Observe your neighbors and remove your seatbelt

Type introspection and type-unsafety in Qt

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KDAB

Stephen Kelly

- C++/Qt user since 2006
- KDE contributor since 2007
- Qt contributor since 2009
- CMake contributor since 2011
- Interested in clang tooling
- Living in Berlin

oCaml
scala
ActionScript
javascript
ruby
Haskell
scheme
erlang
c
C#
C++
o
Java
lisp
python
shauryashaurya

C++1y

Qt DeveloperDays 2012

JTC1/SC22/WG21 - Papers 2012

WG21 Number	Title	Author
N3326	Sequential access to data members and base sub-objects	Andrzej Krzemieński
N3340	Rich Pointers	D. M. Berris, M. Austern, L. Crowl
N3390	Any Library Proposal (Revision 1)	B. Dawes, K. Henney
N3403	Use Cases for Compile-Time Reflection	Mike Spertus
N3410	Rich Pointers with Dynamic and Static Introspection	D. M. Berris, M. Austern, L. Crowl, L. Singh
N3437	Type Name Strings For C++	Axel Naumann
N3449	Open and Efficient Type Switch for C++	B. Stroustrup, G. Dos Reis, Y. Solodkyy

Motivation

- Language Binding
  - Domain Specific Languages
- Introspection/Reflection
  - Tooling
  - Testing/Unit tests

Language Bindings

JavaScript™

Problems

- Moving types through API boundaries
- Type to string conversion
- String to type conversion
- Finding the capabilities of types
- Introspection

N3437:

Type Name Strings For C++

6 Summary

While C++ is providing more and more compile-time-centric features, string-based type identification enables C++ to cover more use cases.

This paper has shown that type name strings can dramatically simplify problems that are currently impossible to solve without crude external scaffolding.

Scaffolding

Runtime features

- QVariant
- QMetaType
- QObject
- QMetaObject

Scaffolding

Runtime features

- QVariant
- QMetaType
- QObject
- QMetaObject

Compile-time features

- Macros
- Templates

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?

Qt classes

- QVariant
- QMetaType
- QObject
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QVariant

```
class QVariant {
    …
private:
    union Data {
            char c;
            int i;
            bool b;
            double d;
            qlonglong ll;
            void *ptr;
    } data;
};
```

QVariant

QVariant

QVariant

```
class QVariant {
private:
    union Data {
      ...
    } data;
    int type;
};
```

Built-in Meta-types

- Implicit constructors
  - `QVariant var1 = 42;`
  - `QVariant var2 = 3.14158`
  - `QVariant var3 = “Hello, world!”;`
- Static factory
  - `QVariant var4 = QVariant::fromValue<MyClass*>(myObject);`
  - `QVariant var5 = QVariant::fromValue<EnumType>(myEnumVal);`
- Accessors
  - `int i = var1.toInt();`
  - `MyClass *obj = var4.value<MyClass*>();`

MetaTypes

```
QVariant QVariant::fromValue<T>(T t)
{
    int id = QMetaTypeId<T>::qt_metatype_id();
    return QVariant(id, reinterpret_cast<void*>(&t));
}
```

MetaTypes

```
T QVariant::value<T>() const
{
    int id = QMetaTypeId<T>::qt_metatype_id();
    if (this->userType() == id)
        return *reinterpret_cast<T*>(this->data);
    return T();
}
```

User-defined types

```
struct Customer
{
    QString name;
    nsCity *city;
};
Q_DECLARE_METATYPE(Customer)
```

- `QVariant variant = QVariant::fromValue(cust);`
- `Customer cust = variant.value<Customer>();`

MetaTypes

```
#define Q_DECLARE_METATYPE(TYPE)                                    \
    template <>                                                     \
    struct QMetaTypeId< TYPE >                                      \
    {                                                               \
        static int qt_metatype_id()                                 \
        {                                                           \
            return qRegisterMetaType< TYPE >(#TYPE);                \
        }                                                           \
    };
```

MetaTypes

```
template<typename T>
int qRegisterMetaType(const char *typeName)
{
    QMetaType::Destructor dtor = qMetaTypeDeleteHelper<T>;
    QMetaType::Constructor ctor = qMetaTypeConstructHelper<T>;
    return QMetaType::registerType(typeName, dtor, ctor);
}
```

MetaTypes

```
class QMetaType
{
    static const char *typeName(int id);
    static int type(const char *typeName);
}

int qRegisterMetaType<T>() {
    return QMetaTypeId<T>::qt_metatype_id();
}
```

Intermediate summary

- QMetaType maps integer id ↔ type string
- Strings extracted at compile-time
- Mapping defined at and available at run-time

Qt classes

- QVariant
- QMetaType
- QObject
- QMetaObject

Tooling

- GammaRay (Runtime debugging)
- Squish (Gui testing tool)

Scaffolding

Runtime

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Compile-time

- Macros
- Templates

?

