Qt5 Cadaques

Release master

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CONTENTS

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Welcome to the online book of Qt5 Cadaques! Why Qt5? Because Qt5 is awesome! Why Cadaques? Because one of the authors had a great holiday in this rocky coastline in the north-east of Spain.

The entire collection of chapters covering Qt5 programming, written by Jürgen Bocklage-Ryannel and Johan Thelin, is available here. All book content is licensed under the Creative Commons Attribution Non-Commercial Share Alike 4.0 license and examples are licensed under the BSD license.

Personal Note

Jürgen Ryannel, the lead author has stopped working in his normal job and is bootstrapping a new company called ApiGear, which is all about API architectures. While the company is slowly forming, Jürgen is available for freelancing, ideally in the area of UI creating using QML or UI Architecture coaching. You can reach him via LinkedIn.

/ jryannel

Enjoy!

Content

CHAPTER

ONE

MEET QT 5

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Tip: The source code of this chapter can be found in the assets folder.

This book provides you with a walkthrough of the different aspects of application development using Qt 5.12. It focuses on the new Qt Quick technology, but also provides necessary information about writing C++ back-ends and extension for Qt Quick.

This chapter provides a high-level overview of Qt 5. It shows the different application models available for developers, as well as a Qt 5 showcase application, as a sneak preview of things to come. Additionally, the chapter aims to provide a wide overview of the Qt 5 content and how to get in touch with the makers of Qt 5.

1.1 Preface

History

Qt 4 has evolved since 2005 and provided a solid ground for thousands of applications and even full desktop and mobile systems. The usage patterns of computer users changed in the recent years. From stationary PCs towards portable notebook and nowadays mobile computers. The classical desktop is more and more replaced with mobile touch-based always connected screens. With it, the desktop UX paradigms also change. Whereas in the past Windows UI has dominated the world we spend more time nowadays on other screens with another UI language.

Qt 4 was designed to satisfy the desktop world to have a coherent set of UI widgets available on all major platforms. The challenge for Qt users has changed today and it lies more to provide a touch-based user interface for a customer-driven user interface and to enable modern user interface on all major desktop and mobile systems. Qt 4.7 started to introduce the Qt Quick technology which allows users to create a set of user interface components from simple elements to achieve a completely new UI, driven by customer demands.

1.1.1 Qt 5 Focus

Qt 5 is a complete refreshing of the very successful Qt 4 release. With Qt 4.8, the Qt 4 release is almost 7 years old. It's time to make an amazing toolkit even more amazing. Qt 5 is focused on the following:

- **Outstanding Graphics**: Qt Quick 2 is based on OpenGL (ES) using a scene graph implementation. The recomposed graphics stack allows a new level of graphics effects combined with an ease of use never seen before in this field.
- **Developer Productivity**: QML and JavaScript are the primary means for UI creation. The back-end will be driven by C++. The split between JavaScript and C++ allows a fast iteration for front-end developers concentrating on creating beautiful user interfaces and back-end C++ developers concentrating on stability, performance and extending the runtime.

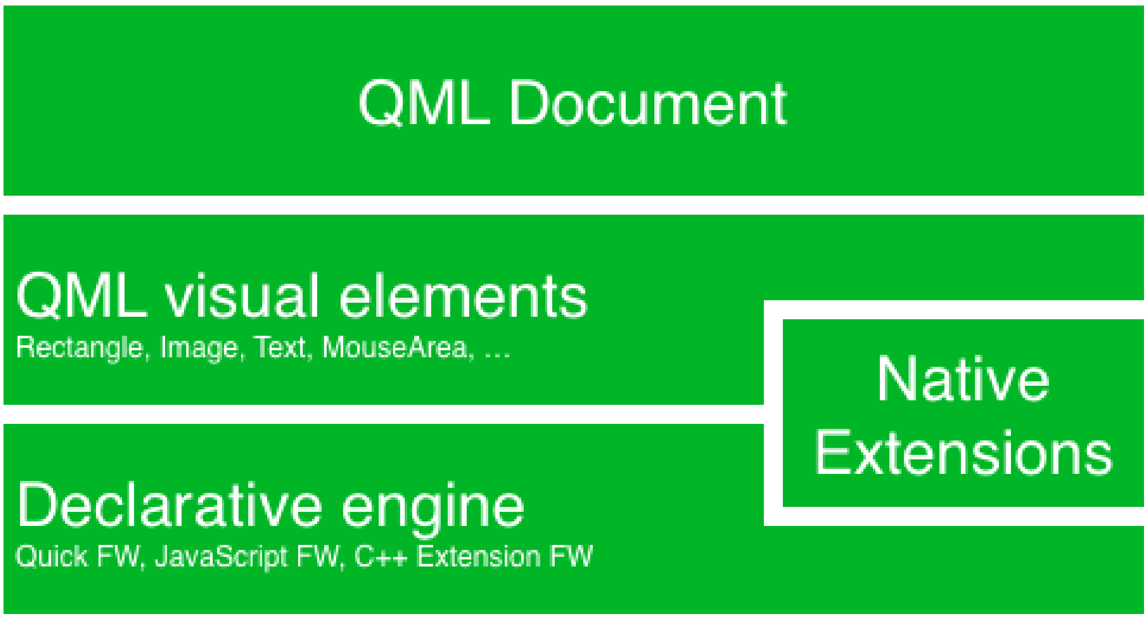
- **Cross-platform portability**: With the consolidated Qt Platform Abstraction, it is now possible to port Qt to a wider range of platforms easier and faster. Qt 5 is structured around the concept of Qt Essentials and Add-ons, which allows OS developer to focus on the essentials modules and leads to a smaller runtime altogether.
- **Open Development**: Qt is now a truly open-governance project hosted at qt.io. The development is open and community driven.

1.2 Qt 5 Introduction

1.2.1 Qt Quick

Qt Quick is the umbrella term for the user interface technology used in Qt 5. Qt Quick itself is a collection of several technologies:

- QML - Markup language for user interfaces
- JavaScript - The dynamic scripting language
- Qt C++ - The highly portable enhanced c++ library

