Qt – Introduction to GUI programming

Timo Strömmer, May 27, 2010

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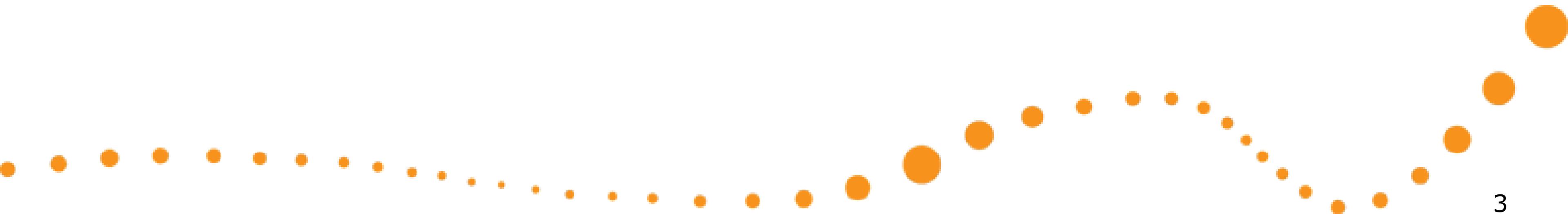

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QtCreator UI designer

Building ”traditional” desktop UI’s

UI designer introduction

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- This is interactive part…
  - Widgets walkthrough
  - How to add signal handlers
  - How to use layouts
  - Widget properties

Event handling

Events

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- Any object that inherits from QObject can be target of events
  - QCoreApplication::postEvent, QObject::Event
- In GUI programs events are propagated to widget, which has the focus
  - Focus can be switched with mouse or *tab* key
  - If widget doesn't process the event, it is forwarded to parent widget etc.

Events

- In order to process GUI events, you'll need to
  - Create your own widget class, which inherits from one of the regular widgets *or*
  - Use *event filters*
- Event filter can be added to any object
  - *QObject::installEventFilter(anotherQObject);*
  - Events go to *anotherQObject*::*eventFilter*

Event filters

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- Why filtering?
  - You can suppress unwanted functionality
    - Although the result might not be something that users are accustomed to
  - You can install new functionality
    - Replace the original function
    - Do something in addition to original function
- See *helloevents* from examples directory

Notes about events

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- In general, the required functionality is available via signals & slots
  - Events are needed when implementing custom widgets
- Need for event filters is quite rare

Models and views

Displaying data in GUI

MVC pattern

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- Model-view-controller
  - Model takes care of storing the data
  - View displays the data to user
  - Controller takes care of user interaction
- Why?
  - Model can be tested separately
  - Different views can be applied to same data
    - Portability of data

MVC in Qt - model

- Model framework in core module
  - Generic model interface (QAbstractItemModel)
  - More specialized models
    - List model (QAbstractListModel)
    - Table model (QAbstractTableModel)
  - Ready-made models
    - QStandardItemModel
    - QStringListModel

MVC in Qt - view

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- Views in GUI module
  - Generic view interface (QAbstractItemView)
    - Usually there’s no need to implement a view
  - Ready-made views
    - QListView, QTableView, QTreeView
    - Can work with any type of model
  - View delegates
    - Way to extend the ready-made views

MVC in Qt - controller

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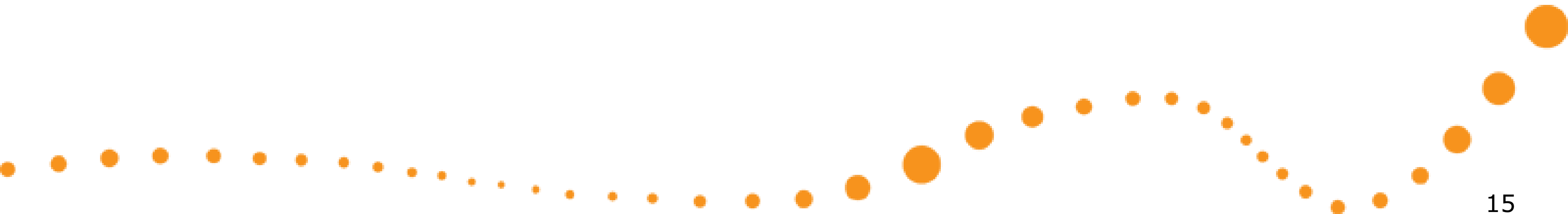
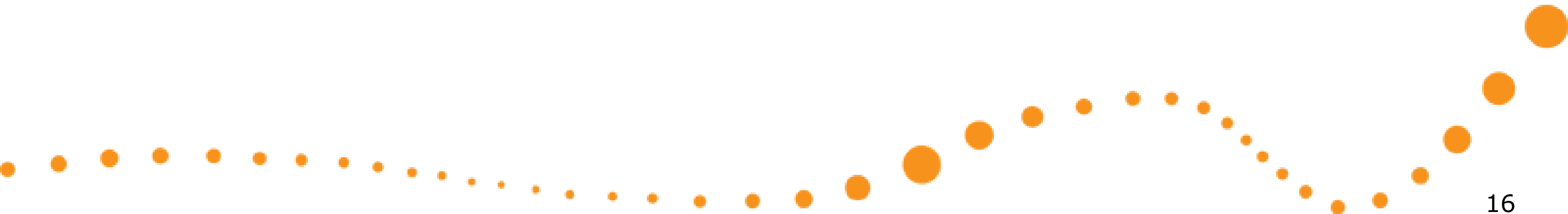
- Application works as controller
  - No generic frameworks



Model framework

- Use ready-made *QStandardItemModel*
  - Usually simpler to use and works with any kind of model (tree, list, column)
- Create your own model
  - Usually more efficient, as data can be directly mapped from your data storage into the view
  - Helpers for list and column models, tree a bit more complicated



Model basics

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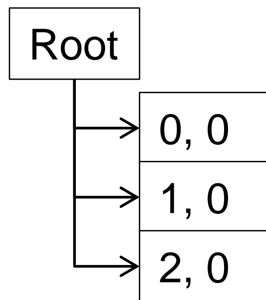
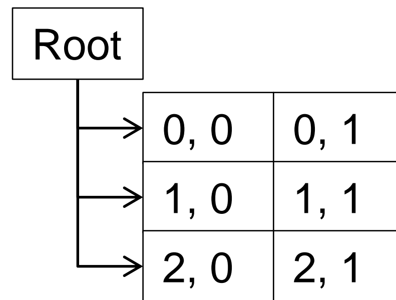
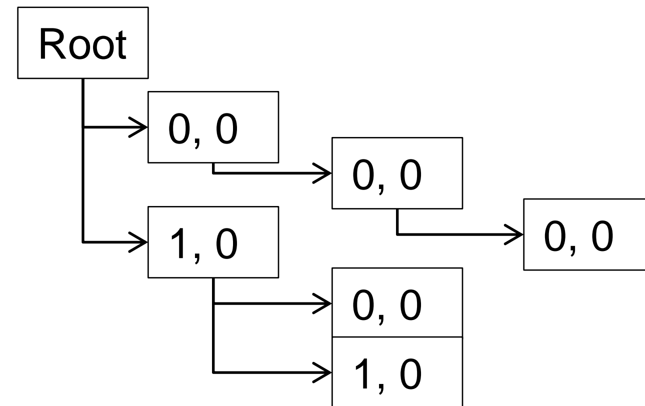
- Each element in model is identified by *model index*
  - Each model index has *row* and *column* identifiers and *parent* index

