

CubeLib 4.4 | Derived Metrics

Intoduction in CubePL and Cube's derived metrics

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The Scalasca Development Team
scalasca@fz-juelich.de

Attention

The Cube Derived Metrics User Guide is currently being rewritten and still incomplete. However, it should already contain enough information to get you started and avoid the most common pitfalls.

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1 Introduction into Cube Derived Metrics

1.1 Introduction

With Cube 4.1.0 derived metrics are introduced and provide a powerful tool for performance data processing.

Unlike normal metrics of the cube, derived metrics do not store any data inside of the cube report, but derive their value according to an expression, formulated using CubePL (Cube Processing Language) syntax ('3').

Cube supports different kinds ('1.3') of derived metrics. Derived metric can be a child metric of any metric of cube or other derived metrics.

Derived metrics are naturally metrics with the value DOUBLE

1.2 Creation of a derived metric in Cube

Derived metrics play the very same role as a normal metric in cube, therefore one proceeds with creation of derived metrics as usual. The only difference is the specification of the CubePL expression.

1.2.1 Using the C writer

To create a derived metric in a C program, one calls `cube_metric_set_expression(...)` subsequently to `cube_def_met(...)`. Here is a code example:

```
cube_metric * met = cube_def_met(cube,
                                "Derived metric",
                                "derivedmetric1",
                                "DOUBLE",
                                "sec",
                                "",
                                "https://doc.web.org/metrics.html#derived",
                                "Average execution time",
                                NULL,
                                CUBE_METRIC_PREDERIVED_EXCLUSIVE
                                );
cube_metric_set_expression(met, "metric::time(i)/metric::visits(e)");
```

Derived metric specification allows to define an CubePL expression, which will be executed only once before the actual metric expression is executed. To specify an initialization expression, one uses the call `cube_metric_set_init_expression(...)`.

Prederived metrics allow to redefine operators "+" and "-" in the aggregation formula by any user defined expression using same CubePL syntax.

Any such expression should be a formula of "arg1" and "arg2" parameters. E.g. `max(arg1, arg2)`.

To specify an expression for an aggregation operator one uses the call `cube_metric_set_aggr_expression(me` where operator can be `CUBE_METRIC_AGGR_PLUS` or `CUBE_METRIC_AGGR_MINUS`

1.2.2 Using the C++ library

To create a derived metric in C++ programs, one specifies the expression as the last parameter of the metric definition. This parameter can be omitted, in this case the derived metric returns always 0.

Here is a code example:

```
Metric * met = cube.def_met(
    "Derived metric",
    "derivedmetric1",
    "DOUBLE",
    "sec",
    "",
    "https://doc.web.org/metrics.html#derived",
    "Average execution time",
    NULL,
    CUBE_METRIC_PREDERIVED_EXCLUSIVE,
    "${unit}*metric::time(i)/metric::visits(e)",
    "{ ${unit}=1000; }",
    "min(arg1,arg2)",
    ""
);
```

`CUBE_METRIC_PREDERIVED_EXCLUSIVE` defines the kind of the derived metric (see '1.3' below).

Derived metric specification allows to define an CubePL expression, which will be executed only once before the actual metric expression is executed. This expression is the last argument in the parameter `{ ${unit}=1000; }`.

Operator "+" is redefined like `min(arg1,arg2)`.

Note, that the CubePL expression should be valid at the time of execution. It means, if there is a reference to metric, this metric should be defined before.

1.3 The three kinds of derived metrics

Cube provides an API to calculate different inclusive and exclusive values aggregated over different dimensions.

In the context of derived metrics it is sometimes useful, when evaluation of the expression is done after the aggregation of the metrics in the expression, sometimes it is needed to aggregate values of the derived metrics.

Therefor Cube provides three kinds of derived metrics:

1. **Predetermined exclusive metric** - metric, which value of which expression is observed as "being stored" inside of cube report and it behaves as a usual exclusive (along call tree) metric.

One specifies this type of metric using constant

CUBE_METRIC_PREDERIVED_EXCLUSIVE

For this metric one can redefine only operator "+". Operator "-" will be ignored.

