

#### metacode and Compile-Time Reflection

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# metacode and Compile-Time Reflection

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# metacode DB Example Threading Example AOP Discussion

#### metacode

- metacode presentation by Daveed Vandevoorde at ACCU conference 2003
  - no C++ proposal yet
  - not much publicly visible work since 2003
- metacode mechanisms
  - compile-time functions
  - code injection
- metacode library
  - namespace stdmeta
  - type, id, string\_literal, array, table
  - is accessible(),is lvalue(),in normal function(),error()

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### **Function Example**

#### [from original presentation]

Function Example Insights

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metacode functions

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- ... can be templates
  - can also be non-templates
- ... can have normal parameters
  - but no implicit conversion
- ... can use normal declarations, control structures and expressions
- From a programmer's view, metacode functions are just normal functions that cannot access runtime values

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## **Injection Example 1**

#### [from original presentation]

```
metacode
double mypow(double b, int n) {
  using ::stdmeta::is_constant;
  if (is_constant(b) &&
      is_constant(n) &&
      n >= 0) {
    return power<>(b, (unsigned)n);
  } else {
    return-> ::std::pow(b, n);
  }
}
```

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# Injection Example 1 Insights

- special kind of "magic" type for built-in functions
  - is constant(xyz)
- no implicit conversion
  - but explicit casts
- metacode functions can return normal values
  - as seen before
- ... or can return code to be injected

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### Injection Example 2

#### [from original presentation]

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# Injection Example 2 Insights

- no return type
  - actually makes sense: it is not void, but it is also no other type
- container template types
  - sequential array<> (possibly not the same as std::tr1::array)
  - associative table<>
- stdmeta::type
  - base for reflection
- stdmeta::id
  - useful for injection
- stdmeta::string literal
  - string manipulation for identifiers (only?)

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# **DB** Example

[this is probably along the lines of Daveed Vandevoorde's ideas]

- DB Libraries are classic examples for reflection
  - persistence in general
- General approach:
  - iterate through data members
    - · recursively
  - private and public
  - save them type specific
    - use member name as field name

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```
Usage
// DB example
class X
    // ...
private:
    int i;
    double d;
   string s;
    pair<int, int> p;
};
void foo()
    X myX;
    DbSaveNewRecord(myX, myDb, "MyTable");
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```

# Implementation

```
template <typename T> metacode DbSaveMember(id rec, id obj,
                                              string literal memberName)
    // just delegate to general implementation
    DbSaveGeneral(T, rec, obj, memberName);
template <> metacode DbSaveMember<string>(id rec, id obj,
                                           string_literal memberName)
    if (memberName.empty()) {
       error("strings can only be stored as members of aggregates");
    } else {
       metacode-> {
               string dbTypeName(rec.getTypeName(memberName));
               DbSaver *saver(lookupSaverObject(rec, "string", dbTypeName));
               saver->save(rec, memberName, obj.id(memberName));
// alternative approach
template <> metacode DbSaveMember<string>(id rec, id obj, id member)
                saver->save(rec, string literal(member), obj.member);
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```

## Implementation

#### Details / Issues

- DbSaveNewRecord(myX, myDb, "MyTable");
   void DbSaveNewRecord(id obj, ...
  - implicit conversion from (any named) object to id
- type t(obj);
  - Is this possible?
  - Lookup rules for id
  - Additional type object?
- DbSaveMember<t.the type()>(rec, obj, "");
  - We need a way to get the type for template instantiation.
    - Or else it is not possible to instantiate a template with type or overload a function on type, which is also an option.

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#### Details / Issues

- template <> metacode void DbSaveMember<string>
  - metacode template specialization
- DbSaveGeneral(T, rec, obj, memberName);
  - implicit conversion from any ("normal") type to type
- saver->save(rec, memberName, obj.id(memberName));
  - obj.id (memberName) injects the correct object member access expression myX.i

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# Resulting Code

```
void foo()
   X myX;
    //DbSaveNewRecord(myX, myDb, "MyTable");
   DbRecord rec(db.prepareNewRecord(tabName));
    // DbSaveMember<X>(rec, myX, "");
   // DbSaveGeneral(X, rec, myX, "");
       DbSaveMember<int>(rec, myX, ".i");
         DbSaveGeneral(int, rec, myX, ".i");
       string dbTypeName(rec.getTypeName(".i"));
       DbSaver *saver(lookupSaverObject(rec, "int", dbTypeName));
       saver->save(rec, ".i", myX.i);
       DbSaveMember<double>(rec, myX, ".d");
         DbSaveGeneral(double, rec, myX, ".d");
       string dbTypeName(rec.getTypeName(".d"));
       DbSaver *saver(lookupSaverObject(rec, "double", dbTypeName));
       saver->save(rec, ".d", myX.d);
```

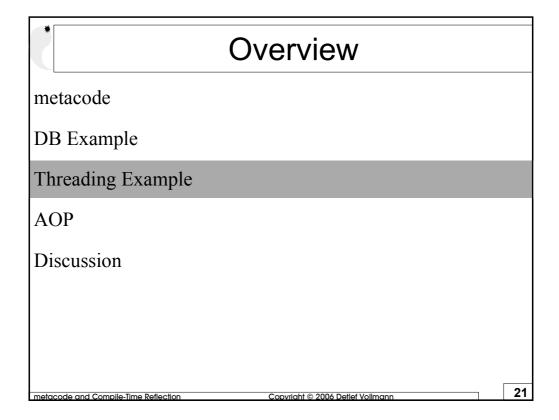
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# **Resulting Code**