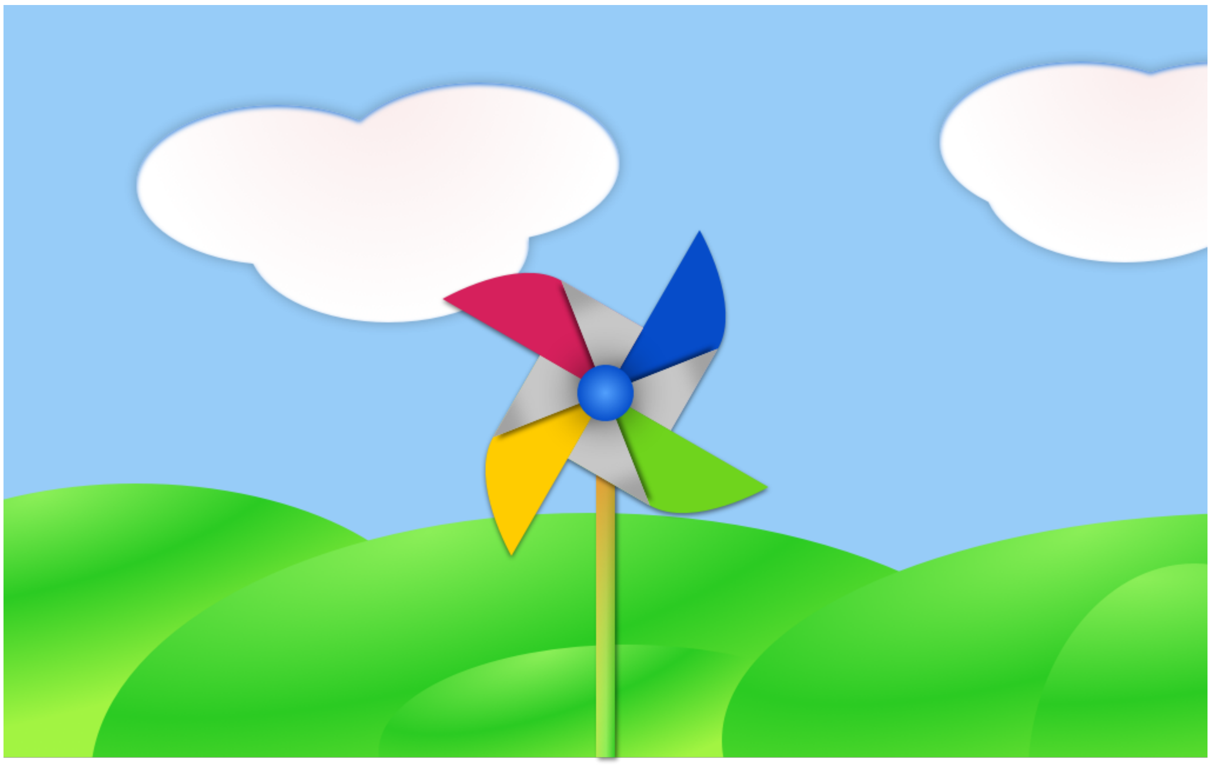

QML Document
QML visual elements
Rectangle, Image, Text, MouseArea, ...
Declarative engine
Quick FW, JavaScript FW, C++ Extension FW
Native Extensions

Similar to HTML, QML is a markup language. It is composed of tags, called types in Qt Quick, that are enclosed in curly brackets: `Item {}`. It was designed from the ground up for the creation of user interfaces, speed and easier reading for developers. The user interface can be enhanced further using JavaScript code. Qt Quick is easily extendable with your own native functionality using Qt C++. In short, the declarative UI is called the front-end and the native parts are called the back-end. This allows you to separate the computing intensive and native operation of your application from the user interface part.

In a typical project, the front-end is developed in QML/JavaScript. The back-end code, which interfaces with the system and does the heavy lifting, is developed using Qt C++. This allows a natural split between the more design-oriented developers and the functional developers. Typically, the back-end is tested using Qt Test, the Qt unit testing framework, and exported for the front-end developers to use.

1.2.2 Digesting a User Interface

Let's create a simple user interface using Qt Quick, which showcases some aspects of the QML language. In the end, we will have a paper windmill with rotating blades.



We start with an empty document called `main.qml`. All our QML files will have the suffix `.qml`. As a markup language (like HTML), a QML document needs to have one and only one root type. In our case, this is the `Image` type with a width and height based on the background image geometry:

```
import QtQuick 2.12

Image {
    id: root
    source: "images/background.png"
}
```

As QML doesn't restrict the choice of type for the root type, we use an `Image` type with the source property set to our background image as the root.

Note: Each type has properties. For example, an image has the properties `width` and `height`, each holding a count of pixels. It also has other properties, such as `source`. Since the size of the image type is automatically derived from the image size, we don't need to set the `width` and `height` properties ourselves.

The most standard types are located in the `QtQuick` module, which is made available by the import statement at the start of the `.qml` file.

The `id` is a special and optional property that contains an identifier that can be used to reference its associated type elsewhere in the document. Important: An `id` property cannot be changed after it has been set, and it cannot be set during runtime. Using `root` as the id for the root-type is a convention used in this book to make referencing the top-most type predictable in larger QML documents.

The foreground elements, representing the pole and the pinwheel in the user interface, are included as separate images.

We want to place the pole horizontally in the center of the background, but offset vertically towards the bottom. And we want to place the pinwheel in the middle of the background.

Although this beginners example only uses image types, as we progress you will create more sophisticated user interfaces that are composed of many different types.

```
Image {
    id: root
    ...
    Image {
        id: pole
        anchors.horizontalCenter: parent.horizontalCenter
        anchors.bottom: parent.bottom
        source: "images/pole.png"
    }

    Image {
        id: wheel
        anchors.centerIn: parent
        source: "images/pinwheel.png"
    }
    ...
}
```

To place the pinwheel in the middle, we use a complex property called `anchor`. Anchoring allows you to specify geometric relations between parent and sibling objects. For example, place me in the center of another type (`anchors.centerIn: parent`). There are left, right, top, bottom, centerIn, fill, verticalCenter and horizontalCenter relations on both ends. Naturally, when two or more anchors are used together, they should complement each other: it wouldn't make sense, for instance, to anchor a type's left side to the top of another type.

For the pinwheel, the anchoring only requires one simple anchor.

Note: Sometimes you will want to make small adjustments, for example, to nudge a type slightly off-center. This can be done with `anchors.horizontalCenterOffset` or with `anchors.verticalCenterOffset`. Similar adjustment properties are also available for all the other anchors. Refer to the documentation for a full list of anchors properties.

Note: Placing an image as a child type of our root type (the `Image`) illustrates an important concept of a declarative language. You describe the visual appearance of the user interface in the order of layers and grouping, where the topmost layer (our background image) is drawn first and the child layers are drawn on top of it in the local coordinate system of the containing type.

To make the showcase a bit more interesting, let's make the scene interactive. The idea is to rotate the wheel when the user presses the mouse somewhere in the scene.

We use the `MouseArea` type and make it cover the entire area of our root type.

```
Image {
    id: root
    ...
    MouseArea {
        anchors.fill: parent
        onClicked: wheel.rotation += 90
    }
    ...
}
```

The mouse area emits signals when the user clicks inside the area it covers. You can connect to this signal by overriding the `onClicked` function. When a signal is connected, it means that the function (or functions) it corresponds to are called whenever the signal is emitted. In this case, we say that when there's a mouse click in the mouse area, the type whose `id` is `wheel` (i.e., the pinwheel image) should rotate by +90 degrees.

Note: This technique works for every signal, with the naming convention being `on` + `SignalName` in title case.