2. **Predetermined inclusive metric** - metric, which value of which expression is observed as "being stored" inside of cube report and it behaves as a usual inclusive (along call tree) metric.

One specifies this type of metric using constant

CUBE_METRIC_PREDERIVED_INCLUSIVE

For this metric one can redefine both operators, "+" and "-".

3. **Postderived metric** - metric, which expression evaluated only after metrics, which were used inside of the expression, get aggregated according to the aggregation context (along system tree or along call tree).

If expression doesn't contain references to another metrics, no aggregation is done. In this case the expression gets calculated and its value returned.

One specifies this type of metric using constant

CUBE_METRIC_POSTDERIVE

This metric doesn't allow to redefine any operators, because calculation of this metric is performed AFTER aggregation within another metric.

2 Reference of CubePL

2.1 Supported calls in CubePL

Here is the table of currently supported calls in CubePL:

| Operation | Explanation |
|--|--|
| 123.34 | a numerical constant |
| "STRING" | a string constant |
| -x | negative value of x |
| () | grouping (priority) |
| | absolute value |
| + - / * | arithmetical operations |
| A^x | A in power of x |
| > < >= <= != == | numerical comparison |
| and or xor not | boolean operations |
| eq | string comparison |
| seq | case insensitive string comparison |
| =~ /expression/ | matching of regular <i>expression</i> |
| sin(x) cos(x) asin(x) acos(x) tan(x) cot(x) atan(x) acot(x) | trigonometrical functions |
| ln(x) | natural logarithm of x |
| exp(x) | natural exponent of x |
| sqrt(x) | square root value of x |
| random(x) | random number from 0 to x |
| pos(x) | returns x, if x>, or 0 |
| neg(x) | returns x, if x<0, or 0 |
| sgn(x) | returns -1, if x<0, 0 if x is 0 and 1 is x>0 |
| abs(x) | returns absolut value |
| ceil(x) | returns smallest integer value, which is bigger than x |
| floor(x) | returns biggest integer value, which is smaller than x |
| min(x,y) | returns smaller value of x and y |
| max(x,y) | returns bigger value of x and y |

| | |
|--|---|
| uppercase(x) | returns uppercase version of x |
| lowercase(x) | returns lowercase version of x |
| env("x") | returns a value of the environment variable x |
| local(var) | Declares (to compile time) a variable <i>var</i> as local. It cannot be redeclared later |
| global(var) | Declares (to compile time) a variable <i>var</i> as global. It cannot be redeclared later |
| \${var} | 0th element of the variable with name <i>var</i> |
| \${var}[x] | x-th element of the variable with name <i>var</i> |
| sizeof(var) | number of elements in the variable <i>var</i> |
| defined(var) | returns true (1), if the variable <i>var</i> is defined, otherwise it returns false (0) |
| metric:: <i>uniq_name</i> (i e *, i e *) | context sensitive value of metric <i>uniq_name</i> |
| metric::context:: <i>uniq_name</i> (i e *, i e *) | context sensitive value of metric <i>uniq_name</i> |
| metric::fixed:: <i>uniq_name</i> (i e *, i e *) | context independend value of metric <i>uniq_name</i> |
| metric::call:: <i>uniq_name</i> (c_id, i e *, s_id, i e *) | value of metric <i>uniq_name</i> for the call path with id <i>c_id</i> and system resource with an id <i>s_id</i> |
| cube::metric::set:: <i>uniq_name</i> ("X", "Y") | sets a property X of a metric <i>uniq_name</i> to value Y. Corrently supported are only "value" with value "VOID" or else |
| cube::metric::get:: <i>uniq_name</i> ("X") | returns a property X of a metric <i>uniq_name</i> . Corrently supported are <ol style="list-style-type: none">1. <i>unique name</i> - returns unique name of a metric <i>uniq_name</i>2. <i>display name</i> - returns display name of a metric <i>uniq_name</i>3. <i>uom</i> - returns unit of measurement of a metric <i>uniq_name</i>4. <i>dtype</i> - returns data type of a metric <i>uniq_name</i> as a string5. <i>url</i> - returns url of online help for the metric <i>uniq_name</i>6. <i>description</i> - returns description of a metric <i>uniq_name</i>7. <i>value</i> - returns property "value" for the metric <i>uniq_name</i>. Its value "VOID" deactivates metric and it returns always a zero. |

3 Syntax of CubePL

3.1 Syntax step by step

This chapter introduced the CubePL syntax of the most common programming structures.