Scaffolding

Runtime

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Code-generation

- moc
- QMetaObject
- qt_metacall()

Qt Properties

```
class Customer : public QObject
{
    Q_OBJECT
    Q_PROPERTY(QString name READ name)
public:
    QString name() const;
}

QObject *o = new Customer;
QVariant var = o->property(“name”);
QString name = var.value<QString>();
```

QMetaObject

```
static const uint qt_meta_data_Customer[] = {
 // content:
       6,       // revision
       0,       // classname
       0,    0, // classinfo
       0,    0, // methods
       1,   14, // properties
       0,    0, // enums/sets
       0,    0, // constructors
       0,       // flags
       0,       // signalCount

 // properties: name, type, flags
      17,    9, 0x0a095001,

       0        // eod
};
```

QMetaObject

```
static const char qt_meta_stringdata_Customer[] = {
    "Customer\0QString\0name\0"
};

const QMetaObject Customer::staticMetaObject = {
    { &QObject::staticMetaObject, // Base class
       qt_meta_stringdata_Customer,
       qt_meta_data_Customer
    }
};
```

QMetaObject

```
int Customer::qt_metacall(QMetaObject::Call _c, int _id, void **_a)
{
    _id = QObject::qt_metacall(_c, _id, _a);
    if (_id < 0)
        return _id;
    if (_c == QMetaObject::ReadProperty) {
        void *_v = _a[0];
        switch (_id) {
        case 0: *reinterpret_cast< QString*>(_v) = name();
                break;
        }
        …
```

Bindings

```
function myFunc(customer) {
    var name = customer.name;
}
```

```
def myFunc(customer):
    name = customer.name
```

DSLs

```
Shopping list for {{ person.name }}
{% for item in itemlist %}
 * {{ item.name }} (${{ item.cost }})
{% endfor %}
```

Qt 5 Improvements

Built-in `qobject_cast`

```
QVariant v1 = QVariant::fromValue(new QLabel);
Q_ASSERT(v1.canConvert<QWidget*>());
QWidget *w1 = v1.value<QWidget*>();
Q_ASSERT(v1.canConvert<QObject*>());
QObject *o1 = v1.value<QObject*>();
QString s1 =
o1->property(“text”).value<QString>();
```

Qt 5 Improvements

TU 1

```
#include <QLabel>
#include <QVariant>

QVariant getVar()
{
    return
      QVariant::fromValue(
       new QLabel);
}
```

TU 2

```
#include <QVariant>

{
    QVariant v = getVar();
    setVar(v);
}
```

TU 3

```
#include <QObject>
#include <QVariant>

void setVar(QVariant v)
{
    QObject *o
           = v.value<QObject*>();
    o->property("text");
}
```

Qt 5 Improvements

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TU 1

```
#include <QLabel>

#include <QVariant>

QVariant getVar()
{
    return
      QVariant::fromValue
       <QObject*>
       (new QLabel);
}
```

TU 2

```
#include <QVariant>

{
    QVariant v = getVar();
    setVar(v);
}
```

TU 3

```
#include <QObject>

#include <QVariant>

void setVar(QVariant v)
{
    QObject *o
          = v.value<QObject*>();
    o->property("text");
}
```

Qt 5 Improvements

Automatic MetaType declaration

- No need for **`Q_DECLARE_METATYPE`**
  - QObject subclasses
  - Qt Containers
  - Smart (Qt) pointers

Qt 5 Improvements

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Automatic MetaType declaration

