fn make_expr_datetime_component

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This proof resides in **"contrib"** because it has not completed the vetting process.

Proves soundness of `make_expr_datetime_component` in `mod.rs` at commit f5bb719 (outdated[1]).
`make_expr_datetime_component` returns a Transformation that extracts a component from a temporal data type.

1 Hoare Triple

Precondition

Compiler-verified

- Argument `input_domain` of type `ExprDomain`
- Argument `input_metric` of type `M`
- Generic `M` implements `OuterMetric`
  - `OuterMetric` defines an associated type `InnerMetric` that must implement `DatasetMetric`
- `(ExprDomain, M)` implements `MetricSpace`
- `Expr` implements `StableExpr<M, M>`

Caller-verified

None

Pseudocode

```
def make_expr_datetime_component(
    input_domain: ExprDomain,
    input_metric: M,
    expr: Expr,
) -> Transformation:
    match expr:  #
        case Expr.Function(input=inputs, function=FunctionExpr.TemporalExpr(
    temporal_function)):
            pass
        case _:
            raise ValueError("expected datetime component expression")

    to_dtype, _ = match_datetime_component(temporal_function)  #

```

[1] See new changes with `git diff f5bb719..7b6eb5e rust/src/transformations/make_stable_expr/namespace_dt/expr_datetime_component/mod.rs`

```
    # raises an error if there is not exactly one input
    input, = inputs  #

    t_prior = input.make_stable(input_domain, input_metric)  #
    middle_domain, middle_metric = t_prior.output_space()

    in_dtype = middle_domain.column.dtype
    if in_dtype not in {DataType.Time, DataType.Datetime, DataType.Date}:  #
        raise ValueError("expected a temporal input type")

    output_domain = middle_domain.clone()  #
    output_domain.column.set_dtype(to_dtype) #

    def function(expr: Expr) -> Expr:
        return Expr.Function(
            input=[expr],
            function=FunctionExpr.TemporalExpr(temporal_function),
            options=FunctionOptions(
                collect_groups=ApplyOptions.ElementWise,
            ),
        )

    return t_prior >> Transformation.new(  #
        middle_domain,
        output_domain,
        Function.then_expr(function),
        middle_metric,
        middle_metric,
        StabilityMap.new(lambda d_in: d_in),
    )
```

Postcondition

Theorem 1.1. For every setting of the input parameters `(input_domain, input_metric, M)` to `make_expr_datetime_component` such that the given preconditions hold, `make_expr_datetime_component` raises an error (at compile time or run time) or returns a valid transformation. A valid transformation has the following properties:

1. (Data-independent runtime errors). For every pair of members x and x' in `input_domain`, `invoke`(x) and `invoke`(x') either both return the same error or neither return an error.

2. (Appropriate output domain). For every member x in `input_domain`, `function`(x) is in `output_domain` or raises a data-independent runtime error.

3. (Stability guarantee). For every pair of members x and x' in `input_domain` and for every pair (`d_in`, `d_out`), where `d_in` has the associated type for `input_metric` and `d_out` has the associated type for
`output_metric`, if x, x' are `d_in`-close under `input_metric`, `stability_map(d_in)` does not raise an error, and `stability_map(d_in)` $=$ `d_out`, then `function`(x), `function`(x') are `d_out`-close under `output_metric`.

2 Proof

Starting from line 6, `expr` is matched as if it were a temporal expression, or otherwise rejects the expression. All preconditions for `make_datetime_component` on line 12 are satisfied by the compiler, therefore by the postcondition `to_dtype` and `max_num_partitions` are the output data type and upper bound on the number of unique values in the output.

All preconditions for `make_stable` on line 17 are compiler-verified, therefore by the postcondition `t_prior` is a valid transformation. To prove that the output is a valid transformation, we must first prove that the transformation on line 36 is a valid transformation.

Proof of Data-Independent Errors. If the input data type does not include the component, then all possible choices of input dataset would fail, resulting in data-independent errors.

If the input data type does include the component, then Polars will never raise an error. □

Proof of Output Domain. The output domain is the same as the input domain, but the active series has a new data type and margin metadata needs to be updated. Line 25 updates the series domain so that non-null elements are of type `to_type`, which by the postcondition of `match_datetime_component` on line 12 represents the type of outputs when `temporal_function` is applied to the data.

Other domain descriptors, like the nullity and name, remain unchanged. New null values cannot be introduced, because retrieval of a time component fails (in a data-independent way) if the component is not present in the type. The output domain now accounts for all transformations made to data in the input domain. □

Proof of Stability. Datetime component retrieval is a 1-stable row-by-row transformation, as the component retrieval is applied independently to each and every row. See `make_row_by_row` for a proof of the stability of row-by-row functions. □

Since it has been shown that both `t_prior` and the component transformation are valid transformations, then the preconditions for `make_chain_tt` are met (invoked via the right-shift operator shorthand), and therefore the output is a valid transformation.