3.1.1 Expressions

3.1.1.1 Constants

Any constant expression is an expression. eg. 123.0, "someString"

3.1.1.2 Arithmetical Expressions

Common mathematical notation of an arithmetical expression is valid in CubePL. Any arithmetical expression is an expression. eg. 123.0 + 23.6, sin(23)

3.1.1.3 Boolean Expressions

Common literal notation of a boolean expression is valid in CubePL. Any boolean expression is an expression.

```
[expression] or|and|xor [expression]
```

```
or
```

```
not [expression]
```

Any expression can be a term of a boolean expression. Non zero value is observed as TRUE, zero value is FALSE.

3.1.1.4 Function call expressions

Function calls have the following syntax:

```
name ( [expression ] )
```

3.1.2 Lambda function (In-place function definition)

To define a function in-place, one uses the following syntax:

```
{
  [statement];
  [statement];
  ...
  return [expression];
}
```

In-place definition of a function is an expression. It means, it can appear everywhere, where one can use an expression.

3.1.3 Control structures

Control structures like *if-else* or *while* are statements.

3.1.3.1 Condition IF-ELSE

One can execute series of statements under a condition using the short form of the *if* statement:

```
if ( condition )
{
  [statement];
  [statement];
  ...
}
```

or full form with *else* :

```
if ( condition )
{
  [statement];
  [statement];
  ...
}
else
{
  [statement];
  [statement];
  ...
}
```

condition is a boolean expression

3.1.3.2 Loop WHILE

One can execute a series of statements as long as a condition is true using the *while* statement:

```
while ( condition )
{
  [statement];
  [statement];
  ...
}
```

Sequence of statements will be executed till condition is not fulfilled, max 1000000000 times.

3.1.4 Variables

CubePL allows to work with memory, by using variables. All variables are multi-typed:

- In string context value of a numeric variable is presented in string format.
- In numerical context a string variable is converted to its numerical representation, if possible. Otherwise it is 0.

All variables are arrays. Indexless access to the variable assumes mutually index value 0.

3.1.4.1 User defined Variables

The user can define a variable using the syntax:

```
${ name } = [expression];
```

or

```
${ name }[index] = [expression];
```

Currently its name is a fixed string of characters. In later versions of CubePL it will allow any expression.

Example of a string context :

```
${name} seq "STRING"
```

Example of a numeric context :

```
${name} >= 0.34
```

Example of an array access to the variable :

```
${name}[ ${i} ] >= 0.34
```

Access to the variable is an expression.

Index for the access to the value is also an expression.

3.1.4.2 Predefined Variables

Cube provides a set of predefined variables for every calculation, which values are independent. Following predefined variables do contain the general information about the cube:

| Predefined variable | Explanation |
|--------------------------------|--|
| cube::#mirrors | Number of mirrors in cube file |
| cube::#metrics | Number of metrics in cube file |
| cube::#root::metrics | Number of root metrics in cube file |
| cube::#regions | Number of regions in cube file |
| cube::#callpaths | Number of call paths in cube file |
| cube::#root::callpaths | Number of root call paths |
| cube::#locations | Number of locations in cube file |
| cube::#locations::void | Number of void locations in cube file |
| cube::#locations::nonvoid | Number of nonvoid locations in cube file |
| cube::#locationgroups | Number of location groups in cube file |
| cube::#locationgroups::void | Number of void location groups in cube file |
| cube::#locationgroups::nonvoid | Number of nonvoid location groups in cube file |
| cube::#stns | Number of system tree nodes in cube file |
| cube::#rootstns | Number of root system tree nodes in cube file |
| cube::filename | Name of the cube file |