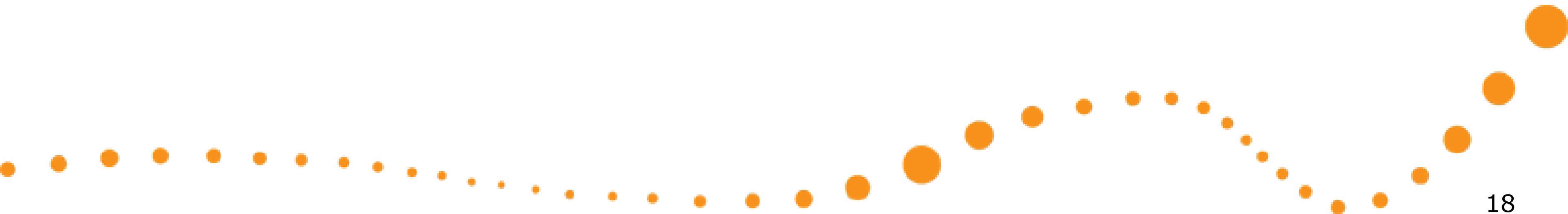






Standard item model

- List, table or tree of *QStandardItem* objects
  - Each item contains a string, which is shown in the view
  - Also other data may be associated with the item
- Can be used without subclassing
  - Mapping between data model and the standard item model is needed



Standard item model - lists

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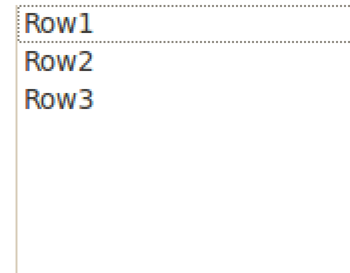
- Standard item model root is accessed with *invisibleRootItem()*

- When used as list, all items are added under the root item

```
QStringList rowList;
rowList << "Row1" << "Row2" << "Row3";

QStandardItemModel *listModel = new QStandardItemModel(this);
QStandardItem *root = listModel->invisibleRootItem();
foreach(QString str, rowList) {
    root->appendRow(new QStandardItem(str));
}
ui->listView->setModel(listModel);
```



Standard item model - table

- In table model each row consists of multiple items, but all rows are still added under the *invisibleRootItem()*

```
QStringList rowList;
rowList << "Row1" << "Row2" << "Row3";
QStringList columnList;
columnList << "Col1" << "Col2" << "Col3";

QStandardItemModel *tableModel = new QStandardItemModel(this);
QStandardItem *root = tableModel->invisibleRootItem();
foreach (QString row, rowList) {
    QList<QStandardItem *> rowData;
    foreach (QString column, columnList) {
        rowData << new QStandardItem(row + " " + column);
    }
    root->appendRow(rowData);
}
ui->tableView->setModel(tableModel);
```

	1	2	3
1	Row1 Col1	Row1 Col2	Row1 Col3
2	Row2 Col1	Row2 Col2	Row2 Col3
3	Row3 Col1	Row3 Col2	Row3 Col3

Standard item model - tree

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- In tree model each item may contain *child* items in addition to having rows and columns

```
QStringList nodeList;
nodeList << "Node1" << "Node2" << "Node3";
QStringList rowList;
rowList << "Row1" << "Row2" << "Row3";
QStringList columnList;
columnList << "Col1" << "Col2" << "Col3";

QStandardItemModel *treeModel = new QStandardItemModel(this);
treeModel->setColumnCount(3); // Doesn't resize automatically
QStandardItem *root = treeModel->invisibleRootItem();
int nodeIndex = 0;
foreach (QString node, nodeList) {
    QStandardItem *nodeItem = new QStandardItem(node);
    root->setChild(nodeIndex++, nodeItem);
    foreach (QString row, rowList) {
        QList<QStandardItem *> rowData;
        foreach (QString column, columnList) {
            rowData << new QStandardItem(row + " " + column);
        }
        nodeItem->appendRow(rowData);
    }
}
ui->treeView->setModel(treeModel);
```

1	2	3
– Node1		
Row1 Col1	Row1 Col2	Row1 Col3
Row2 Col1	Row2 Col2	Row2 Col3
Row3 Col1	Row3 Col2	Row3 Col3
– Node2		
Row1 Col1	Row1 Col2	Row1 Col3
Row2 Col1	Row2 Col2	Row2 Col3
Row3 Col1	Row3 Col2	Row3 Col3
– Node3		
Row1 Col1	Row1 Col2	Row1 Col3
Row2 Col1	Row2 Col2	Row2 Col3
Row3 Col1	Row3 Col2	Row3 Col3

Creating own models

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- If your data is already somehow structured, it’s usually a good idea to implement the model directly on top of that
  - Standard item model has a separate item tree, which can be avoided
  - With standard items any changes need to be delegated between data and model
- Check ”model subclassing reference” from QtCreator integrated help

Using the view

- To use a view, add one to your UI form with Qt designer

- Associate model to view from source code

```
ui->tableView->setModel(tableModel);
```

Interaction with model

- Model elements may contain any data
  - Data is identified with *role*
    - Data that is shown in view has *Qt::DisplayRole*
    - User-defined data can be added with *Qt::UserRole*
  - To store data into a standard item model, use *setData(something, Qt::UserRole)* when setting up the model
    - Data can later be accessed via a model index

Interaction with model

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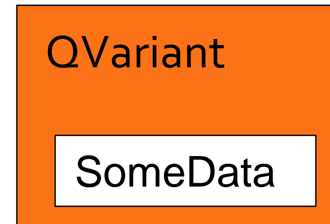
- Model data is stored as *QVariant* type
  - A container for other data types
  - Type-safe way to pass data around Qt
    - For example, an object pointer cannot used as string
  - Variants should be used with helper functions
    - *qVariantFromValue, qVariantValue*




```
// Map QObject-based object to a QVariant
MyObject *obj = new MyObject();
QVariant var = qVariantFromValue<QObject *>(obj);
```

```
// Map a variant back to QObject
MyObject *obj = static_cast<MyObject *>(qVariantValue<QObject *>(var));
```

Interaction with model

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- Adding data to standard item –based model

```
QStandardItem *item = new QStandardItem(str);
MyObject *obj = new MyObject();
item->setData(qVariantFromValue<QObject *>(obj));
root->appendRow(item);
```