```
DbSaveMember<string>(rec, myX, ".s");
        string dbTypeName(rec.getTypeName(".s"));
        DbSaver *saver(lookupSaverObject(rec, "string", dbTypeName));
        saver->save(rec, ".s", myX.s);
        DbSaveMember<pair<int, int> >(rec, myX, ".p");
         DbSaveGeneral(pair<int, int>, rec, myX, ".p");
          DbSaveMember<int>(rec, myX, ".p.first");
            DbSaveGeneral(int, rec, myX, ".p.first");
        string dbTypeName(rec.getTypeName(".p.first"));
        DbSaver *saver(lookupSaverObject(rec, "int", dbTypeName));
        saver->save(rec, ".p.first", myX.d);
           DbSaveMember<int>(rec, myX, ".p.second");
           DbSaveGeneral(int, rec, myX, ".p.second");
        string dbTypeName(rec.getTypeName(".p.second"));
        DbSaver *saver(lookupSaverObject(rec, "int", dbTypeName));
        saver->save(rec, ".p.second", myX.d);
    rec.insert();
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```



# Threading Example Usage

[this is not along the lines of Daveed Vandevoorde's ideas, as it exposes the AST]

• Populating an array in parallel:

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### **Implementation**

```
metacode
template <typename T>
parallel_for(id var, T start, T end, T step, block b)
    static int funcCounter = 0;
    ++funcCounter;
    \ensuremath{//} injecting an empty function definition for thread
    id funcName("f" + string literal(funcCounter);
   metacode->ThreadImplNamespace
        void funcName(id(T) var) {}
    // injecting the function body
    for (code::statement_iterator s(b.statement\_begin());
         s != b.statement_end();
       metacode->ThreadImplNamespace::funcName
            s; // maintain order
                                                                             23
```

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**Implementation** 

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```
// injecting thread management
     metacode->
              thread group workers;
              for (T j = start; j != end; j += step)
                  workers.create_thread(ThreadImplNamespace::funcName, j);
              workers.join all();
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```

#### Details / Issues

- parallel\_for(id var, T start, T end, T step, block b)
  - block b matches the block after the closing parenthesis
  - might cause problems with ellipsis (...)
- static for compile-time functions
  - code type
- injecting full function definitions seperately
  - first empty body, then inject into that body
  - keep order
- iterate through statement sequence

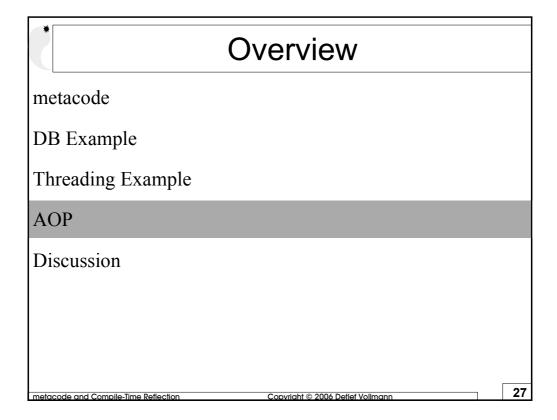
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# **Resulting Code**

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# AOP

• adding a tracing aspect to a function: void goo();

```
add_trace(goo);
void goo()
{
     // ...
}
```

what we want to get:

```
void goo()
{
    clog << "Entering goo..." << endl;
    // ...
    clog << "Leaving goo..." << endl;
}</pre>
```

- same approach can be used to check pre / post conditions
  - can be done at call site or in function
    - but optimization benefits only when in function

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#### Implementation

```
metacode
add_trace(id f)
{
    block b(f.get_function_body());

    // inject at begin
    code::statement_iterator s(b.statement_begin());
    ++s;
    metacode->s
    {
        clog << string_literal("Entering " + string_literal(f) + "...") << endl;
    }

    // inject at end
    s = b.statement_end();
    metacode->s
    {
        clog << string_literal("Leaving " + string_literal(f) + "..." << endl;
    }
}</pre>
```

Details / Issues

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• inject at specific places

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- possibly first search for the place, then inject

- injecting code into an already closed scope is problematic!
  - is the definition available?
  - ODR
- a different option would be to add changes at the call sites
  - also viable for pre / post conditions
    - but optimization benefits only when in function

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#### Discussion

- some tasks effectively require reflection
- most runtime reflection can (also) be done with compiletime reflection
- some features that are normally part of a language can be implemented by a library

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#### Disclaimer

- all this is highly speculative
  - no implementation yet
    - some parts are implemented by Daveed Vandevoorde in an internal version of the EDG front end
- possibly never in ISO C++
  - quite probably not in C++0x
  - but possibly in a TR
  - probably with lots of changes

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#### References

- Daveed Vandevorde's original paper:
  - http://www.openstd.org/jtc1/sc22/wg21/docs/papers/2003/n1471.pdf
- Discussion about metacode:
  - http://www.vandevoorde.com/Daveed/News/Archives/000015.html
- possibly updated version of this paper at
  - http://www.vollmann.ch/en/pubs/accu06meta.html

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