CubePL engine defines a set of variables, which do depend on an index, their "id". Using call `sizeof(...)` one can run over them and inspect within CubePL expression.

| | |
|------------------------------|--|
| cube::metric::unit::name | Unique name of the metric |
| cube::metric::disp::name | Display name of the metric |
| cube::metric::url | URL of the documentation of the metric |
| cube::metric::description | Description of the metric |
| cube::metric::dtype | Data type of the metric |
| cube::metric::uom | Unit of measurement of the metric |
| cube::metric::expression | CubePL expression of the metric |
| cube::metric::initexpression | CubePL initialisation expression of the metric |
| cube::metric::parentd::id | ID of the parent of the metric |
| cube::metric::#children | Number of children in the metric |

| | |
|----------------------------|-------------------------------------|
| cube::callpath::mod | Module of the call path |
| cube::callpath::line | File line of the call path |
| cube::calleeid | ID of the callee region |
| cube::callpath::#children | Number of children in the call path |
| cube::callpath::parent::id | ID of the parent callpath |

| | |
|-----------------------------|--|
| cube::region::name | Name of the region |
| cube::region::mangled::name | Mangled name of the region |
| cube::region::paradigm | Name of the paradigm of the region |
| cube::region::role | Name of the role the region is playing within the paradigm |
| cube::region::url | URL with the description of the region of the call path |

| | |
|---------------------------|--|
| cube::region::description | Description of the region of the call path |
| cube::region::mod | Module of the region of the call path |
| cube::region::begin::line | Begin line of the region of the call path |
| cube::region::end::line | End line of the region of the call path |

| | |
|----------------------------|--|
| cube::stn::name | Name of the system tree node |
| cube::stn::class | Class of the system tree node |
| cube::stn::description | Description of the system tree node |
| cube::stn::#children | Number of children (other system tree nodes) of the system tree node |
| cube::stn::#locationgroups | Number of location groups of the system tree node |
| cube::stn::parent::id | ID (among all system tree nodes) of the parent of the system tree node |
| cube::stn::parent::sysid | ID (global) of the parent of the system tree node |

| | |
|------------------------------------|---|
| cube::locationgroup::name | Name of the location group |
| cube::locationgroup::rank | Rank of the location group |
| cube::locationgroup::type | Type of the location group |
| cube::locationgroup::void | Is the this location group void? |
| cube::locationgroup::#locations | Number of locations of the location group |
| cube::locationgroup::parent::id | ID (among all system tree nodes) of the parent system tree node |
| cube::locationgroup::parent::sysid | ID (global) of the parent system tree node |

| | |
|-------------------------------|---|
| cube::location::name | Name of the location |
| cube::location::rank | Rank of the location |
| cube::location::type | Type of the location |
| cube::location::void | Is the this location void? |
| cube::location::parent::id | ID (among all location groups) of the parent location group |
| cube::location::parent::sysid | ID (global) of the parent location group |

CubePL engine sets a series of context sensitive variables, which value depends on the parameters, for which the derived metric is being calculated. Their value can be used to refer to the values of context insensitive variables described above:

| | |
|---------------------------|--|
| calculation::metric::id | ID of the metric, being calculated |
| calculation::callpath::id | ID of the callpath, for what is the metric being calculated |
| calculation::region::id | ID of the region, for what is the metric being calculated |
| calculation::sysres::id | ID (local within system resource type) if the system resource, for what is the metric being calculated |

| | |
|----------------------------|--|
| calculation::sysres::sysid | ID (global) if the sysem resource, for what is the metric being calculated |
| calculation::sysres::kind | Type of the system element: <ul style="list-style-type: none">• 0 = unknown• 5 = system tree node• 6 = location group• 7 = location |

3.1.5 Different ways to refer an another metric

3.1.5.1 Context sensitive reference to another metric

To use values of another metric in the same calculation context, one uses syntax:

```
metric::[uniq_name]( modifier, modifier )
```

or

```
metric::[uniq_name]( modifier)
```

or

```
metric::[uniq_name]()
```

There are three version of this call:

1. with two arguments (call path and system);
2. with one argument (call path);
3. with no argument(an arguments takes as '*').