- From that point on, *obj* can be accessed via the model API

Interaction with model

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- Each view has a *selection model*, which tracks the selected items from that particular view
  - Is same model is displayed in multiple views, each view still has separate selection model
- Selection changes are notified as signals
  - However, selection model is not a GUI widget, so signals are not visible in designer

```
connect(ui->treeView->selectionModel(), SIGNAL(selectionChanged(QItemSelection,QItemSelection)),
        SLOT(treeSelectionChanged(QItemSelection,QItemSelection)));
```

Interaction with model

- The data that was stored into the model can now be accessed from the selection change slot

```
void MainWindow::listSelectionChanged(const QItemSelection &selected, const QItemSelection &deselected)
{
    QModelIndexList list = selected.indexes();
    if (!list.isEmpty()) {
        QModelIndex first = list.at(0);
        MyObject *data = static_cast<MyObject *>(qVariantValue<QObject *>(first.data(Qt::UserRole)));
        // Do something with data
    }
}
```

Updating model elements

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- Standard item model elements can be changed with model *setData* function
  - *Qt::DisplayRole* changes the content that's shown on the views
  - When model changes, all views are automatically updated

```
void MainWindow::listSelectionChanged(const QItemSelection &selected, const QItemSelection &deselected)
{
    QModelIndexList list = selected.indexes();
    if (!list.isEmpty()) {
        QModelIndex first = list.at(0);
        ui->listView->model()->setData(first, "Selected!!!", Qt::DisplayRole);
    }
}
```

GUI dialogs

Basic concepts and functionality

Dialogs overview

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- A dialog is a separate window, which performs some user interaction
  - Informs users about events
  - Asks user for some kind of input
- Modality
  - A modal dialog blocks program interaction until the dialog has been dismissed
  - Modeless dialog can be left open into background

Dialogs in Qt

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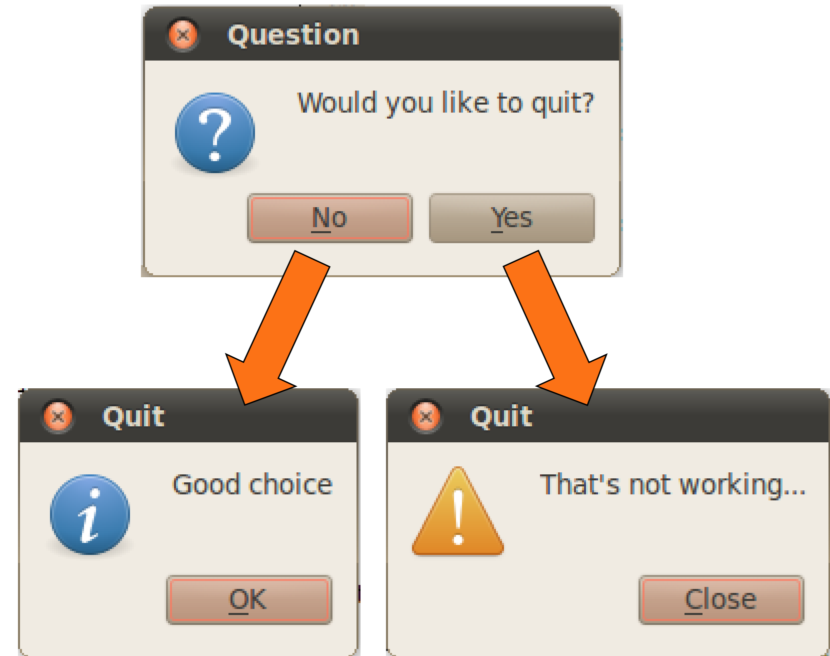
- Qt provides built-in dialogs for simple tasks
  - Displaying messages and alerts
  - Asking for some input

```
QMessageBox::StandardButton result = QMessageBox::question(
        this, "Question", "Would you like to quit?",
        QMessageBox::Yes | QMessageBox::No);
if (result == QMessageBox::Yes) {
    QMessageBox::warning(this, "Quit", "That's not working...",
                         QMessageBox::Close);
} else {
    QMessageBox::information(this, "Quit", "Good choice");
}
```



Dialogs in Qt

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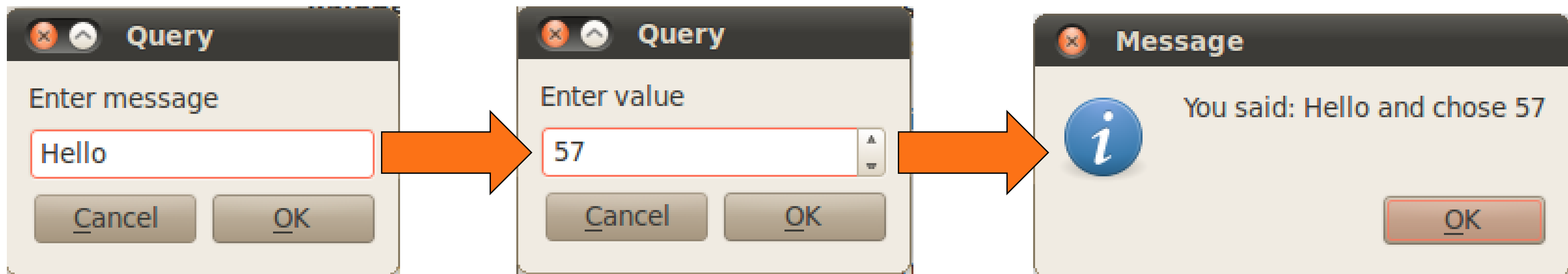
- Input dialog can be used to ask for different kinds of data

```
QString msg = QInputDialog::getText(this, "Query", "Enter message");
int value = QInputDialog::getInt(this, "Query", "Enter value", 0, -100, 100);
QMessageBox::information(this, "Message", "You said: " + msg +
                         " and chose " + QString::number(value));
```