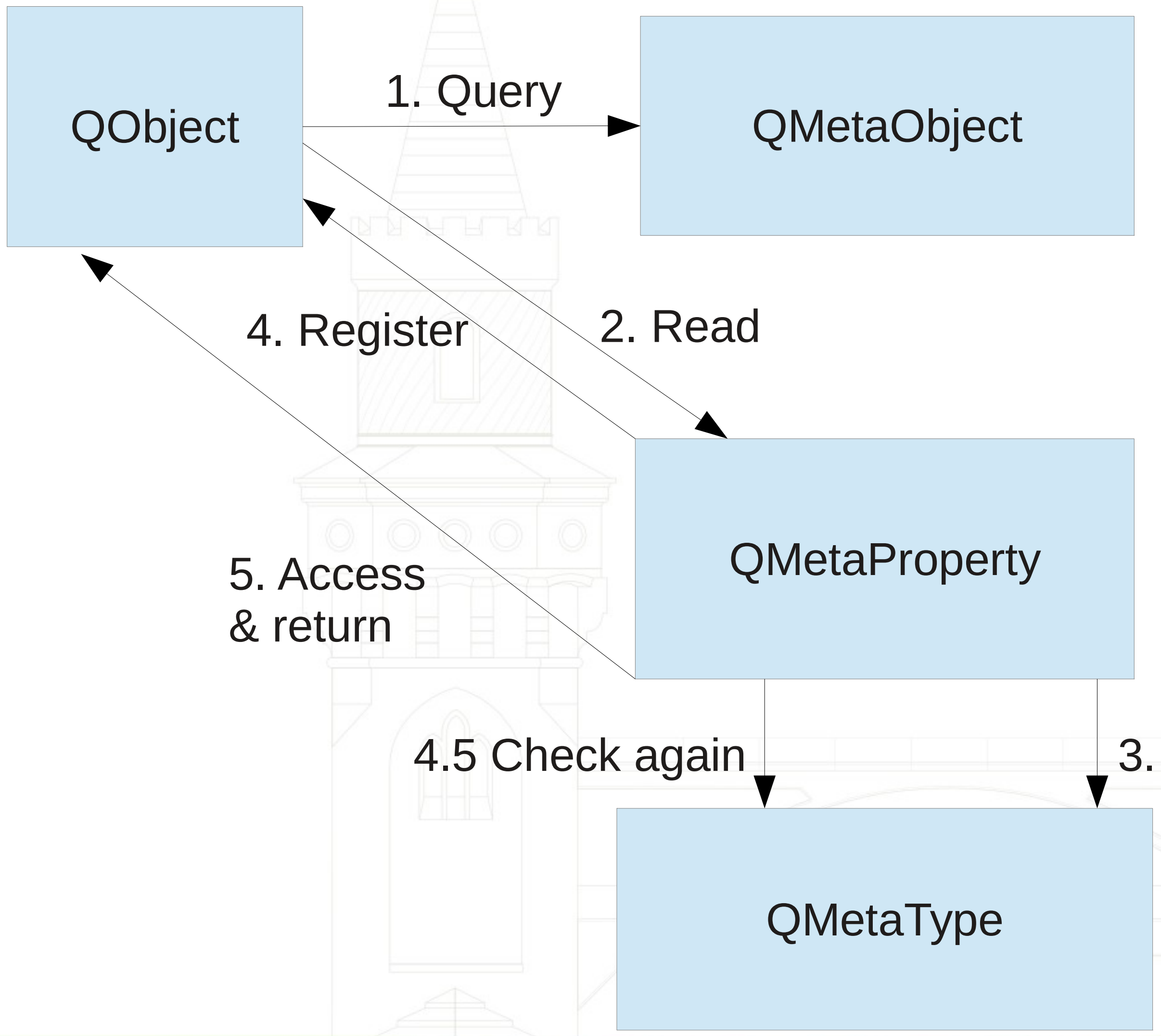
- No need for **`Q_DECLARE_METATYPE`**
  - QVariant::fromValue(myWidget);
  - QVariant::fromValue(QList<int>());
  - QVariant::fromValue(QList<MyWidget*>());
  - QVariant::fromValue(QSharedPointer<MyWidget>());
  - QVariant::fromValue(QVector<QSharedPointer<MyWidget>>());

Qt 5 Improvements

Automatic MetaType registration

- No more need for qRegisterMetaType (almost)
- Code generated by moc to register types

Reading properties



Summary

- Runtime type introspection in Qt
- Language bindings and tools
- Runtime registration
- Type conversions
- Inspecting properties, signals, slots

Thank You

Questions ?

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