`modifier` specifies flavor of the calculation: `i` - inclusive, `e` - exclusive, `*` - same like in calculation context.

Metric reference is an expression.

3.1.5.2 Context insensitive reference to another metric

To use values of another metric in the some fixed calculation context (e.g. aggregated over threads), one uses syntax:

```
metric::fixed::[uniq_name]( modifier, modifier )
```

or

```
metric::fixed::[uniq_name]( modifier)
```

or

```
metric::fixed::[uniq_name]()
```

There are three version of this call:

1. with two arguments (call path and system);
2. with one argument (call path);
3. with no argument(an arguments takes as '*').

modifier specifies flavor of the calculation: i - inclusive, e - exclusive, * - same like in calculation context.

Metric reference is an expression.

3.1.5.3 Direct reference to another metric

To use values of another metric with an specific call path id and system resource id (!), one uses syntax:

```
metric::call::[uniq_name]( callpath id, modifier, sysres id, modifier )
```

or

```
metric::call::[uniq_name]( callpath id, modifier )
```

There are two version of this call:

1. with four arguments (call path and system); - Only callculation of an inclusive or exclusive value is performed
2. with one argument (call path); - Aggragation over system tree is performed additionally to the calculation of the inclisive or exclusive value for the calltree id

modifier specifies flavor of the calculation: i - inclusive, e - exclusive.

Metric reference is an expression.

Note that "sysres id" is a global identificador and can be refered using `${calculation::sysres::id}`.

3.1.5.4 Definition of an encapsulated calculation within CubePL expression using metrics of Cube.

One special mechanis of CubePL processing engine allows some level of calculation separation. A derived metric can be created within another CubePL expression. Such "ghost" metric gets its name and properties and exists inside of the cube object as a casual metric. Only difference to the casual metric is in the fact that ghost metric is not visible in GUI and tools and is not stored inside of the metric tree of the cube file.

One can refer such metric as a casual metric using metric references (see ['3.1.5.1'](#) , ['3.1.5.2'](#) and ['3.1.5.3'](#)).

Example for definition of such metric :

```
cube::metric::nvisitors(e)
<<
{
  ${return}=0;
  if ( ${cube::locationgroup::void}[${calculation::sysres::id}] != 1)
  {
    if (metric::visits()>0 )
    {
      ${return} = 1;
    };
  };
  return ${return};
}
>>;
${visitors} = metric::fixed::nvisitors(e);
```

where

```
cube::metric::prederived::nvisitors(e)
```

gives a type (prederives, exclusive) and unique name (nvisitors) of this metric. Unique name is used then later to refer to this metric via

```
${visitors} = metric::fixed::nvisitors(e);
```

There are kinds of metrics, which can be defined on such manner:

1. `cube::metric::prederived::name(e)` - An exclusive prederived metric with the name `name`;
2. `cube::metric::prederived::name(i)` - An inclusive prederived metric with the name `name`;
3. `cube::metric::postderived::name` - A postderived metric with the name `name`.

Notice that once the metric with some unique name created it exists whole lifetime of the cube object. Therefore one can refer to some somewhere previously defined ghost metric from any following it CubePL expressions.

Ghost Metric definition is a statement.

3.1.5.5 Definition of an initialization expression for ghost metrics within CubePL expression.

One can specify within of a CubePL expression an initialisation phase for previously created ghost metric. For that purpose one uses expression `cube::init::metric::[name]`. Notice that named metric should be know by the moment of compilation of the CubePL expression.

Example for definition of such metric :

```
cube::init::metric::init::nvisitors
<<
{
  global(nvisitors);
}
>>;
```

where

```
cube::init::metric::nvisitors
```

uses an unique name (nvisitors) of the metric.

Definition of the initialisation phase of a metric is a statement.