Dialogs in Qt

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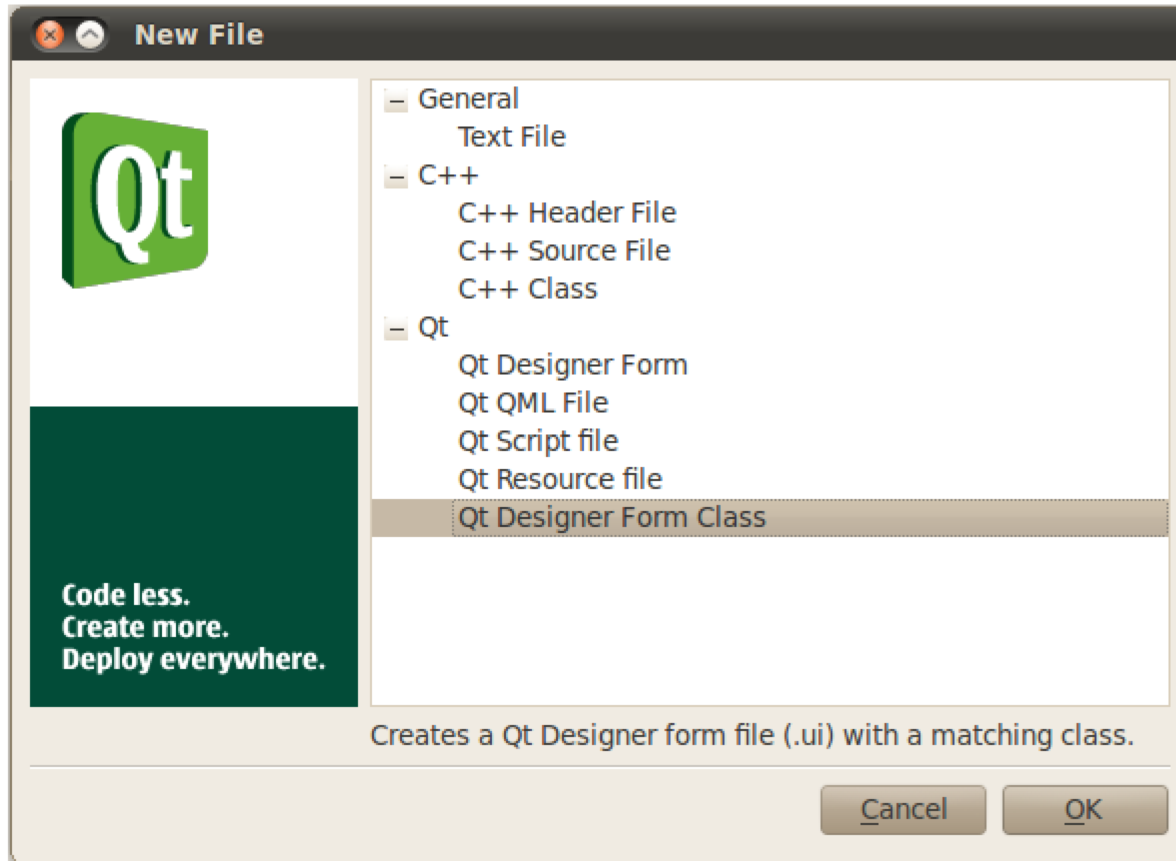
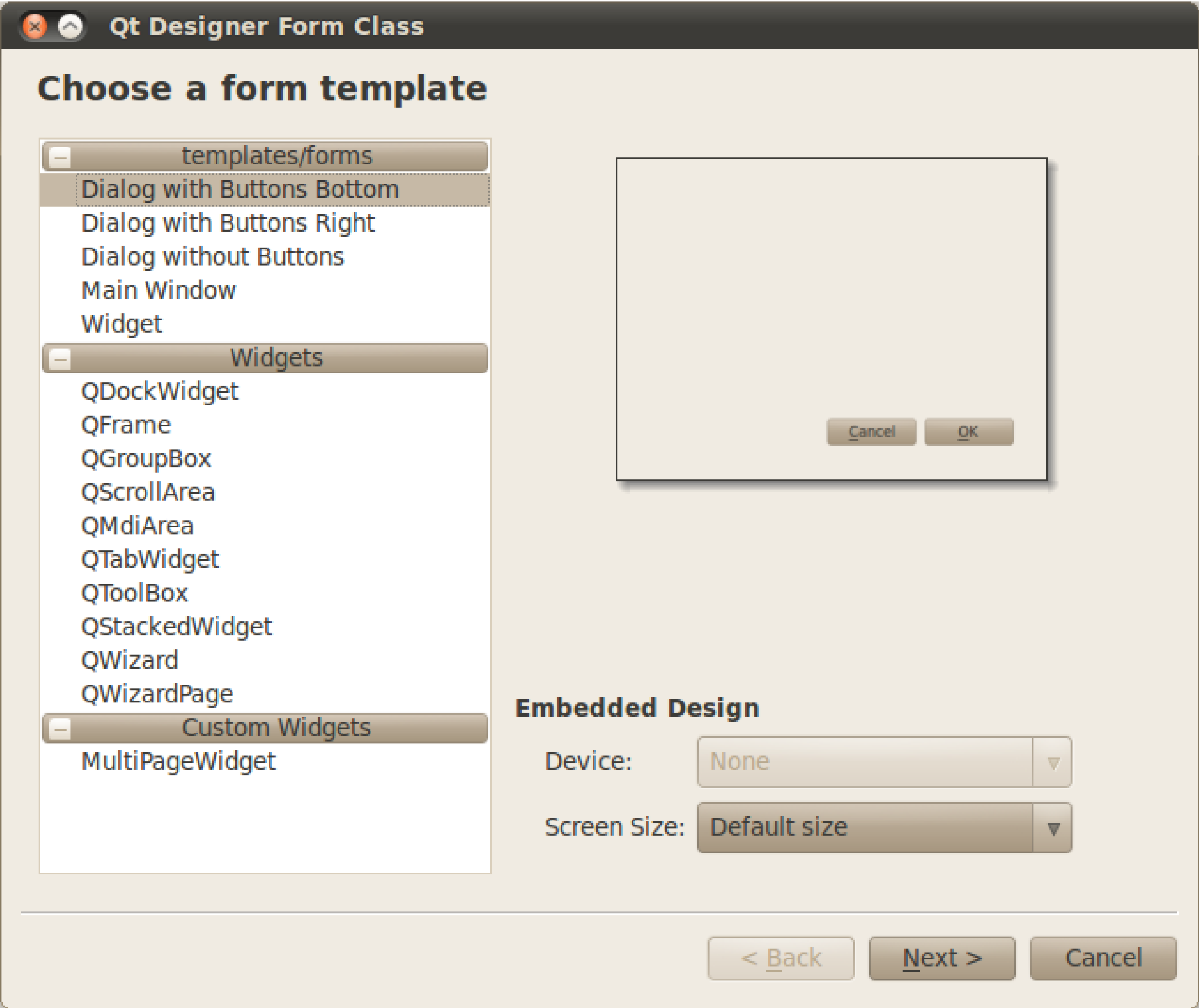
- If built-in dialogs are not suitable, new dialogs can be created with help of QtCreator form editor

