

# fn make\_expr\_datetime\_component

Michael Shoemate

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Proves soundness of `make_expr_datetime_component` in `mod.rs` at commit `f5bb719` (outdated<sup>1</sup>). `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

```
1 def make_expr_datetime_component(
2     input_domain: ExprDomain,
3     input_metric: M,
4     expr: Expr,
5 ) -> Transformation:
6     match expr: #
7         case Expr.Function(input=inputs, function=FunctionExpr.TemporalExpr(
8             temporal_function)):
9             pass
10            case _:
11                raise ValueError("expected datetime component expression")
12
13    to_dtype, _ = match_datetime_component(temporal_function) #
```

<sup>1</sup>See new changes with `git diff f5bb719..5c077eb rust/src/transformations/make_stable_expr/namespace_dt/expr_datetime_component.rs`

```

14     # raises an error if there is not exactly one input
15     input, = inputs #
16
17     t_prior = input.make_stable(input_domain, input_metric) #
18     middle_domain, middle_metric = t_prior.output_space()
19
20     in_dtype = middle_domain.column.dtype
21     if in_dtype not in {DataType.Time, DataType.Datetime, DataType.Date}: #
22         raise ValueError("expected a temporal input type")
23
24     output_domain = middle_domain.clone() #
25     output_domain.column.set_dtype(to_dtype) #
26
27     def function(expr: Expr) -> Expr:
28         return Expr.Function(
29             input=[expr],
30             function=FunctionExpr.TemporalExpr(temporal_function),
31             options=FunctionOptions(
32                 collect_groups=ApplyOptions.ElementWise,
33             ),
34         )
35
36     return t_prior >> Transformation.new( #
37         middle_domain,
38         output_domain,
39         Function.then_expr(function),
40         middle_metric,
41         middle_metric,
42         StabilityMap.new(lambda d_in: d_in),
43     )

```

## 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.  $\square$

*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.  $\square$

*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.  $\square$

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.