3.1.5.6 Definition of an initialization expression for ghost metrics within CubePL expression.

One can specify within of a CubePL expression an aggregation operator "+" or "-" for previously created ghost metric. For that purpose one uses expression `cube::metric::plus::[name]` or `cube::metric::minus::[name]`. Notice that named metric should be know by the moment of compilation of the CubePL expression.

Example for definition of such metric :

```
cube::init::metric::plus::nvisitors
<<
max( arg1, arg2)
>>;
```

or

```
cube::init::metric::minus::nvisitors
<<
min( arg1, arg2)
>>;
```

where

```
cube::init::metric:plus::nvisitors
```

or

```
cube::init::metric:minus::nvisitors
```

uses an unique name (nvisitors) of the metric.

Definition of the initialisation phase of a metric is a statement.

3.2 Grammar of CubePL

Here will be a full grammar of CubePL expressions (later).

4 Examples of CubePL expressions

4.1 Simple Examples

1. Calculation of an arithmetical expression

```
123.4 + 234 - ( 23)^2
```

2. Calculation of an arithmetical expression with different functions

```
sin(23 + ln(12))
```

4.2 Complex Examples

4.2.1 Different made-up expressions

1. Definition of a constant function

```
{ return 24; }
```

2. Definition of a more complex function

```
{ return sin ({ return 1; }); }
```

3. Definition of a function with an access to one variable

```
{ ${a}=123; return ${a}; }
```

4. Definition of a function with a control structure

```
{  
  ${a}=metric::visits();  
  ${b}=0;  
  if (${a}>100)  
  { ${b}=metric::time(); };  
  return ${b};  
}
```

5. Definition of a function with a loop structure

```
{  
  ${a}=0; ${b}=0;  
  while (${a}<123)  
  {  
    ${b}=${b}+metric::time();  
    ${a}=${a}+1;  
  };  
  return ${b};  
}
```

6. Definition of a function with a access to predefined variable

```
{  
  ${a}=0;
```

```

if ( ${calculation::region::name}[ ${calculation::callpath::id} ] =~ /^MPI_/ )
{
    ${a}=metric::time();
};
return ${a};
}

```

4.2.2 Special metrics of Scalasca

1. Calculation of an average runtime of a call path (Kenobi metric, postderived)

```
metric::time(i)/metric::visits(e)
```

2. Calculation of the time, spend in MPI synchronization calls

a) (initialization)

```

{
    global(mpi_synchronization);
    ${i}=0;
    while( ${i} < ${cube::#callpaths} )
    {
        ${mpi_synchronization}[ ${i} ] = 0;
        ${regionid} = ${cube::callpath::calleeid}[ ${i} ] ;
        if (
            ( ${cube::region::paradigm}[ ${regionid} ] seq "mpi" )
            and
            (
                ( ${cube::region::name}[ ${regionid} ] seq "mpi_barrier" )
                or
                ( ${cube::region::name}[ ${regionid} ] seq "mpi_win_post" )
                or
                ( ${cube::region::name}[ ${regionid} ] seq "mpi_win_wait" )
                or
                ( ${cube::region::name}[ ${regionid} ] seq "mpi_win_start" )
                or
                ( ${cube::region::name}[ ${regionid} ] seq "mpi_win_complete" )
                or
                ( ${cube::region::name}[ ${regionid} ] seq "mpi_win_fence" )
                or
                ( ${cube::region::name}[ ${regionid} ] seq "mpi_win_lock" )
                or
                ( ${cube::region::name}[ ${regionid} ] seq "mpi_win_unlock" )
            )
        )
        {
            ${mpi_synchronization}[ ${i} ] = 1;
        };
        ${i} = ${i} + 1;
    };
    return 0;
}

```

b) (actual calculation)

```

{
    ${a}=0;
    if ( ${mpi_synchronization}[ ${calculation::callpath::id} ] == 1 )
    {
        ${a} = metric::time(*,*)-metric::omp_idle_threads(*,*) ;
    };
    return ${a};
}

```

3. Calculation of the Computational load imbalance (single participant)

– NO EXAMPLE YET –