Creating a new dialog

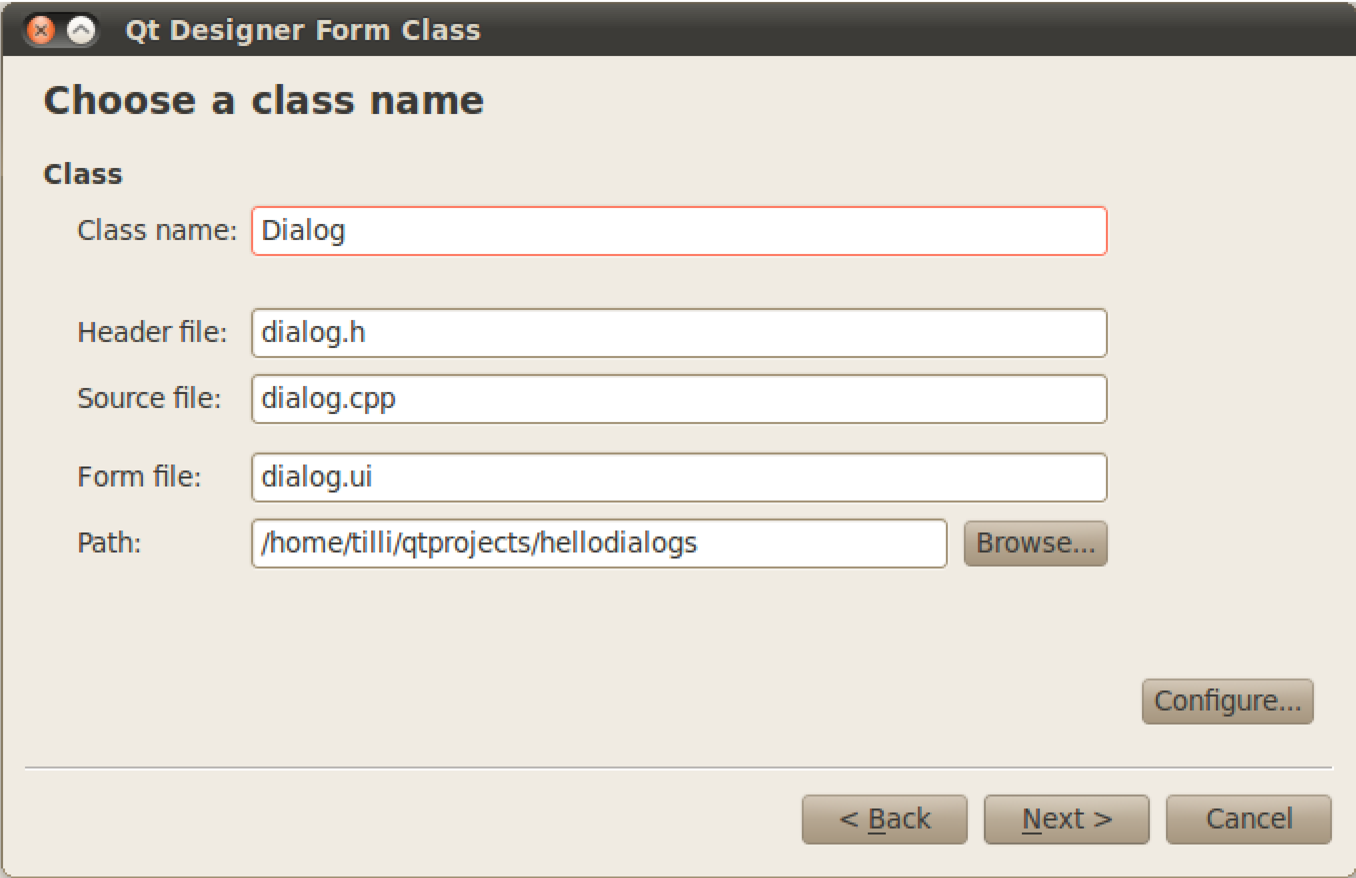
- Select the ”Class” version, not plain form



Creating a new dialog



Creating a new dialog



Creating a new dialog

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- UI resource, header and source are created similarly as when creating a new Qt project
  - Inherits from QDialog

```
class Dialog : public QDialog {
    Q_OBJECT
public:
    Dialog(QWidget *parent = 0);
    ~Dialog();

protected:
    void changeEvent(QEvent *e);

private:
    Ui::Dialog *ui;
};
```

QDialog functionality

- A dialog must always be explicitly shown
  - Modal dialogs may use *exec*, which returns whether dialog was *accepted* or *rejected*
  - Modeless dialogs use *show* and need signal-slot connection to see whether accepted or rejected

Modal dialog

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- Modal dialogs can be allocated from stack
  - Exeption to normal QObject rules
  - The *exec* function, which displays the dialog starts a new *nested event loop*, which quits when the dialog is dismissed

```
Dialog d;
int result = d.exec();
if (result == QDialog::Accepted) {
    QMessageBox::information(this, "Message", "Got OK");
} else {
    QMessageBox::information(this, "Message", "Got cancel");
}
```

Modeless dialog

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- Modeless dialog needs to be allocated from heap (or as class member variable)
  - Needs to be alive until dialog is closed

```
Dialog *d = new Dialog(this);
d->setModal(false);
d->show();
d->raise();
d->activateWindow();

connect(d, SIGNAL(accepted()), SLOT(dialogAccepted()));
connect(d, SIGNAL(rejected()), SLOT(dialogRejected()));
```

```
void MainWindow::dialogAccepted()
{
    QMessageBox::information(this, "Message", "Got OK");
    delete sender();
}

void MainWindow::dialogRejected()
{
    QMessageBox::information(this, "Message", "Got cancel");
    delete sender();
}
```

- Sender of signal is the dialog

Short exercise

- Get the *hellodialogs* example
  - Add two text input widgets into it using Qt form editor
  - If user selects *Ok*, display the content of the two text input widgets in a message box after the input dialog has been closed
- Try to find an alternative way to access and delete the modeless dialog from the slots
  - Instead of using QObject::sender()

Settings

Storing the GUI state

Settings

- In general, it's nice if the application opens into the same state it was left last time
  - QSettings helps with that
- Principle is quite simple, load data in constructor, save in destructor
  - Some UI components seem to cause problems
    - View column width doesn't change until view is visible
    - Also possible to load data in the main window *showEvent*

Settings

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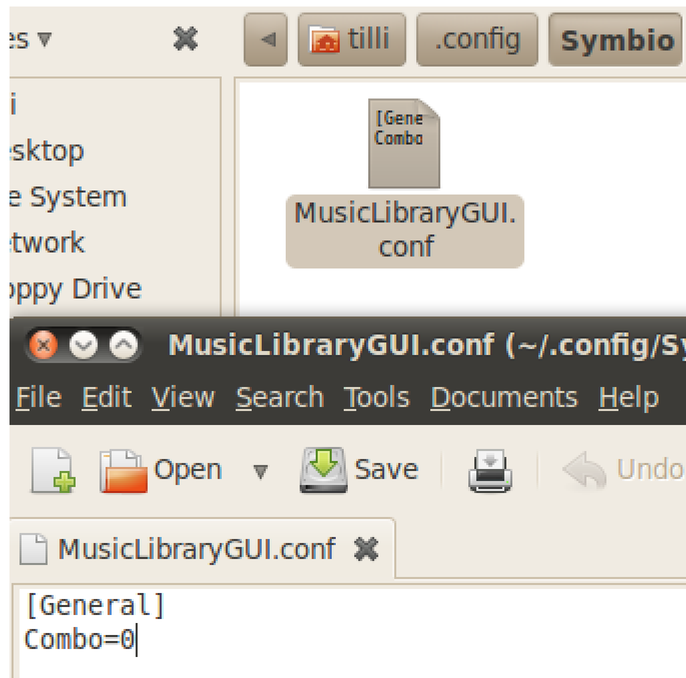
- Settings object takes two parameters when constructed
  - Company name and program name
- Each value is a QVariant
  - To save something, call *setValue*
  - To load, call *value* and provide a default

```
QSettings settings("Symbio", "MusicLibraryGUI");
settings.setValue("Combo", ui->comboBox->currentIndex());
```

```
QSettings settings("Symbio", "MusicLibraryGUI");
ui->comboBox->setCurrentIndex(settings.value("Combo", 0).toInt());
```

Settings

- Settings are stored into a text file
  - ~/.config/<company>/<program>.conf



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Graphics view

Creating ”non-traditional” UI’s

Introduction

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- Why graphics view?
  - Traditional widgets are not designed for hardware-accelerated animated UI’s that users nowadays expect from mobile devices
- What is graphics view?
  - Higher-level abstraction over QPainter used by ”traditional” widgets
    - Based on graphics items, which are cheap to paint compared to painting a QWidget

Introduction

- Can also be integrated with QWidgets
- Uses Model-View-Controller pattern
  - Multiple views can observe the same model (called graphics *scene*)
- Used by
  - KDE plasma desktop
  - Nokia mobile UI frameworks (Orbit, DUI)

Introduction

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- Problems
  - No designer support
  - QtCreator can add a Graphics View widget to the form, but that’s about it

Back to Qt core

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- Today's GUI's usually need pictures, animations and other fancy stuff
  - Qt has animations framework, which works with QObject *properties*
  - Pictures are usually stored in *resources*, which are compiled into the binary during build

Object properties

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- All QObject-based classes support *properties*
  - A property is *QVariant* type, which is stored in a dictionary that uses C-style zero-terminated character arrays as keys
  - Properties can be *dynamic* or *static*
    - *Dynamic properties are assigned at run-time*
    - *Static properties are defined at compile time and processed by the meta-object compiler*

Object properties

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- Static properties are declared into class header using *Q_PROPERTY* macro

```
class AnimatedPixmap : public QObject, public QGraphicsPixmapItem
{
    Q_OBJECT
    Q_PROPERTY(qreal rotation READ rotation WRITE setRotation)
```

- The above statement defines a property
  - Type is *qreal*, which is a floating-point number
  - Name is *rotation*
  - When read, *rotation* function is called
  - When changed, *setRotation* function is called

Object properties

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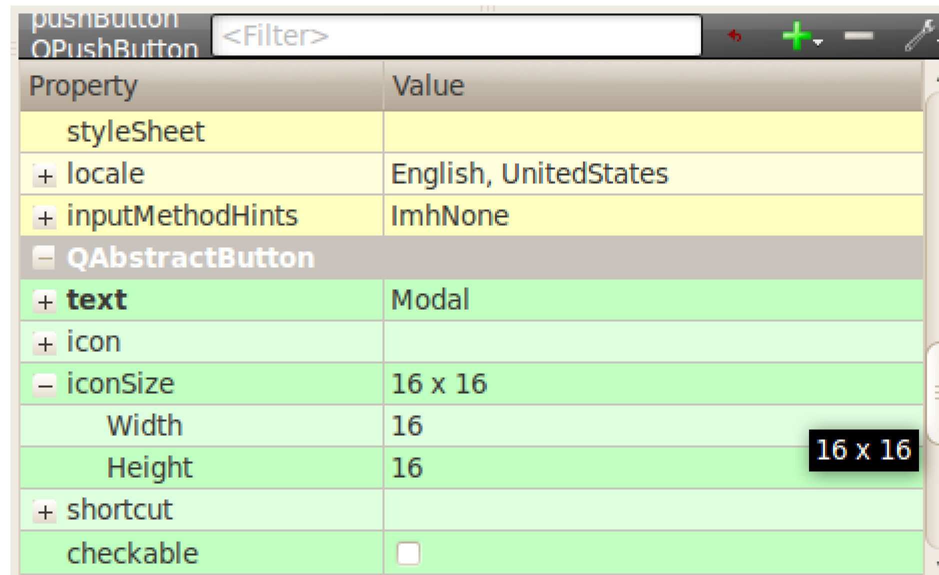
- Static properties are used for example by QtCreator GUI designer



Why properties?

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- When C++ objects are exported and used from *QtScript* or *QML* languages, the properties are automatically available
  - Signals & slots also
- Easiest way to use the animation framework is by modifying object properties

Property animations

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- A property animation is created with help of *QPropertyAnimation* class
  - Specify which object and which property to update
  - Specify duration and start and end points
  - Start the animation
- Optional things
  - Specify number of loops (or infinite)
  - Specify an *easing curve*

Property animations

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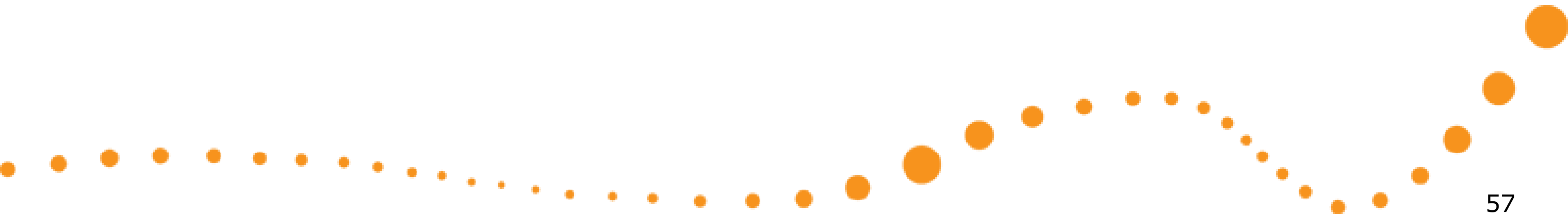
- When a property animation is started, the specified property is updated at regular intervals
  - Starting from start value, ending at end value and lasting for the duration specified
- After animation is finished, it either stops or runs a new loop



Property animations

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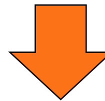
- Property animation provides some signals that can be used to monitor the state
  - *finished* is particularly interesting
    - If animation is repeated, there might be a need to reverse the animation to avoid a jump
    - Just change direction and start again

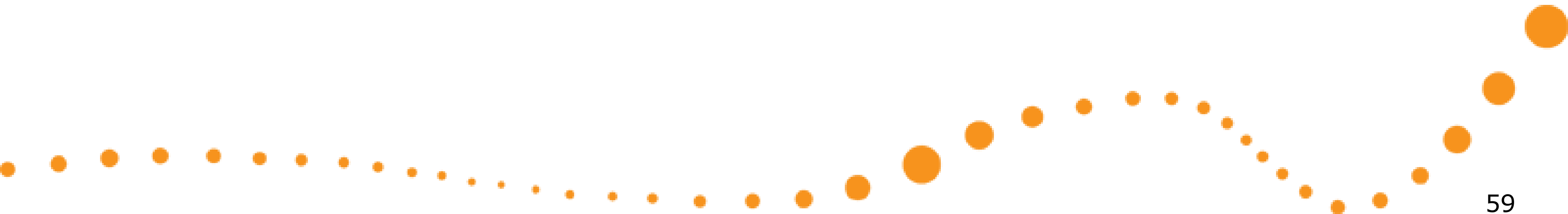
```
animation = new QPropertyAnimation(this, "scale", this);
animation->setStartValue(0.9);
animation->setEndValue(1.1);
animation->setDuration(10000);
connect(animation, SIGNAL(finished()), SLOT(animationFinished()));
animation->start();
```



```
if (animation->direction() == QPropertyAnimation::Backward) {
    animation->setDirection(QPropertyAnimation::Forward);
} else {
    animation->setDirection(QPropertyAnimation::Backward);
}
animation->start();
```

Animation notes

- Although presented here, animations framework is in no way related to graphics framework
  - Anything that requires timer-based events can be scheduled with the animations



Resource files

- Resource file specifies a collection of data that should be bundled into the binary file
  - For example pictures and localization data
- QtCreator can help add resources to project
  - Qt project file has RESOURCES statement, which contains a list of *.qrc* files
  - *qrc* file is a text file, which is parsed by *resource compiler* during project build

Resource files

New...

- Version Control
  - CVS Checkout
  - Git Repository Clone
  - Gitorious Repository Clone
  - Subversion Checkout
- Qt
  - Qt Designer Form
  - Qt Designer Form Class
  - Qt QML File
  - Qt Script file
  - Qt Resource file
- Projects
  - Import of Makefile-based Project
  - QML Application
  - Import of existing QML directory
  - Empty Qt4 Project

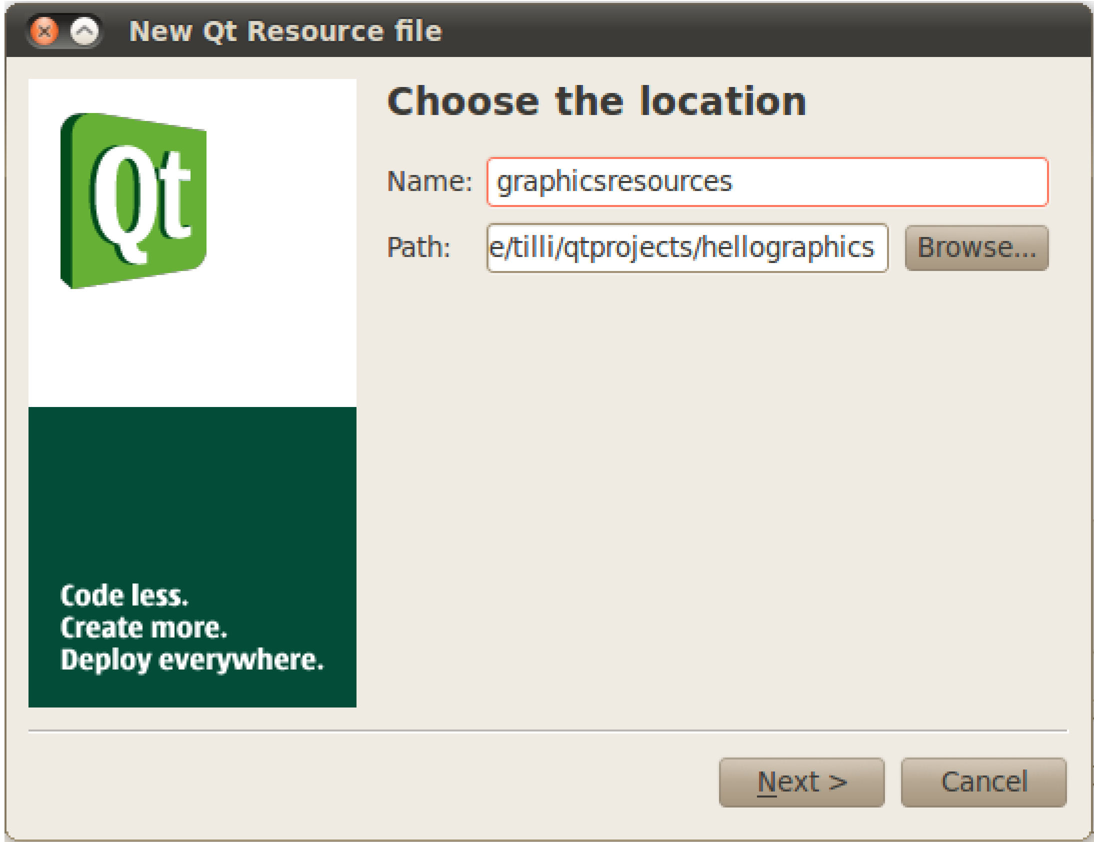
Qt

Code less.
Create more.
Deploy everywhere.

Creates a Qt Resource file (.qrc).

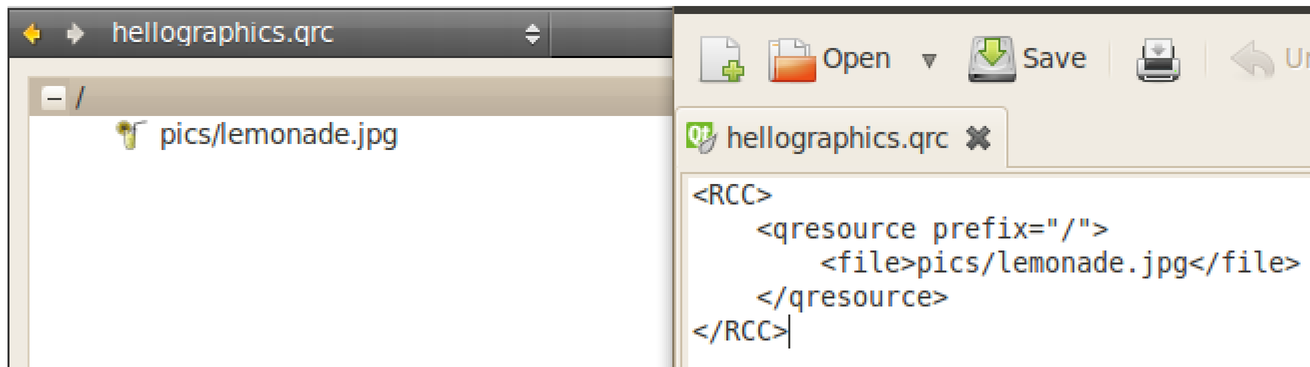
Cancel OK

Resource files



Resource files

- After resource file has been created, add a *prefix* into it and a file under the *prefix*



- Resource is identified with a path, quite similarly as a file
  - :/<prefix>/<resource-name>

Back to graphics

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- Graphics framework is based on *graphics items* and *graphics layouts*
  - Quite similar functionality as with widgets and layouts, but not based on widgets
  - Basic items
    - Shapes (like rectangle, ellipse, polygon), picture, text
  - Graphics widgets
    - Similar to QWidget, but in context of graphics scene
  - Proxy widget
    - Embeds ”traditional” widgets into graphics scene

Graphics item vs. widget

- Graphics items can be target of events, similarly as a widget
- Unlike widgets a graphics item can be *transformed*
  - Move, rotate, shear, scale, project, etc.
  - Multiple transformations can be queued

Graphics items

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- Graphics items are arranged into a tree hierarchy, similarly as widgets
  - Items may have a parent and a number of children
    - Item position is relative to parent item coordinates
    - If item doesn’t have parent, position is relative to scene coordinates
  - When a transformation is applied to an item, it is also applied to the child items

Graphics item events

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- Graphics items get event notifications when user interacts with the scene
  - Similarly as with widgets, the graphics item needs to be subclassed and the required event handler functions implemented

Graphics scene

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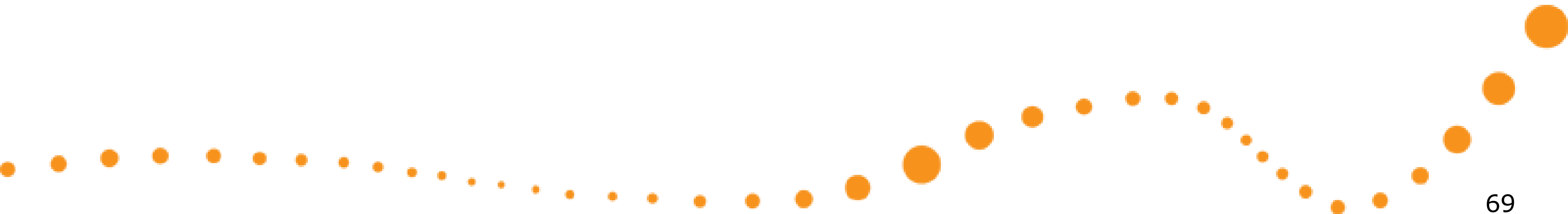
- A graphics scene is a container for items
  - The surface where the items are drawn
    - Each item has a z-order, higher z-order is drawn on top of lower one
  - Propagates events (for example mouse) to correct graphics items for processing
    - Regardless of transformations
  - Scene can be displayed in multiple views

Graphics view

<symbio>

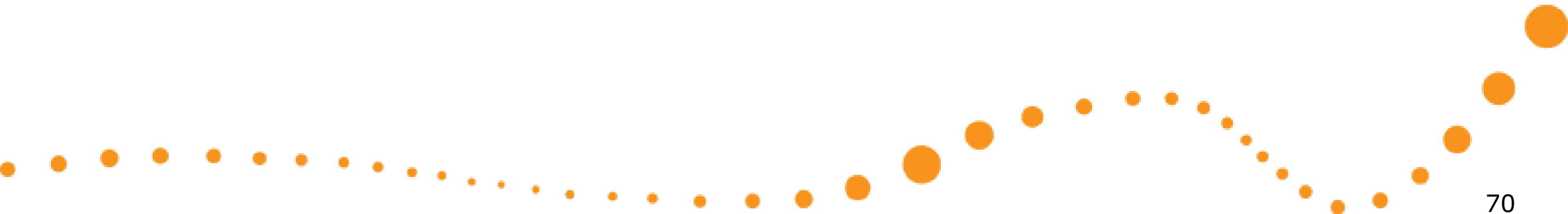
- A graphics view is a *QWidget*
    - Displays the contents of a graphics scene or a part of it
- A transform can be applied to the view
    - Transforms all items within the viewed part of the scene



Graphics example

<symbio>

- Illustrates some aspects of the graphics view and property animations
  - Adding items to scene and other items
  - Moving scene elements around
  - Animating transforms
  - Event handling



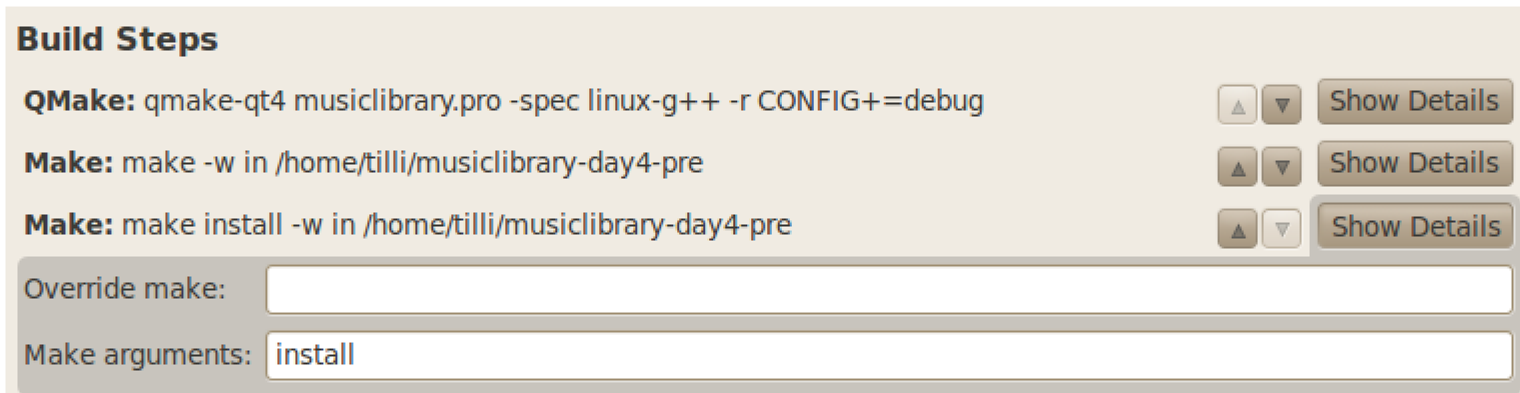
Programming exercise

Add GUI for music library

Programming exercise

<symbio>

- Get *musiclibrary-day4-pre* from the web page and open the root project file into QtCreator
  - Add *make install* build step



Programming exercise

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- Add GUI run configuration, which runs *musiclibrarygui* from the *bin* directory

Run Settings

Edit run configuration: GUI ▾ | Add ▾ | Remove

Running executable: **/home/tilli/musiclibrary-day4-pre/bin/musiclibrarygui** | Show Details

Name: GUI

Executable: /home/tilli/musiclibrary-day4-pre/bin/musiclibrarygui | Browse...

Arguments:

Working Directory: /home/tilli/musiclibrary-day4-pre/bin | Browse...

☐ Run in Terminal

Programming exercise

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- Several models are created in the constructor
  - Add some views to visualize the model contents

```
// Build a music library
MusicLibrary *library = MusicLibraryBuilder::build(this);

// Create a library model object
MusicLibraryModel *model = new MusicLibraryModel(library);

// Tree model of all objects
QAbstractItemModel *treeModel = model->tree();

// List of artists, records and songs
QAbstractItemModel *artistListModel = model->artists();
QAbstractItemModel *recordListModel = model->records();
QAbstractItemModel *songLisgModel = model->songs();
```

Programming exercise

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- Each *Record* in the music library has a cover image
  - Add a graphics view, which displays the cover images

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