	0
WEEK(OrderDate)	5	5	6	7	8
MONTH(OrderDate)	2	2	2	2	2
QUARTER(OrderDate)	1	1	1	1	1
YEAR(OrderDate)	2023	2023	2023	2023	2023

[33]:
```
for i, var_name in enumerate(date_results):
    feat_obj = date_results[var_name]["feature_obj"]
    feat_name = date_results[var_name]["feature_name"]

    print(f"{i+1}. {var_name}")
    display_svg(ft.graph_feature(feat_obj))
    print(f"Feature name\t\t: {feat_name}")
    print(f"Feature description\t: {ft.describe_feature(feat_obj)}")
    print()
```

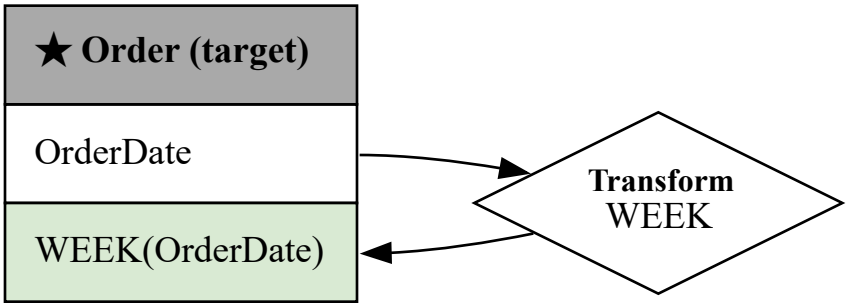
```
1. day
```




```
Feature name            : DAY(OrderDate)
Feature description     : The day of the month of the "OrderDate".

2. weekday
```

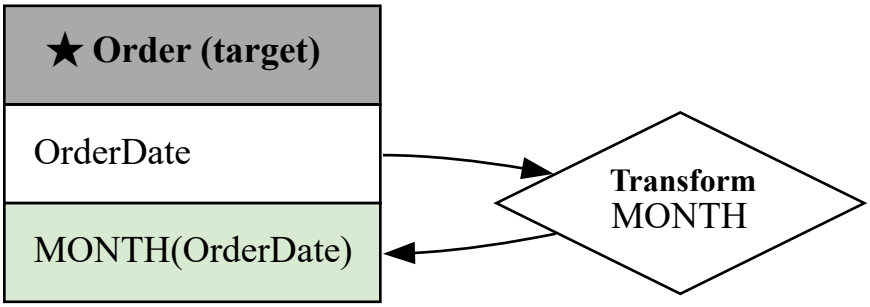



```
Feature name            : WEEKDAY(OrderDate)
Feature description     : The day of the week of the "OrderDate".

3. week
```



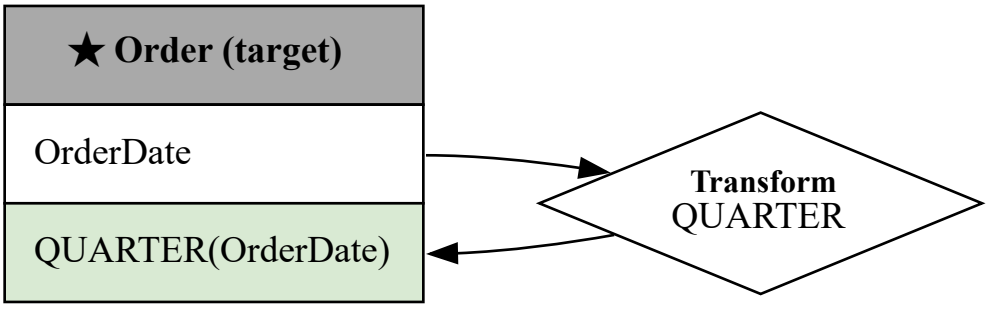

```
Feature name            : WEEK(OrderDate)
Feature description     : The week of the year of the "OrderDate".
```

```
4. month
```



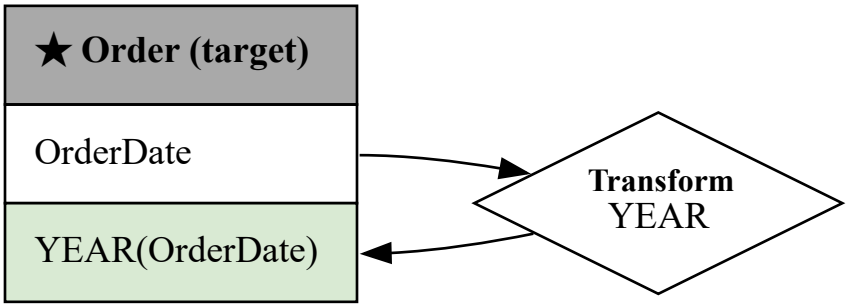

```
Feature name            : MONTH(OrderDate)
Feature description     : The month of the "OrderDate".
```

```
5. quarter
```



```
Feature name            : QUARTER(OrderDate)
Feature description     : The quarter that describes the "OrderDate".
```

6. year




```
Feature name            : YEAR(OrderDate)
Feature description     : The year of the "OrderDate".
```

[ ]: