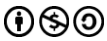

Qt
Qt in Education
Datatypes
Collections
and
Files
NOKIA



Managing text

- Simple C strings are handy, but limited to your local character encoding

```
char *text = "Hello world!";
```

- The QString class attempts to be the modern string class
  - Unicode and codecs
  - Implicit sharing for performance

QString

- Stores Unicode strings capable of representing almost all writing systems in use today
- Supports conversion from and to different local encodings

```
QString::toAscii – QString::toLatin1 – QString::toLocal8Bit
```

- Provides a convenient API for string inspection and modification

Building Strings

- There are three main methods for building strings
- The `operator+` method

```
QString res = "Hello “ + name +
    “, the value is " + QString::number(42);
```

- The `QStringBuilder` method

```
QString res = "Hello “ % name %
    “, the value is " % QString::number(42);
```

- The `arg` method

```
QString res = QString("Hello %1, the value is %2")
    .arg(name)
    .arg(42);
```

QStringBuilder

- Using the + operator to join strings results in numerous memory allocations and checks for string lengths
- A better way to do it is to include `QStringBuilder` and use the `%` operator
- The string builder collects all lengths before joining all strings in one go, resulting in one memory allocation

```
QString res = "Hello “ % name %
    “, the value is %" % QString::number(42);
```

```
QString temp = "Hello “;
temp = temp % name;
temp = temp % “, the value is %"
temp = temp % QString::number(42);
```

Joining strings in small steps will cost you in performance

QString::arg

- The arg method replaces `%1-99` with values

```
"%1 + %2 = %3, the sum is %3"
```

All instances of %n are replaced

- Can handle strings, chars, integers and floats

```
...).arg(qulonglong a)        ...).arg(QString, ... QString)
...).arg(short a)             ...).arg(int a)
...).arg(ushort a)            ...).arg(uint a)
...).arg(QChar a)             ...).arg(long a)
...).arg(char a)              ...).arg(ulong a)
...).arg(double a)            ...).arg(qlonglong
```

Up to nine strings in one go

- Can convert between number bases

```
...).arg(value, width, base, fillChar);
...).arg(42, 3, 16, QChar('0')); // Results in 02a
```

Substrings

- Access substrings using `left`, `right` and `mid`

```
QString s = "Hello world!";
r = s.left(5); // "Hello"
r = s.right(1); // "!"
r = s.mid(6,5); // "world"
```

- By not specifying a length to `mid`, the rest of the string is returned

```
r = s.mid(6); // "world!"
```

- Use `replace` to search and replace in strings

```
r = s.replace("world", "universe"); // "Hello universe!"
```

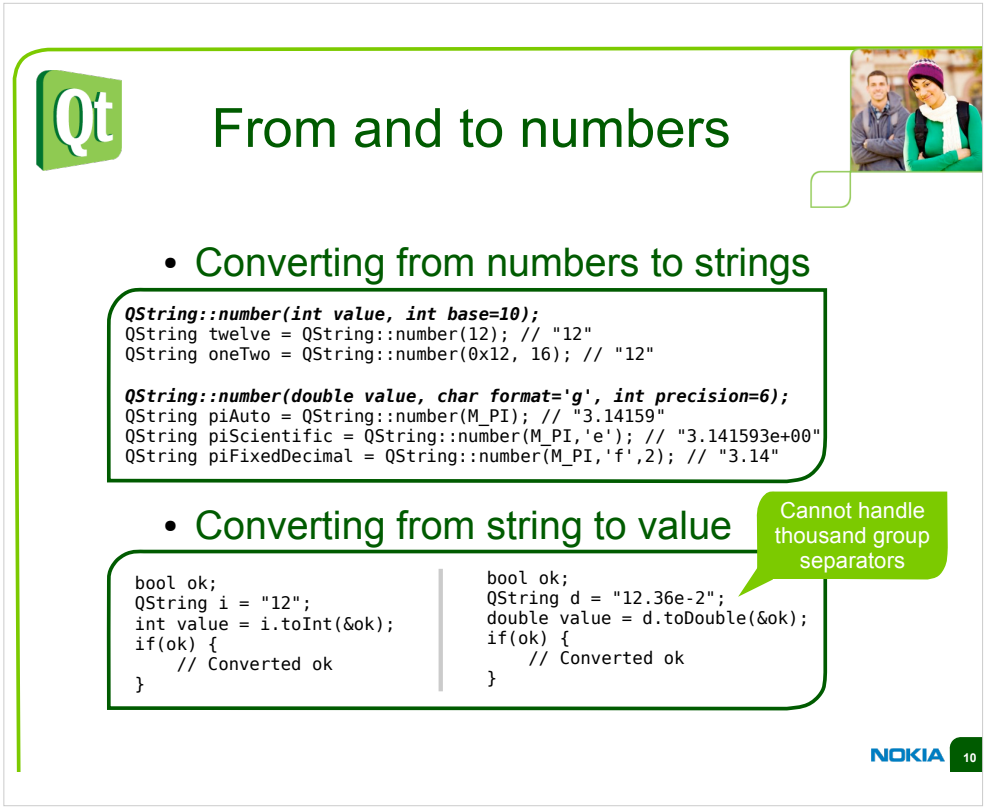
Printing to the console

- Qt is a toolkit primarily for visual applications, i.e. not focused on command line interfaces
- To print, use the `qDebug` function
  - It is always available, but can be silenced when building for release
  - Works like the `printf` function (but appends “\n”)
  - Using the `qPrintable` macro, it is easy to print QString texts

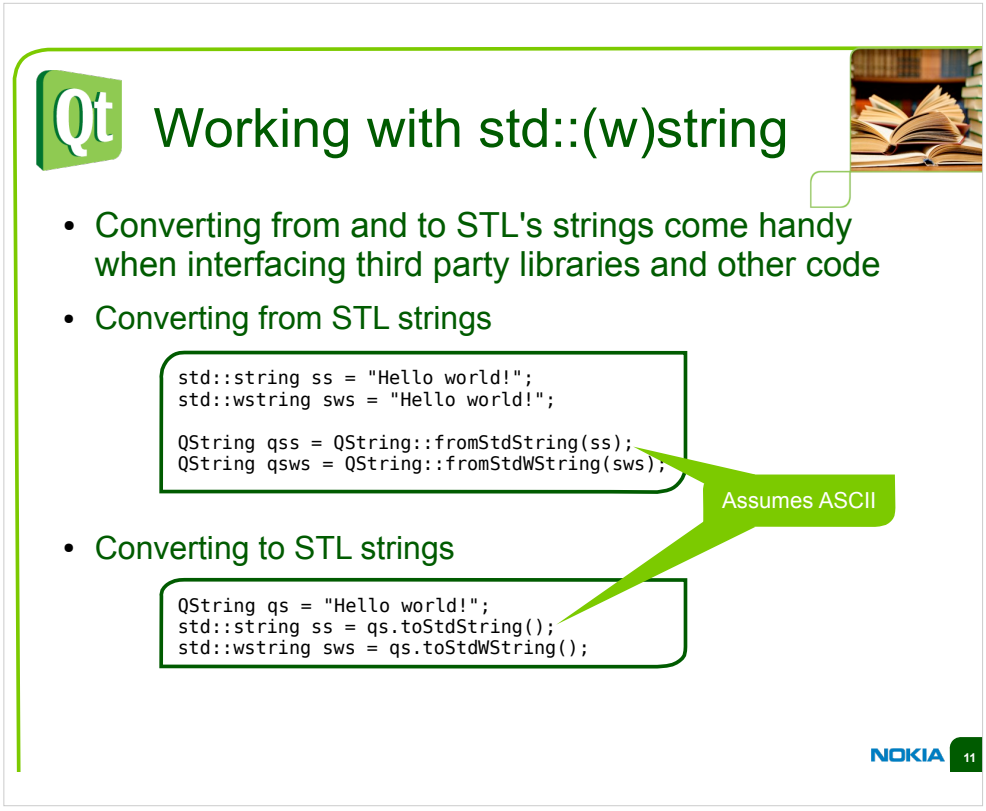
```
qDebug("Integer value: %d", 42);
qDebug("String value: %s", qPrintable(myQString));
```

  - Can be used with streaming operators when QtDebug is included

```
#include <QtDebug>

qDebug() << "Integer value:" << 42;
qDebug() << "String value:" << myQString;
qDebug() << "Complex value:" << myQColor;
```



no prefix for base = 16
g = automatic
e/E = scientific, with exponential
f = fixed, with decimal



Not working? Ensure that Qt is configured with support for STL.

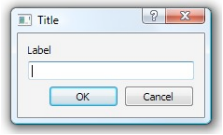
Empty and null strings

- A `QString` can be null, i.e. contain nothing

```
QString n = QString();

n.isNull();  // true
n.isEmpty(); // true
```

This is useful for passing no string, compared to an empty string.

See `QInputDialog::getText` – returns a null string on Cancel.



- It can also be empty, i.e. contain an empty string

```
QString e =  "";

e.isNull();  // false
e.isEmpty(); // true
```

Splitting and joining

- A `QString` can be split into sub-strings

```
QString whole = "Stockholm - Copenhagen - Oslo - Helsinki";
QStringList parts = whole.split(" - ");
```

- The resulting object is a `QStringList`, which can be joined together to form a `QString`

```
QString wholeAgain = parts.join(", ");
    // Results in "Stockholm, Copenhagen, Oslo, Helsinki"
```

QStringList

- The `QStringList` is a specialized list type
- Designed for holding strings

  Provides a convenient API for working with the strings in the list

- The class uses implicit sharing
  - Copies on modification
  - Cheap to pass as const references

Building and modifying strings lists

- Use the << operator to add strings to string lists

```
QStringList verbs;
verbs = "running" << "walking" << "compiling" << "linking";
```

- The `replaceInStrings` method lets you search and replace within all strings of a `QStringList`.

```
qDebug() << verbs; // ("running", "walking", "compiling", "linking")
verbs.replaceInStrings("ing", "er");
qDebug() << verbs; // ("runner", "walker", "compiler", "linker")
```

Sorting and Filtering

- A `QStringList` can be sorted...

```
qDebug() << capitals; // ("Stockholm", "Oslo", "Helsinki", "Copenhagen")
capitals.sort();
qDebug() << capitals; // ("Copenhagen", "Helsinki", "Oslo", "Stockholm")
```

- ...filtered...

Case sensitive by default

```
QStringList capitalsWithO = capitals.filter("o");
qDebug() << capitalsWithO; // ("Copenhagen", "Oslo", "Stockholm")
```

- ...and cleaned for duplicate entries

```
capitals << capitalsWithO;
qDebug() << capitals; // ("Copenhagen", "Helsinki", "Oslo", "Stockholm",
                      //  "Copenhagen", "Oslo", "Stockholm")
capitals.removeDuplicates();
qDebug() << capitals; // ("Copenhagen", "Helsinki", "Oslo", "Stockholm")
```

Iterating over the strings

- Using the `operator[]` and `length` function, you can iterate over the contents of a `QStringList`

```
QStringList capitals;
for(int i=0; i<capitals.length(); ++i)
    qDebug() << capitals[i];
```

- Another option is to use the `at()` function which provides read-only access to the list items

- You can also use the `foreach` macro

```
QStringList capitals;
foreach(const QString &city, capitals)
    qDebug() << city;
```

Qt's Collections

- The interface of `QStringList` is not unique to the string list. `QStringList` is derived from `QList<QString>`
- `QList` is one of many of Qt's container template classes
  - `QLinkedList` – quick insert in the middle, access through iterators
  - `QVector` – uses continous memory, slow inserts
  - `QStack` – LIFO, last in – first out
  - `QQueue` – FIFO, first in – first out
  - `QSet` – unique values
  - `QMap` – associative array
  - `QHash` – associative array, faster than `QMap`, but requires hash
  - `QMultiMap` – associative array with multiple values per key
  - `QMultiHash` – associative array with multiple values per key

Slow or fast relative to `QList` which will be our reference and benchmark

Populating

- You can populate a `QList` using the << operator

```
QList<int> fibonacci;
fibonacci << 0 << 1 << 1 << 2 << 3 << 5 << 8;
```

- The methods `prepend`, `insert` and `append` can also be used

```
QList<int>
list;
list.append(2);
```

index 0: **2**

```
list.append(4);
```

index 0: **2**
index 1: **4**

```
list.insert(1,3);
```

index 0: **2**
index 1: **3**
index 2: **4**

```
list.prepend(1);
```

index 0: **1**
index 1: **2**
index 2: **3**
index 3: **4**

Removing

- Remove item from a `QList` using `removeFirst`, `removeAt`, `removeLast`

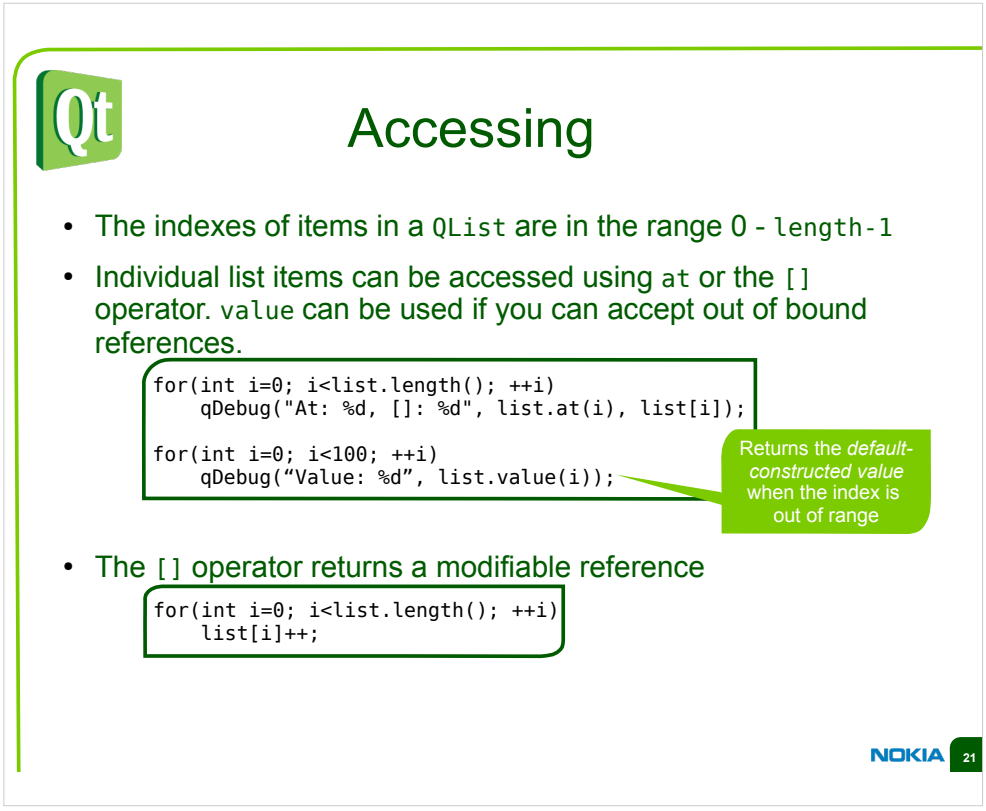
```
while(list.length())
    list.removeFirst();
```

- To take an item, use `takeFirst`, `takeAt`, `takeLast`

```
QList<QWidget*> widgets;
widgets << new QWidget << new QWidget;
while(widgets.length())
    delete widgets.takeFirst();
```

- For removing items of with a specific value, use `removeAll` or `removeOne`

```
QList<int> list;
list << 1 << 2 << 3 << 1 << 2 << 3;
list.removeAll(2); // Leaves 1, 3, 1, 3
```



operator[] exists in a const reference returning variant too.

Iterating – Java style

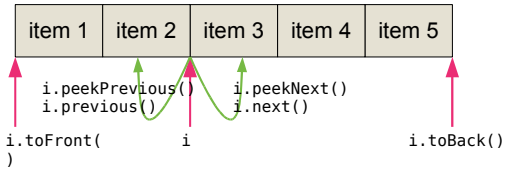
- Qt supports Java style iterators

```
QListIterator<int> iter(list);
        while(iter.hasNext())
            qDebug("Item: %d", iter.next());
```

Both returns a value and steps to the next position of the list

Use a `QMutableListIterator` if you need to modify the items

- Java style iterators point between entries
  - `toFront` places the iterator in front of the first item
  - `toBack` places the iterator after the last item
  - Refer to items using `peekNext` and `peekPrevious`
  - Move to items using `next` or `previous`



Iterating – STL style

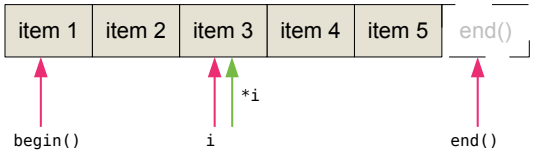
- Qt supports STL style iterators

Use an `Iterator` if you need to modify the items

```
for(QList<int>::ConstIterator iter=list.begin();
    iter!=list.end(); ++iter)
    qDebug("Item: %d", *iter);
```

Both STL and Qt naming can be used. `Iterator|iterator` and `ConstIterator|const_iterator`

- STL iterators point at each item, and use invalid items as end markers
  - The first item is returned by `begin`
  - The end marker is returned by `end`
  - The `*` operator refers to the item value



  - When iterating backwards you must move the operator *before* accessing

Iterating for the lazy

- To iterate over a whole collection, use `foreach`

```
QStringList texts;
foreach(QString text, texts)
    doSomething(text);
```

Using const references helps improve performance. Not using it, still does not let you change the contents of the list

```
QStringList texts;
foreach(const QString &text, texts)
    doSomething(text);
```

- Caveat! Make sure to copy the list when it is returned *by value*

```
const QList<int> sizes = splitter->sizes();
QList<int>::const_iterator i;
for(i=sizes.begin(); i!=sizes.end(); ++i)
     processSize(*i);
```

Copying is cheap thanks to implicit sharing

Interacting with STL

- A `QList` can be converted to and from the corresponding `std::list`

```
QList<int> list;
list << 0 << 1 << 1 << 2 << 3 << 5 << 8 << 13;

std::list<int> stlList = list.toStdList();

QList<int> otherList = QList<int>::fromStdList(stlList);
```

From Qt list to STL list

From STL list to Qt list

- Converting from and to STL means doing a deep copy of the list's contents – no implicit sharing takes place

Other collections

- What are the alternatives to `QList` and how do they compare to `QList`
- `QLinkedList`
  - Slow when using indexed access
  - Fast when using iterators
  - Fast (constant time) insertion in the middle of the list
- `QVector`
  - Uses continous memory
  - Slow inserts and prepending

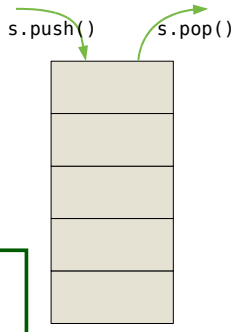
Other collections

Collection	Index access	Insert	Prepend	Append
`QList`	O(1)	O(n)	Amort. O(1)	Amort. O(1)
`QLinkedList`	O(n)	O(1)	O(1)	O(1)
`QVector`	O(1)	O(n)	O(n)	Amort. O(1)

- Notice that amortized behavior means unpredictable times in real-time setting
- Other collections are based on `QList`
  - `QStringList`
  - `QStack`
  - `QQueue`
  - `QSet`

Special cases - QStack

- A stack if a LIFO container
  last in, first out

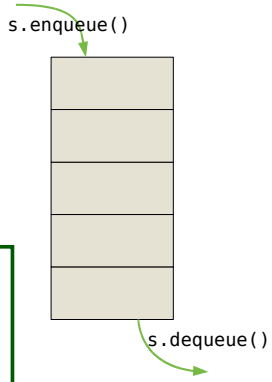


- Items are pushed onto the stack
- Items are popped off the stack
- The top item can be seen using `top()`

```
QStack<int> stack;
stack.push(1);
stack.push(2);
stack.push(3);
qDebug("Top: %d", stack.top()); // 3
qDebug("Pop: %d", stack.pop()); // 3
qDebug("Pop: %d", stack.pop()); // 2
qDebug("Pop: %d", stack.pop()); // 1
qDebug("isEmpty? %s", stack.isEmpty()?"yes":"no");
```

Special Cases - QQueue

- A queue is a FIFO container
  first in, first out



- Items are enqueued into the queue
- Items are dequeued from the queue
- The first item can be seen using `head()`

```
QQueue<int> queue;
queue.enqueue(1);
queue.enqueue(2);
queue.enqueue(3);
qDebug("Head: %d", queue.head());   // 1
qDebug("Pop: %d", queue.dequeue()); // 1
qDebug("Pop: %d", queue.dequeue()); // 2
qDebug("Pop: %d", queue.dequeue()); // 3
qDebug("isEmpty? %s", queue.isEmpty()?"yes":"no");
```

Special cases - QSet

- A set contains values, but only one instance of each value.
- It is possible to determine if a value is a part of the set or not

```
QSet<int> primes;
primes << 2 << 3 << 5 << 7 << 11 << 13;
for(int i=1; i<=10; ++i)
    qDebug("%d is %sprime", i, primes.contains(i)?"":"not ");
```

- You can also iterate over a set, to see all values

```
foreach(int prime, primes)
    qDebug("Prime: %d", prime);
```

- It is possible to convert a `QList` to a `QSet`

```
QList<int> list;
list << 1 << 1 << 2 << 2 << 2 << 3 << 3 << 5;
QSet<int> set = list.toSet();
qDebug() << list; // (1, 1, 2, 2, 2, 3, 3, 5)
qDebug() << set;  // (1, 2, 3, 5)
```

Key – value collections

- The `QMap` and `QHash` classes let you create associative arrays

```
QMap<QString, int> map;

map["Helsinki"] = 1310755;
map["Oslo"] = 1403268;
map["Copenhagen"] = 1892233;
map["Stockholm"] = 2011047;

foreach(const QString &key, map.keys())
    qDebug("%s", qPrintable(key));

if(map.contains("Oslo"))
{
    qDebug("Oslo: %d",
                   map.value("Oslo"));
}
```

```
QHash<QString, int> hash;

hash["Helsinki"] = 1310755;
hash["Oslo"] = 1403268;
hash["Copenhagen"] = 1892233;
hash["Stockholm"] = 2011047;

foreach(const QString &key, hash.keys())
    qDebug("%s", qPrintable(key));
```

Using QMap

- The `QMap` class requires an `operator<` to be defined for the key type

  This operator is used to keep the keys in order

- Populating is done using `operator[]` or `insert`

```
map["Stockholm"] = 2011047;

map.insert("London", 13945000);
```

- For reading, use `value` combined with `contains`

```
if(map.contains("Oslo"))
    qDebug("Oslo: %d",
           map.value("Oslo"));

qDebug("Berlin: %d", map.value("Berlin",42));
```

Use value instead of [] to avoid adding items by mistake

Optional default value. If not specified a *default constructed* value is returned.

Hashing

- `QMap` uses keys of the type that are given in the template
- `QHash` uses `uint` values
- The key type is *hashed* to a `uint` value

- Working with `uint` values potentially improves performance
- Hashed values mean that keys are not sorted
- The hash function must be designed to avoid collisions to achieve good performance

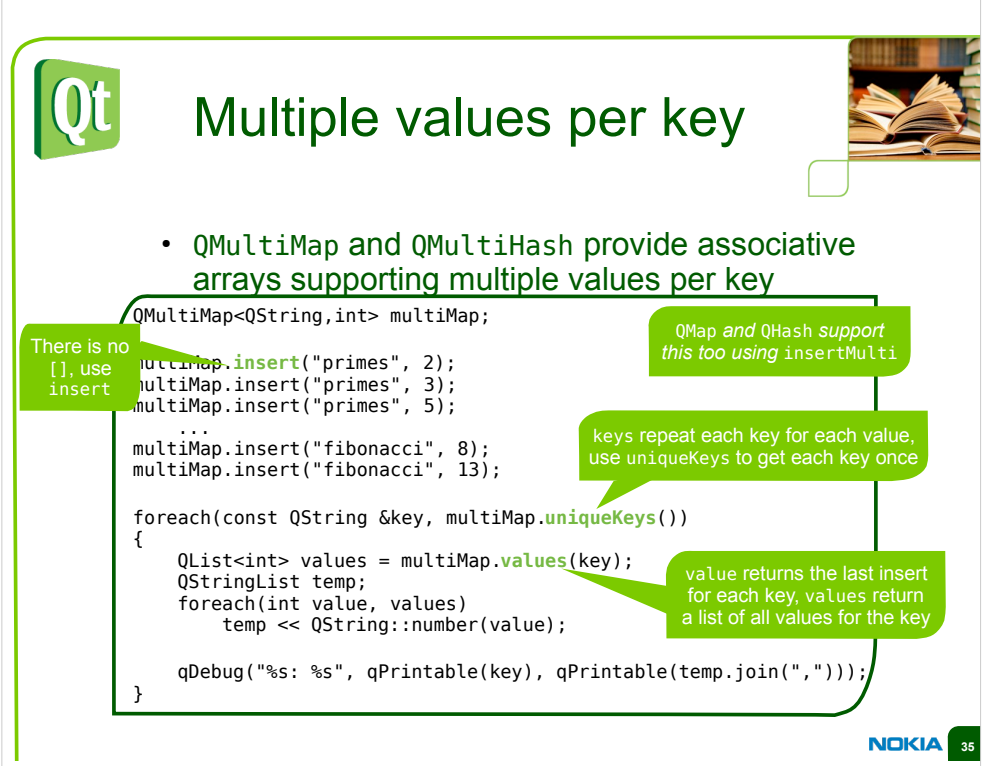
Using QHash

- The key type must provide a `qHash` function and `operator==` to `QHash`

```
uint qHash(const Person &p)
{
    return p.age() + qHash(p.name());
}

bool operator==(const Person &first, const Person &second)
{
    return ((first.name() == second.name()) &&
            (first.age() == second.age()));
}
```

The hash function should be optimized according to known heuristics

- Populating and reading is identical to `QMap`



Multiple values per key

- `QMultiMap` and `QMultiHash` provide associative arrays supporting multiple values per key

There is no `[]`, use `insert`

`QMap` *and* `QHash` *support this too using* `insertMulti`

`keys` repeat each key for each value, use `uniqueKeys` to get each key once

`value` returns the last insert for each key, `values` return a list of all values for the key

```
QMultiMap<QString,int> multiMap;

multiMap.insert("primes", 2);
multiMap.insert("primes", 3);
multiMap.insert("primes", 5);
    ...
multiMap.insert("fibonacci", 8);
multiMap.insert("fibonacci", 13);

foreach(const QString &key, multiMap.uniqueKeys())
{
    QList<int> values = multiMap.values(key);
    QStringList temp;
    foreach(int value, values)
        temp << QString::number(value);

    qDebug("%s: %s", qPrintable(key), qPrintable(temp.join(",")));
}
```

Break

Qt type definitions

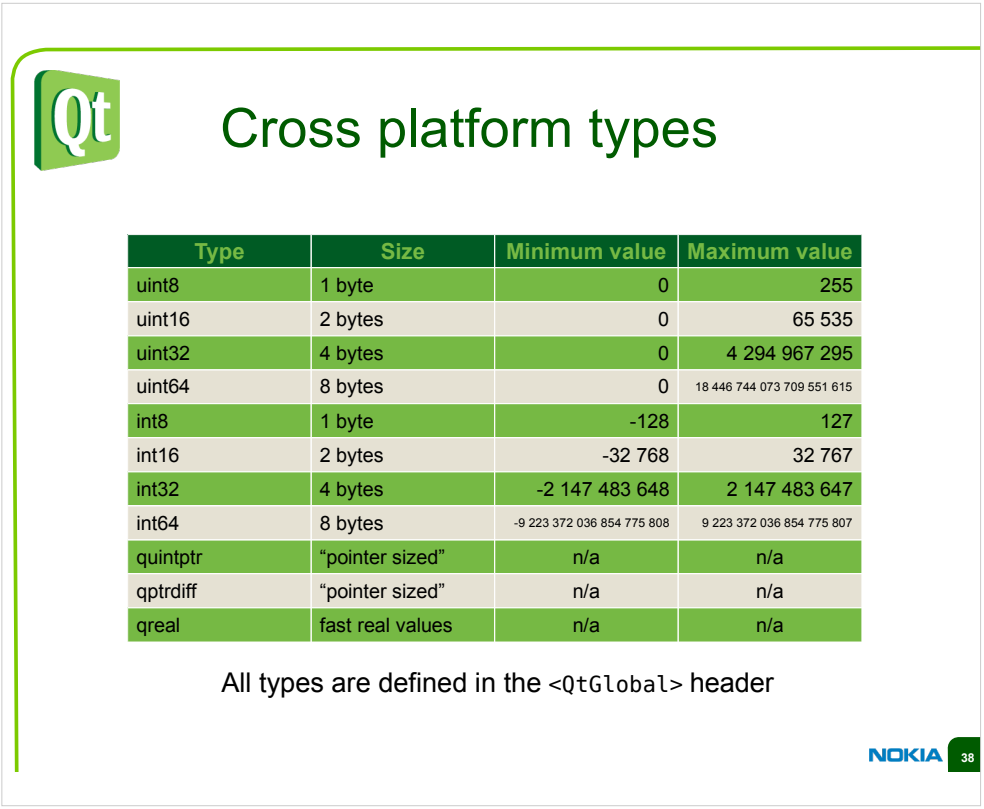
- C++ does not define the size of types strictly across platforms

sizeof(int) = ?

ARM = 4 bytes
x86 = 4 bytes
IA64 = 8 bytes
...

Depends on CPU architecture, operating system, compiler, etc

- For cross platform code it is important to define all types in a strict manner



Make sure to use these types when you want portable code.

The u prefix means unsigned.

quintptr / qptrdiff can be used to represent pointers and pointer differences as integers (e.g. when hashing). The integer is 4 bytes for 32 bit systems, 8 bytes for 64 bit systems.

qreal is the fast real (floating point) type on all systems. Double on all systems except ARM, where float is quicker.

Qt complex types

- Qt comes with a range of complex classes and types

QFont
QList
QColor
QString
QRect
QPen
QBrush
QSize
QPoint
QImage
QPixmap
QByteArray

QVariant

- Sometimes, you want to be able to return any type through a generic interface

```
const QVariant &data(int index);
void setData(const QVariant &data, int index);
```

Data can be a string, a picture, a color, a brush an integer value, etc

- The `QVariant` class can be treated as a union
  - It would be impossible to create a union of Qt types as unions require default constructors
  - The variant class can contain custom complex types, e.g. QColor belongs to QtGui, QVariant to QtCore – unions cannot be extended with more types once they have been declared

Using QVariant

- The basic types are handled using the constructor and `toType` methods

```
QVariant v;
int i = 42;
qDebug() << "Before:" << i; // Before: 42
v = i;
i = v.toInt();
qDebug() << "After:" << i;  // After: 42
```

- Non-QtCore types, such as custom types, are handled using the `setValue` method and templated `value<type>` method

```
QVariant v;
QColor c(Qt::red);
qDebug() << "Before:" << c; // Before: QColor(ARGB 1, 1, 0, 0)
v.setValue(c);
c = v.value<QColor>();      // After: QColor(ARGB 1, 1, 0, 0)
qDebug() << "After:" << c;
```

A custom complex type

- We implement a trivial class holding a person's name and age

```
class Person
{
public:
    Person();
    Person(const Person &);
    Person(const QString &, int);

    const QString &name() const;
    int age() const;

    void setName(const QString &);
    void setAge(int);

    bool isValid() const;

private:
    QString m_name;
    int m_age;
};
```

Does not have to be a QObject.

```
Person::Person() : m_age(-1) {}

...

void Person::setAge(int a)
{
    m_age = a;
}

bool Person::isValid() const
{
    return (m_age >= 0);
}
```

QVariant with Person

- Attempting to pass a `Person` object through a `QVariant` object fails

```
qmetatype.h:200: error: 'qt_metatype_id' is not a member of 'QMetaTypeId<Person>'
```

- Declaring the type in the meta-type system solves this

```
class Person
{
   ...
};

Q_DECLARE_METATYPE(Person)

#endif // PERSON_H
```

QVariant with Person

- When the type is registered as a meta type, Qt can store it in a `QVariant`

```
QVariant var;
var.setValue(Person("Ole", 42));
Person p = var.value<Person>();
qDebug("%s, %d", qPrintable(p.name()), p.age());
```

- Requirements on declared type
  - Public default constructor
  - Public copy constructor
  - Public destructor

And then it breaks...

- When working with signals and slots, most connections are direct
  - With direct connections, the type works
  - There are queued connections, i.e. non-blocking, asynchronous where the type does not work (e.g. across thread boundaries)

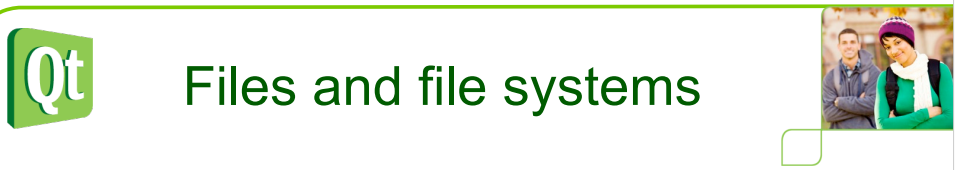
```
connect(src, SIGNAL(), dest, SLOT(), Qt::QueuedConnection);

...

QObject::connect: Cannot queue arguments of type 'Person'
(Make sure 'Person' is registered using qRegisterMetaType().)
```

Error message is printed at run-time

Registering the type

- The error message tells us what it needed
- The `qRegisterMetaType` function must be called before the connection is made (usually from `main`)

```
int main(int argc, char **argv)
{
    qRegisterMetaType<Person>();
    ...
```



Files and file systems

- Referring to files and directories in a cross platform manner poses a number of problems
  - Does the system have drives, or just a root?
  - Are paths separated by “/” or “\”?
  - Where does the system store temporary files?
  - Where does the user store documents?
  - Where is the application stored?

Paths

- Use the `QDir` class to handle paths

```
QDir d = QDir("C:\\");
```

- Learn to use the static methods to initialize

```
QDir d = QDir::root(); // C:/ on windows

QDir::current() // Current directory
QDir::home()    // Home directory
QDir::temp()    // Temporary directory

// Executable directory path
QDir(QApplication::applicationDirPath())
```

Finding directory contents

- The `entryInfoList` returns a list of information for the directory contents

```
QFileInfoList infos = QDir::root().entryInfoList();
foreach(const QFileInfo &info, infos)
    qDebug("%s", qPrintable(info.fileName()));
```

Lists files and directories in arbitrary order.

- You can add filters to skip files or directories

```
QDir::Dirs
QDir::Files
QDir::NoSymLinks
```

Dirs, files or symbolic links?

```
QDir::Readable
QDir::Writable
QDir::Executable
```

Which files?

```
QDir::Hidden
QDir::System
```

Hidden files? System files?

Finding directory contents

- You can also specify sort order

```
QDir::Name
QDir::Time
QDir::Size
QDir::Type
```

Sort by ...

```
QDir::DirsFirst
QDir::DirsLast
```

Dirs before or after files

```
QDir::Reversed
```

Reverse order

Filter

Order

- Listing all directories from the home directory ordered by name

```
QFileInfoList infos =
    QDir::root().entryInfoList(QDir::Dirs, QDir::Name);
foreach(const QFileInfo &info, infos)
    qDebug("%s", qPrintable(info.fileName()));
```

Finding directory content

- Finally, you can add name filters

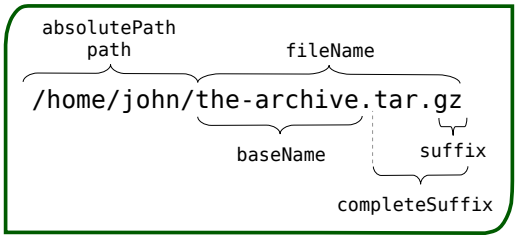
```
QFileInfoList infos =
    dir.entryInfoList(QStringList() << "*.cpp" << "*.h",
                      QDir::Files, QDir::Name);
foreach(const QFileInfo &info, infos)
    qDebug("%s", qPrintable(info.fileName()));
```

All **cpp** and **h** files

QFileInfo

- Each `QFileInfo` object has a number of methods
  - `absoluteFilePath` – full path to item
  - `isDir` / `isFile` / `isRoot` – type of item
  - `isWriteable` / `isReadable` / `isExecutable` – permission for file

Great for creating new `QDir` objects when traversing.



Opening and reading files

- The `QFile` is used to access files

```
QFile f("/home/john/input.txt");

if (!f.open(QIODevice::ReadOnly))
    qFatal("Could not open file");
```

```
QByteArray data = f.readAll();
processData(data);
```

Reads all data in one go.

```
f.close();
```

```
while(!f.atEnd())
{
    QByteArray data = f.read(160);
    processData(data);
}
```

Reads up to 160 bytes each time.

Writing to files

- When writing files, open it in `WriteOnly` mode and use the write method to add data to the file

```
QFile f("/home/john/input.txt");

if (!f.open(QIODevice::WriteOnly))
    qFatal("Could not open file");

QByteArray data = createData();
f.write(data);

f.close();
```

- Files can also be opened in `ReadWrite` mode
- The flags `Append` or `Truncate` can be used in combination with write-enabled modes to either append data to the file or to truncate it (i.e. clear the file from its previous contents)

```
if (!f.open(QIODevice::WriteOnly|QIODevice::Append))
```

The QIODevice

- `QFile` is derived from `QIODevice`
- The constructors `QTextStream` and `QDataStream` take a `QIODevice` pointer as an argument, not a `QFile` pointer
- There are `QIODevice` implementations
  - `QBuffer` – for reading and writing to memory buffers
  - `QextSerialPort` – for serial (RS232) communication (3rd party)
  - `QAbstractSocket` – the base of TCP, SSL and UDP socket classes
  - `QProcess` – for reading and writing to processes' standard input and output

Streaming to files

- The read and write methods feel awkward in many situations – handling complex types, etc
- A modern approach is to use stream operators
- Qt offers two types of stream operators
  - For handling text files
  - For handling binary file formats

QTextStream

- The `QTextStream` class handles reading and writing from text based files
- The class is
  - codec aware (uses locale by default, but can be set explicitly as well)
  - aware of lines and words
  - aware of numbers

Writing to text streams

- Use the << operator and modifiers, much as using STL's streams

```
QFile f(...);
if(!f.open(QIODevice::WriteOnly))
    qFatal("Could not open file");

QTextStream out(&f);
out << "Primes: " << qSetFieldWidth(3) << 2 << 3 << 5 << 7 << endl;
```

Numbers can be put directlv into the stream

Modifier, sets the minimum field width

Adds a line break to the stream

Results in:

```
Primes:   2  3  5  7
```

Reading using text streams

- It is possible to read the file line by line

```
QTextStream in(&f);
while(!f.atEnd())
    qDebug("line: '%s'", qPrintable(in.readLine()));
```

- You can also extract words and numbers

```
QTextStream in(&f);
QString s;
int i;
in >> s >> i;
```

- Use `atEnd` to determine if you've reached the end of the file

Handling binary files

- The `QDataStream` class is used for streaming bytes
  - Guarantees byte-ordering (default big endian)
  - Supports basic types
  - Support Qt complex types
  - Supports adding custom complex types

```
if (!f.open(QIODevice::WriteOnly))
    qFatal("Could not open file");

QDataStream ds(&f);
ds << QString("Unicode string data");
```

Simply pass a pointer to a `QFile` object to the stream constructor to setup a stream for a specific file.

Data streams as a file format

- When basing a file format on `QDataStream` there are some details to keep in mind
  - Versioning – as Qt's structures evolve, so do their binary serialization formats. Using `QDataStream::setVersion`, you can explicitly force a specific serialization format to be used.
  - Type information – Qt does not add type information, so you need to keep track of which you store in what order.
  - Byte ordering – Qt's data streams are big endian by default, but when using the class for handling legacy file formats you can set the byte ordering using `QDataStream::setByteOrder`.

Data streams as a file format

```
QFile f("file.fmt");
if (!f.open(QIODevice::WriteOnly))
    qFatal("Could not open file");

QDataStream out(&f);
out.setVersion(QDataStream::Qt_4_6);

quint32 value = ...;
QString text = ...;
QColor color = ...;

out << value;
out << text;
out << color;
```

Versions down to Qt 1.0 are supported here.

Ensure to match types and order when writing and reading streams.

If you want to serialize objects of mixed types without specifying the order of the types you can serialize `QVariant` objects.

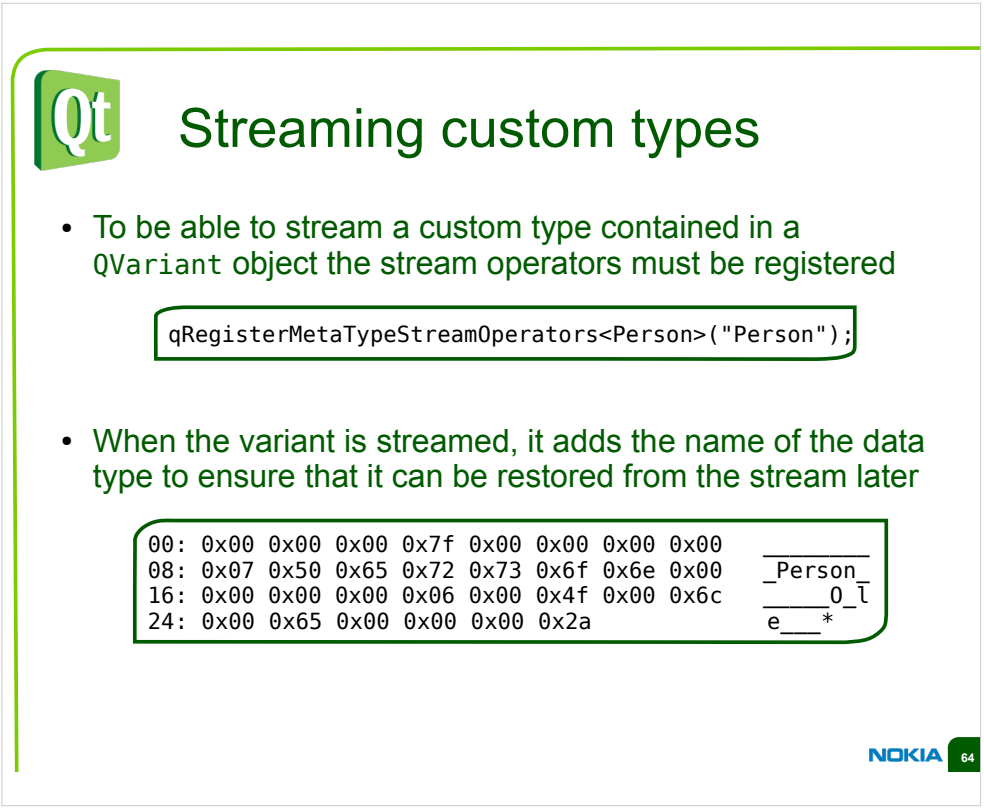
```
QFile f("file.fmt");
if (!f.open(QIODevice::ReadOnly))
    qFatal("Could not open file");

QDataStream in(&f);
in.setVersion(QDataStream::Qt_4_6);

quint32 value = ...;
QString text = ...;
QColor color = ...;

in >> value;
in >> text;
in >> color;
```

Streaming custom types

- By implementing the stream operators << and >> custom types can be streamed from and to data streams

```
QDataStream &operator<<(QDataStream &out, const Person &person)
{
    out << person.name();
    out << person.age();
    return out;
}

QDataStream &operator>>(QDataStream &in, Person &person)
{
    QString name;
    int age;
    in >> name;
    in >> age;
    person = Person(name, age);
    return in;
}
```

A friend function could have accessed `m_age` and `m_name` directly.



In the resulting data, notice the type name (Person)
The data being 16-bit unicode (_O_l_e)
The age 0x2a = 42 (decimal, int = 32 bits, i.e. _ _ _*)

Also, point out the overhead from using QVariant instead of keeping track of this yourself.

Custom types check-list

- Implement
  - `Type::Type()` – Public default constructor
  - `Type::Type(const Type &other)` – Public copy constructor
  - `Type::~Type()` – Public destructor
  - `QDebug operator<<` – Convenient debugging
  - `QDataStream operator<<` and `>>` – Streaming
- Register
  - `Q_DECLARE_METATYPE` – In header
  - `qRegisterMetaType` – In main
  - `qRegisterMetaTypeStreamOperators` – In main