Also, all properties emit a signal when their value changes. For these signals, the naming convention is:

> `on` + `PropertyName` + `Changed`

For example, if a `width` property is changed, you can observe it with `onWidthChanged: print(width)`.

The wheel will now rotate whenever the user clicks, but the rotation takes place in one jump, rather than a fluid movement over time. We can achieve smooth movement using animation. An animation defines how a property change occurs over a period of time. To enable this, we use the `Animation` type's property called `Behavior`. The `Behavior` specifies an animation for a defined property for every change applied to that property. In other words, whenever the property changes, the animation is run. This is only one of many ways of doing animation in QML.

```
Image {
    id: root
    Image {
        id: wheel
        Behavior on rotation {
            NumberAnimation {
                duration: 250
            }
        }
    }
}
```

Now, whenever the wheel's rotation property changes, it will be animated using a `NumberAnimation` with a duration of 250 ms. So each 90-degree turn will take 250 ms, producing a nice smooth turn.

Note: You will not actually see the wheel blurred. This is just to indicate the rotation. (A blurred wheel is in the assets folder, in case you'd like to experiment with it.)

Now the wheel looks much better and behaves nicely, as well as providing a very brief insight into the basics of how Qt Quick programming works.

1.3 Qt Building Blocks

Qt 5 consists of a large number of modules. In general, a module is a library for the developer to use. Some modules are mandatory for a Qt-enabled platform and form the set called *Qt Essentials Modules*. Many modules are optional, and form the *Qt Add-On Modules*. The majority of developers may not need to use the latter, but it's good to know about them as they provide invaluable solutions to common challenges.

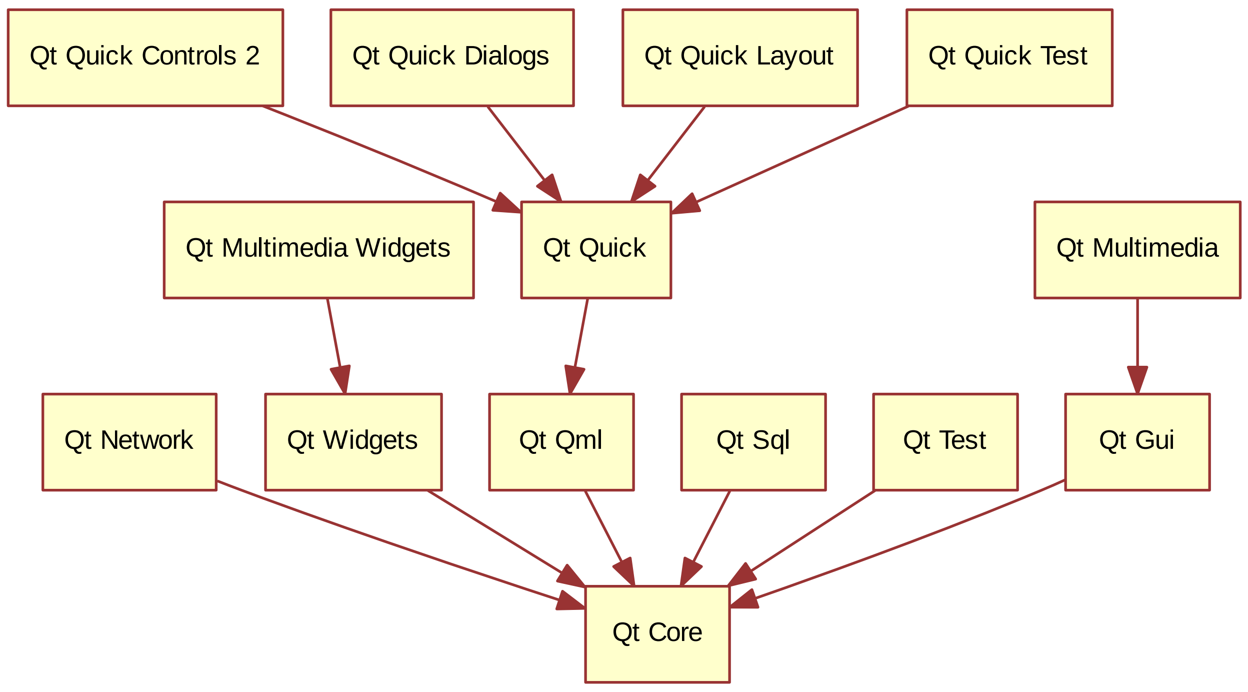
1.3.1 Qt Modules

The Qt Essentials modules are mandatory for any Qt-enabled platform. They offer the foundation to develop modern Qt 5 Applications using Qt Quick 2. The full list of modules is available in the Qt documentation module list.

Core-Essential Modules

The minimal set of Qt 5 modules to start QML programming.

Module	Description
Qt Core	Core non-graphical classes used by other modules.
Qt GUI	Base classes for graphical user interface (GUI) components. Includes OpenGL.
Qt Multimedia	Classes for audio, video, radio and camera functionality.
Qt Multimedia Widgets	Widget-based classes for implementing multimedia functionality.
Qt Network	Classes to make network programming easier and more portable.
Qt QML	Classes for QML and JavaScript languages.
Qt Quick	A declarative framework for building highly dynamic applications with custom user interfaces.
Qt Quick Controls 2	Provides lightweight QML types for creating performant user interfaces for desktop, embedded, and mobile devices. These types employ a simple styling architecture and are very efficient.
Qt Quick Dialogs	Types for creating and interacting with system dialogs from a Qt Quick application.
Qt Quick Layouts	Layouts are items that are used to arrange Qt Quick 2 based items in the user interface.
Qt Quick Test	A unit test framework for QML applications, where the test cases are written as JavaScript functions.
Qt SQL	Classes for database integration using SQL.
Qt Test	Classes for unit testing Qt applications and libraries.
Qt Widgets	Classes to extend Qt GUI with C++ widgets.



Qt Add-On Modules

Besides the essential modules, Qt offers additional modules that target specific purposes. Many add-on modules are either feature-complete and exist for backwards compatibility, or are only applicable to certain platforms. Here is a list of some of the available add-on modules, but make sure you familiarize yourself with them all in the Qt documentation add-ons list and in the list below.

Module	Description
Qt 3D	A set of APIs to make 3D graphics programming easy and declarative.
Qt Bluetooth	C++ and QML APIs for platforms using Bluetooth wireless technology.
Qt Canvas 3D	Enables OpenGL-like 3D drawing calls from Qt Quick applications using JavaScript.
Qt Graphical Effects	Graphical effects for use with Qt Quick 2.
Qt Location	Displays map, navigation, and place content in a QML application.
Qt Network Authorization	Provides support for OAuth-based authorization to online services.
Qt Positioning	Provides access to position, satellite and area monitoring classes.
Qt Purchasing	Enables in-app purchase of products in Qt applications. (Only for Android, iOS and MacOS).
Qt Sensors	Provides access to sensors and motion gesture recognition.
Qt Wayland Compositor	Provides a framework to develop a Wayland compositor. (Only for Linux).
Qt Virtual Keyboard	A framework for implementing different input methods as well as a QML virtual keyboard. Supports localized keyboard layouts and custom visual themes.

Note: As these modules are not part of the release, the state of each module may differ depending on how many contributors are active and how well it's tested.

1.3.2 Supported Platforms

Qt supports a variety of platforms including all major desktop and embedded platforms. Through the Qt Application Abstraction, it's now easier than ever to port Qt to your own platform if required.

Testing Qt 5 on a platform is time-consuming. A subset of platforms was selected by the Qt Project to build the reference platforms set. These platforms are thoroughly tested through the system testing to ensure the best quality. However, keep in mind that no code is error-free.

1.4 Qt Project

From the Qt Project wiki:

> "The Qt Project is a meritocratic consensus-based community interested in Qt. Anyone who shares that interest can join the community, participate in its decision-making processes, and contribute to Qt's development."

The Qt Project is an organization which develops the open-source part of the Qt further. It forms the base for other users to contribute. The biggest contributor is The Qt Company, which holds also the commercial rights to Qt.

Qt has an open-source aspect and a commercial aspect for companies. The commercial aspect is for companies which can not or will not comply with the open-source licenses. Without the commercial aspect, these companies would not be able to use Qt and it would not allow The Qt Company to contribute so much code to the Qt Project.

There are many companies worldwide, which make the living out of consultancy and product development using Qt on the various platforms. There are many open-source projects and open-source developers, which rely on Qt as their major development library. It feels good to be part of this vibrant community and to work with this awesome tools and libraries. Does it make you a better person? Maybe:-)

Contribute here: http://wiki.qt.io/

CHAPTER

TWO

GET STARTED

Section author: jryannel@LinkedIn

This chapter will introduce you to developing with Qt 5. We will show you how to install the Qt SDK and how you can create as well as run a simple *hello world* application using the Qt Creator IDE.

Note: The source code of this chapter can be found in the assets folder.

2.1 Installing Qt 5 SDK

The Qt SDK includes the tools you need to build desktop or embedded applications. You can grab the latest version from the Qt Company's homepage. There is an offline and online installer. The author personally prefers the online installer package as it allows you to install and update multiple Qt releases. This is the recommended way to start. The SDK itself has a maintenance tool, which allows you to update the SDK to the latest version.

The Qt SDK is easy to install and comes with its own IDE for rapid development called *Qt Creator*. The IDE is a highly productive environment for Qt coding and recommended to all readers. Many developers use Qt from the command line, however, and you are free to use the code editor of your choice.

When installing the SDK, you should select the default option and ensure that Qt 5.12 is enabled. Then you're ready to go.

2.2 Hello World

To test your installation, we will create a small *hello world* application. Please, open Qt Creator and create a Qt Quick UI Project (*File → New File or Project → Other Project → Qt Quick UI prototype*) and name the project `HelloWorld`.

Note: The Qt Creator IDE allows you to create various types of applications. If not otherwise stated, we always use a *Qt Quick UI prototype* project.

Hint: A typical Qt Quick application is made out of a runtime called the QmlEngine which loads the initial QML code. The developer can register C++ types with the runtime to interface with the native code. These C++ types can also be bundled into a plugin and then dynamically loaded using an import statement. The `qmlscene` and `qml` tool are pre-made runtimes, which can be used directly. For the beginning, we will not cover the native side of development and focus only on the QML aspects of Qt 5. This is why we start from a *prototype* project.

Qt Creator creates several files for you. The `HelloWorld.qmlproject` file is the project file, where the relevant project configuration is stored. This file is managed by Qt Creator, so don't edit it yourself.

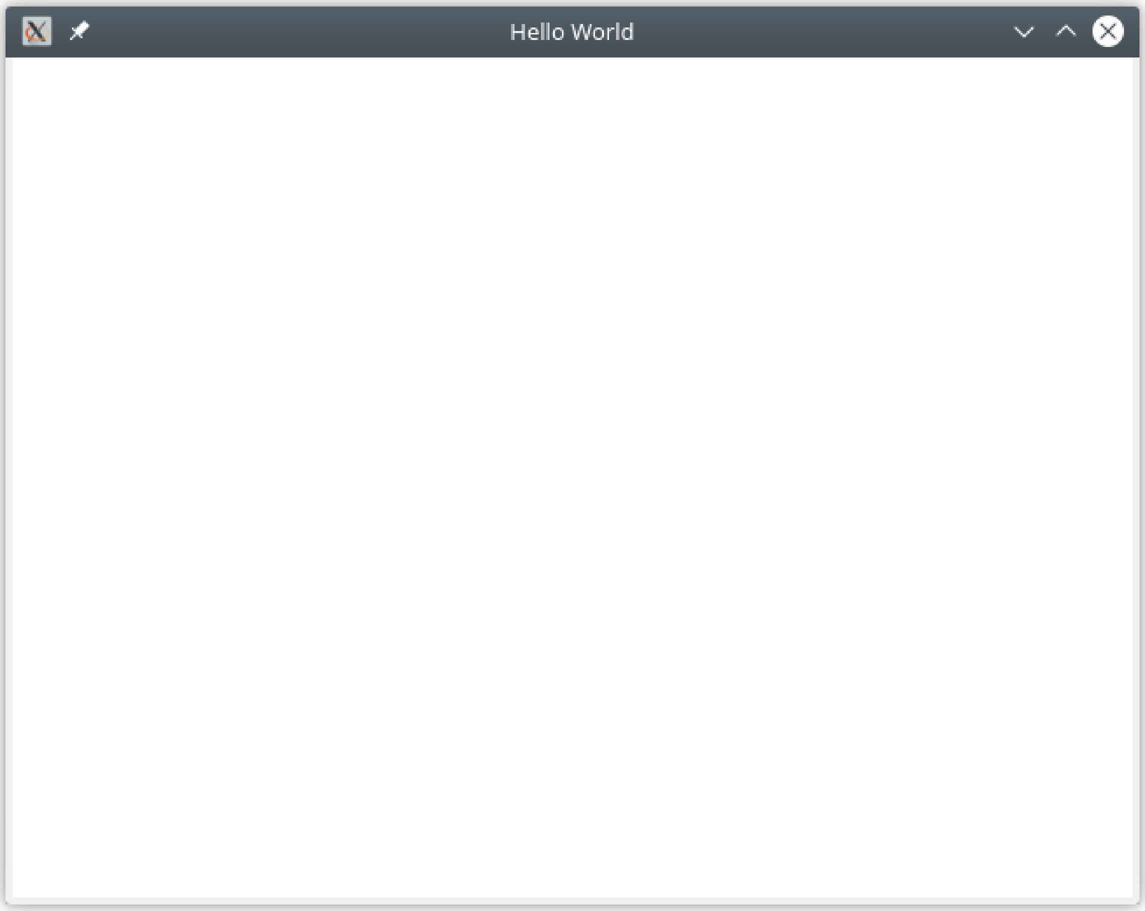
Another file, `HelloWorld.qml`, is our application code. Open it and try to understand what the application does before you read on.

```
// HelloWorld.qml

import QtQuick 2.12
import QtQuick.Window 2.12

Window {
    visible: true
    width: 640
    height: 480
    title: qsTr("Hello World")
}
```

The `HelloWord.qml` program is written in the QML language. We'll discuss the QML language more in-depth in the next chapter. QML describes the user interface as a tree of hierarchical elements.

To run the application on your own, press the ▶ *Run* tool on the left side, or select *Build* > *Run* from the menu.

In the background, Qt Creator runs `qmlscene` and passes your QML document as the first argument. The `qmlscene` application parses the document, and launches the user interface. You should see something like this:



Qt 5 works! That means we're ready to continue.

Tip: If you are a system integrator, you'll want to have Qt SDK installed to get the latest stable Qt release, as well as a Qt version compiled from source for your specific device target.

Build from Scratch

If you'd like to build Qt 5 from the command line, you'll first need to grab a copy of the code repository and build it. Visit Qt's wiki for an up-to-date explanation of how to build Qt from git.

After a successful compilation (and 2 cups of coffee), Qt 5 will be available in the `qtbase` folder. Any beverage will suffice, however, we suggest coffee for best results.

If you want to test your compilation, you can now run the example with the default runtime that comes with Qt 5:

```
$ qtbase/bin/qmlscene
```

2.3 Application Types

This section is a run through of different application types one can write with Qt 5. It's not limited to the selection presented here, but it will give you a better idea of what you can achieve with Qt 5 in general.

2.3.1 Console Application

A console application does not provide a graphical user interface, and is usually called as part of a system service or from the command line. Qt 5 comes with a series of ready-made components which help you create cross-platform console applications very efficiently. For example, the networking file APIs, string handling, and an efficient command line parser. As Qt is a high-level API on top of C++, you get programming speed paired with execution speed. Don't think of Qt as being *just* a UI toolkit - it has so much more to offer!

String Handling

This first example demonstrates how you could add 2 constant strings. Admittedly, this is not a very useful application, but it gives you an idea of what a native C++ application without an event loop may look like.

```
// module or class includes
#include <QtCore>

// text stream is text-codec aware
QTextStream cout(stdout, QIODevice::WriteOnly);

int main(int argc, char** argv)
{
    // avoid compiler warnings
    Q_UNUSED(argc)
    Q_UNUSED(argv)
    QString s1("Paris");
    QString s2("London");
    // string concatenation
    QString s = s1 + " " + s2 + "!";
    cout << s << endl;
}
```

Container Classes

This example adds a list, and list iteration, to the application. Qt comes with a large collection of container classes that are easy to use, and has the same API paradigms as other Qt classes.

```
QString s1("Hello");
QString s2("Qt");
QList<QString> list;
// stream into containers
list << s1 << s2;
// Java and STL like iterators
QListIterator<QString> iter(list);
while(iter.hasNext()) {
    cout << iter.next();
    if(iter.hasNext()) {
        cout << " ";
    }
}
cout << "!" << endl;
```

Here is a more advanced list function, that allows you to join a list of strings into one string. This is very handy when you need to proceed line based text input. The inverse (string to string-list) is also possible using the `QString::split()` function.

```
QString s1("Hello");
QString s2("Qt");
// convenient container classes
QStringList list;
list <<  s1 << s2;
// join strings
QString s = list.join(" ") + "!";
cout << s << endl;
```

File IO

In the next snippet, we read a CSV file from the local directory and loop over the rows to extract the cells from each row. Doing this, we get the table data from the CSV file in ca. 20 lines of code. File reading gives us a byte stream, to be able to convert this into valid Unicode text, we need to use the text stream and pass in the file as a lower-level stream. For writing CSV files, you would just need to open the file in write mode, and pipe the lines into the text stream.

```
QList<QStringList> data;
// file operations
QFile file("sample.csv");
if(file.open(QIODevice::ReadOnly)) {
    QTextStream stream(&file);
    // loop forever macro
    forever {
        QString line = stream.readLine();
        // test for null string 'String()'
        if(line.isNull()) {
            break;
        }
        // test for empty string 'QString("")'
        if(line.isEmpty()) {
            continue;
        }
        QStringList row;
        // for each loop to iterate over containers
        foreach(const QString& cell, line.split(",")) {
            row.append(cell.trimmed());
        }
        data.append(row);
    }
```

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```
}
// No cleanup necessary.
```

This concludes the section about console based applications with Qt.

2.3.2 C++ Widget Application

Console based applications are very handy, but sometimes you need to have a graphical user interface (GUI). In addition, GUI-based applications will likely need a back-end to read/write files, communicate over the network, or keep data in a container.

In this first snippet for widget-based applications, we do as little as needed to create a window and show it. In Qt, a widget without a parent is a window. We use a scoped pointer to ensure that the widget is deleted when the pointer goes out of scope. The application object encapsulates the Qt runtime, and we start the event loop with the `exec()` call. From there on, the application reacts only to events triggered by user input (such as mouse or keyboard), or other event providers, such as networking or file IO. The application only exits when the event loop is exited. This is done by calling `quit()` on the application or by closing the window.

When you run the code, you will see a window with the size of 240 x 120 pixels. That's all.

```
#include <QtGui>

int main(int argc, char** argv)
{
    QApplication app(argc, argv);
    QScopedPointer<QWidget> widget(new CustomWidget());
    widget->resize(240, 120);
    widget->show();
    return app.exec();
}
```

Custom Widgets

When you work on user interfaces, you may need to create custom-made widgets. Typically, a widget is a window area filled with painting calls. Additionally, the widget has internal knowledge of how to handle keyboard and mouse input, as well as how to react to external triggers. To do this in Qt, we need to derive from *QWidget* and overwrite several functions for painting and event handling.

```
#ifndef CUSTOMWIDGET_H
#define CUSTOMWIDGET_H

#include <QtWidgets>

class CustomWidget : public QWidget
{
    Q_OBJECT
public:
    explicit CustomWidget(QWidget *parent = 0);
    void paintEvent(QPaintEvent *event);
    void mousePressEvent(QMouseEvent *event);
    void mouseMoveEvent(QMouseEvent *event);
private:
    QPoint m_lastPos;
};

#endif // CUSTOMWIDGET_H
```

In the implementation, we draw a small border on our widget and a small rectangle on the last mouse position. This is very typical for a low-level custom widget. Mouse and keyboard events change the internal state of the widget and trigger a painting update. We won't go into too much detail about this code, but it is good to know that you have the possibility. Qt comes with a large set of ready-made desktop widgets, so it's likely that you don't have to do this.

```
#include "customwidget.h"

CustomWidget::CustomWidget(QWidget *parent) :
    QWidget(parent)
{
}

void CustomWidget::paintEvent(QPaintEvent *)
{
    QPainter painter(this);
    QRect r1 = rect().adjusted(10,10,-10,-10);
    painter.setPen(QColor("#33B5E5"));
    painter.drawRect(r1);

    QRect r2(QPoint(0,0),QSize(40,40));
    if(m_lastPos.isNull()) {
        r2.moveCenter(r1.center());
    } else {
        r2.moveCenter(m_lastPos);
    }
    painter.fillRect(r2, QColor("#FFBB33"));
}

void CustomWidget::mousePressEvent(QMouseEvent *event)
{
    m_lastPos = event->pos();
    update();
}

void CustomWidget::mouseMoveEvent(QMouseEvent *event)
{
    m_lastPos = event->pos();
    update();
}
```

Desktop Widgets

The Qt developers have done all of this for you already and provide a set of desktop widgets, with a native look on different operating systems. Your job, then, is to arrange these different widgets in a widget container into larger panels. A widget in Qt can also be a container for other widgets. This is accomplished through the parent-child relationship. This means we need to make our ready-made widgets, such as buttons, checkboxes, radio buttons, lists, and grids, children of other widgets. One way to accomplish this is displayed below.

Here is the header file for a so-called widget container.

```
class CustomWidget : public QWidget
{
    Q_OBJECT
public:
    explicit CustomWidget(QWidget *parent = 0);
private slots:
    void itemClicked(QListWidgetItem* item);
    void updateItem();
private:
    QListWidget *m_widget;
    QLineEdit *m_edit;
```

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```
    QPushButton *m_button;
};
```

In the implementation, we use layouts to better arrange our widgets. Layout managers re-layout the widgets according to some size policies when the container widget is re-sized. In this example, we have a list, a line edit, and a button, which are arranged vertically and allow the user to edit a list of cities. We use Qt's `signal` and `slots` to connect sender and receiver objects.

```
CustomWidget::CustomWidget(QWidget *parent) :
    QWidget(parent)
{
    QVBoxLayout *layout = new QVBoxLayout(this);
    m_widget = new QListWidget(this);
    layout->addWidget(m_widget);

    m_edit = new QLineEdit(this);
    layout->addWidget(m_edit);

    m_button = new QPushButton("Quit", this);
    layout->addWidget(m_button);
    setLayout(layout);

    QStringList cities;
    cities << "Paris" << "London" << "Munich";
    foreach(const QString& city, cities) {
        m_widget->addItem(city);
    }

    connect(m_widget, SIGNAL(itemClicked(QListWidgetItem*)), this,␣
↪SLOT(itemClicked(QListWidgetItem*)));
    connect(m_edit, SIGNAL(editingFinished()), this, SLOT(updateItem()));
    connect(m_button, SIGNAL(clicked()), qApp, SLOT(quit()));
}

void CustomWidget::itemClicked(QListWidgetItem *item)
{
    Q_ASSERT(item);
    m_edit->setText(item->text());
}

void CustomWidget::updateItem()
{
    QListWidgetItem* item = m_widget->currentItem();
    if(item) {
        item->setText(m_edit->text());
    }
}
```

Drawing Shapes

Some problems are better visualized. If the problem at hand looks remotely like geometrical objects, Qt graphics view is a good candidate. A graphics view arranges simple geometrical shapes in a scene. The user can interact with these shapes, or they are positioned using an algorithm. To populate a graphics view, you need a graphics view and a graphics scene. The scene is attached to the view and is populated with graphics items. Here is a short example. First the header file with the declaration of the view and scene.

```
class CustomWidgetV2 : public QWidget
{
    Q_OBJECT
```

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(continued from previous page)

```
public:
    explicit CustomWidgetV2(QWidget *parent = 0);
private:
    QGraphicsView *m_view;
    QGraphicsScene *m_scene;

};
```

In the implementation, the scene gets attached to the view first. The view is a widget and gets arranged in our container widget. In the end, we add a small rectangle to the scene, which is then rendered on the view.

```
#include "customwidgetv2.h"

CustomWidget::CustomWidget(QWidget *parent) :
    QWidget(parent)
{
    m_view = new QGraphicsView(this);
    m_scene = new QGraphicsScene(this);
    m_view->setScene(m_scene);

    QVBoxLayout *layout = new QVBoxLayout(this);
    layout->setMargin(0);
    layout->addWidget(m_view);
    setLayout(layout);

    QGraphicsItem* rect1 = m_scene->addRect(0,0, 40, 40, Qt::NoPen, QColor("#FFBB33
↪"));
    rect1->setFlags(QGraphicsItem::ItemIsFocusable|QGraphicsItem::ItemIsMovable);
}
```

2.3.3 Adapting Data

Up to now, we have mostly covered basic data types and how to use widgets and graphics views. In your applications, you will often need a larger amount of structured data, which may also need to be stored persistently. Finally, the data also needs to be displayed. For this, Qt uses models. A simple model is the string list model, which gets filled with strings and then attached to a list view.

```
m_view = new QListView(this);
m_model = new QStringListModel(this);
m_view->setModel(m_model);

QList<QString> cities;
cities << "Munich" << "Paris" << "London";
m_model->setStringList(cities);
```

Another popular way to store and retrieve data is SQL. Qt comes with SQLite embedded, and also has support for other database engines (e.g. MySQL and PostgreSQL). First, you need to create your database using a schema, like this:

```
CREATE TABLE city (name TEXT, country TEXT);
INSERT INTO city value ("Munich", "Germany");
INSERT INTO city value ("Paris", "France");
INSERT INTO city value ("London", "United Kingdom");
```

To use SQL, we need to add the SQL module to our .pro file

```
QT += sql
```

And then we can open our database using C++. First, we need to retrieve a new database object for the specified database engine. With this database object, we open the database. For SQLite, it's enough to specify the path to the database file. Qt provides some high-level database models, one of which is the table model. The table model uses a table identifier and an optional where clause to select the data. The resulting model can be attached to a list view as with the other model before.

```
QSqlDatabase db = QSqlDatabase::addDatabase("QSQLITE");
db.setDatabaseName("cities.db");
if(!db.open()) {
    qFatal("unable to open database");
}

m_model = new QSqlTableModel(this);
m_model->setTable("city");
m_model->setHeaderData(0, Qt::Horizontal, "City");
m_model->setHeaderData(1, Qt::Horizontal, "Country");

m_view->setModel(m_model);
m_model->select();
```

For a higher level model operations, Qt provides a sorting file proxy model that allows you sort, filter, and transform models.

```
QSortFilterProxyModel* proxy = new QSortFilterProxyModel(this);
proxy->setSourceModel(m_model);
m_view->setModel(proxy);
m_view->setSortingEnabled(true);
```

Filtering is done based on the column that is to be filters, and a string as filter argument.

```
proxy->setFilterKeyColumn(0);
proxy->setFilterCaseSensitive(Qt::CaseInsensitive);
proxy->setFilterFixedString(QString)
```

The filter proxy model is much more powerful than demonstrated here. For now, it is enough to remember it exists.

Note: This has been an overview of the different kind of classic applications you can develop with Qt 5. The desktop is moving, and soon the mobile devices will be our desktop of tomorrow. Mobile devices have a different user interface design. They are much more simplistic than desktop applications. They do one thing and they do it with simplicity and focus. Animations are an important part of the mobile experience. A user interface needs to feel alive and fluent. The traditional Qt technologies are not well suited for this market.

Coming next: Qt Quick to the rescue.

2.3.4 Qt Quick Application

There is an inherent conflict in modern software development. The user interface is moving much faster than our back-end services. In a traditional technology, you develop the so-called front-end at the same pace as the back-end. This results in conflicts when customers want to change the user interface during a project, or develop the idea of a user interface during the project. Agile projects, require agile methods.

Qt Quick provides a declarative environment where your user interface (the front-end) is declared like HTML and your back-end is in native C++ code. This allows you to get the best of both worlds.

This is a simple Qt Quick UI below

```
import QtQuick 2.5

Rectangle {
    width: 240; height: 1230
    Rectangle {
```

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(continued from previous page)

```
        width: 40; height: 40
        anchors.centerIn: parent
        color: '#FFBB33'
    }
}
```

The declaration language is called QML and it needs a runtime to execute it. Qt provides a standard runtime called `qmlscene` but it's also not so difficult to write a custom runtime. For this, we need a quick view and set the main QML document as a source. The only thing left is to show the user interface.

```
QQuickView* view = new QQuickView();
QUrl source = QUrl::fromLocalFile("main.qml");
view->setSource(source);
view->show();
```

Let's come back to our earlier examples. In one example, we used a C++ city model. It would be great if we could use this model inside our declarative QML code.

To enable this, we first code our front-end to see how we would want to use a city model. In this case, the front-end expects an object named `cityModel` which we can use inside a list view.

```
import QtQuick 2.5

Rectangle {
    width: 240; height: 120
    ListView {
        width: 180; height: 120
        anchors.centerIn: parent
        model: cityModel
        delegate: Text { text: model.city }
    }
}
```

To enable the `cityModel`, we can mostly re-use our previous model, and add a context property to our root context. The root context is the other root-element in the main document.

```
m_model = new QSqlTableModel(this);
... // some magic code
QHash<int, QByteArray> roles;
roles[Qt::UserRole+1] = "city";
roles[Qt::UserRole+2] = "country";
m_model->setRoleNames(roles);
view->rootContext()->setContextProperty("cityModel", m_model);
```

Hint: This is not completely correct, as the SQL table model contains the data in columns and a QML model expects the data as roles. So there needs to be a mapping between columns and roles. See the QML and QSqlTableModel wiki page.

2.3.5 Qt Quick Controls Application

tbd

2.3.6 Qt Quick Controls Application

tbd

2.4 Summary

We have seen how to install the Qt SDK and how to create our first application. Then we walked you through the different application types to give you an overview of Qt, showing off some features Qt offers for application development. I hope you got a good impression that Qt is a very rich user interface toolkit and offers everything an application developer can hope for and more. Still, Qt does not lock you into specific libraries, as you can always use other libraries, or even extend Qt yourself. It is also rich when it comes to supporting different application models: console, classic desktop user interface, and touch user interface.

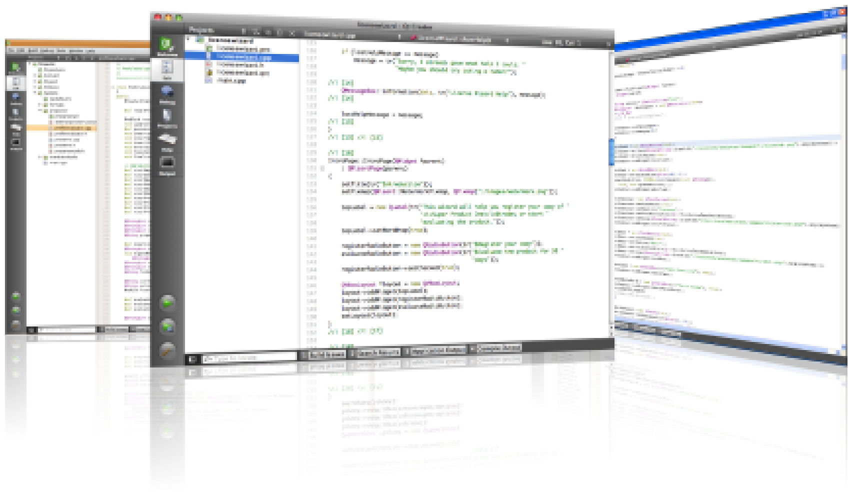
CHAPTER

THREE

QT CREATOR IDE

Section author: jryannel@LinkedIn

Qt Creator is the default integrated development environment for Qt. It's written by Qt developers for Qt developers. The IDE is available on all major desktop platforms, e.g. Windows/Mac/Linux. We have already seen customers using Qt Creator on an embedded device. Qt Creator has a lean efficient user interface and it really shines in making the developer productive. Qt Creator can be used to run your Qt Quick user interface but also to compile c++ code and this for your host system or for another device using a cross-compiler.



Note: The source code of this chapter can be found in the assets folder.

3.1 The User Interface

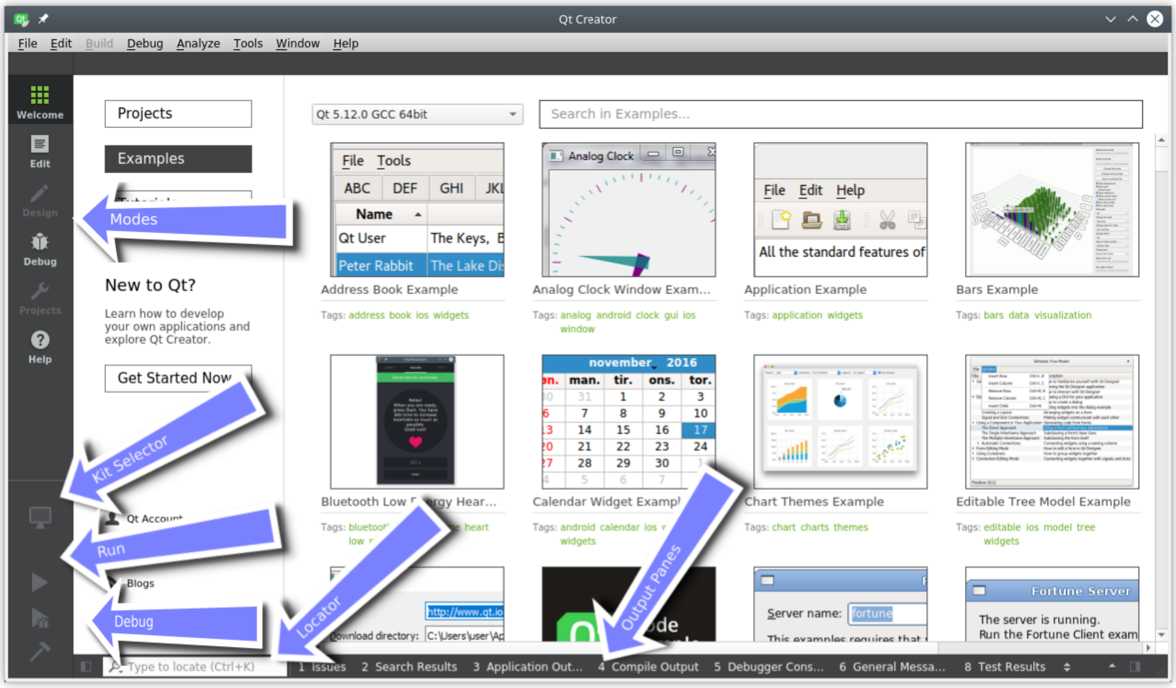
When starting Qt Creator you are greeted by the *Welcome* screen. There you will find the most important hints on how to continue inside Qt Creator and your recently used projects. You will also see the sessions list, which might be empty for you. A session is a collection of projects stored for your reference. This comes really handy when you have several customers with larger projects.

On the left side, you will see the mode-selector. The mode selectors contain typical steps from your workflow.

- Welcome mode: For your orientation.
- Edit mode: Focus on the code
- Design mode: Focus on the UI design
- Debug mode: Retrieve information about a running application
- Projects mode: Modify your projects run and build configuration

- Analyze mode: For detecting memory leaks and profiling
- Help mode: Easy access to the Qt documentation

Below the mode-selectors, you will find the actual project-configuration selector and the run/debug


Qt Creator
File Edit Build Debug Analyze Tools Window Help
Welcome
Edit
Design
Debug
Projects
Help
Projects
Examples
Modes
New to Qt?
Learn how to develop your own applications and explore Qt Creator.
Get Started Now
Kit Selector
Qt Account
Run
Blogs
Debug
Locator
Output Panes
Qt 5.12.0 GCC 64bit
Search in Examples...
Address Book Example
Analog Clock Window Exam...
Application Example
Bars Example
Bluetooth Low Energy Hear...
Calendar Widget Example
Chart Themes Example
Editable Tree Model Example
Type to locate (Ctrl+K)
1 Issues 2 Search Results 3 Application Out... 4 Compile Output 5 Debugger Cons... 6 General Messa... 8 Test Results

Most of the time you will be in the edit mode with the code-editor in the central panel. From time to time, you will visit the Projects mode when you need to configure your project. And then you press `Run`. Qt Creator is smart enough to ensure your project is fully built before running it.

In the bottom are the output panes for issues, application messages, compile messages, and other messages.

3.2 Registering your Qt Kit

The Qt Kit is probably the most difficult aspect when it comes to working with Qt Creator initially. A Qt Kit is a set of a Qt version, compiler and device and some other settings. It is used to uniquely identify the combination of tools for your project build. A typical kit for the desktop would contain a GCC compiler and a Qt version (e.g. Qt 5.12.0) and a device ("Desktop"). After you have created a project you need to assign a kit to a project before qt creator can build the project. Before you are able to create a kit first you need to have a compiler installed and have a Qt version registered. A Qt version is registered by specifying the path to the `qmake` executable. Qt Creator then queries `qmake` for information required to identify the Qt version.

Adding a kit and registering a Qt version is done in the *Settings* → *Build & Run* entry. There you can also see which compilers are registered.

Note: Please first check if your Qt Creator has already the correct Qt version registered and then ensure a Kit for your combination of compiler and Qt and device is specified. You can not build a project without a kit.

3.3 Managing Projects

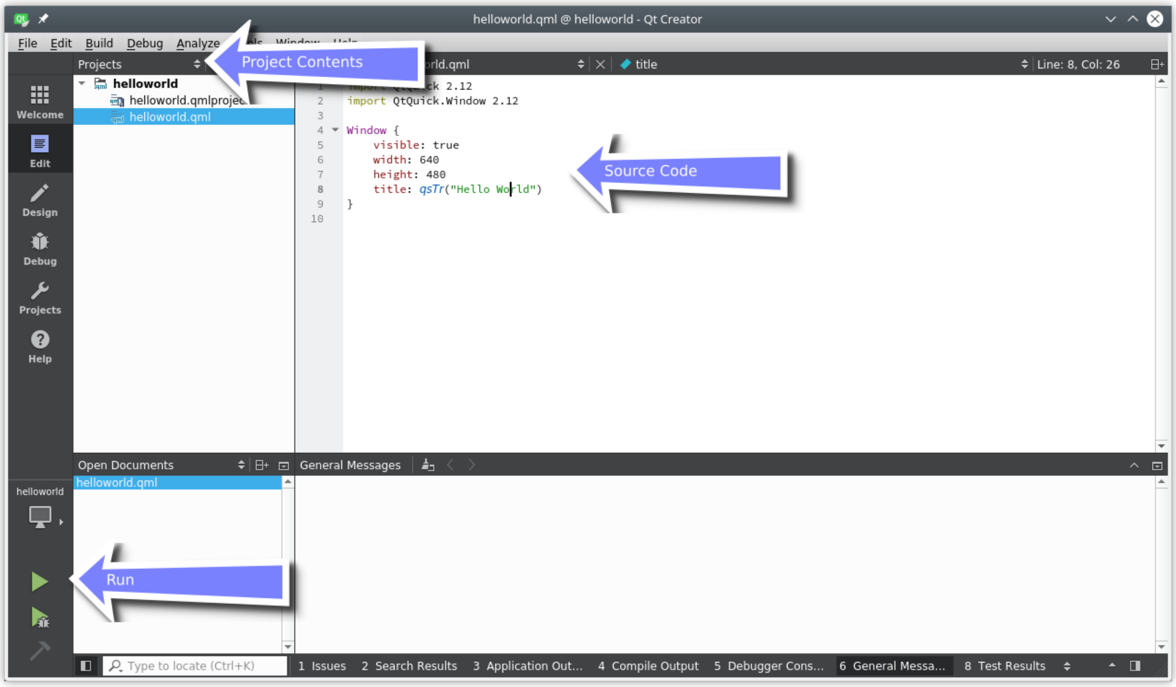
Qt Creator manages your source code in projects. You can create a new project by using *File* → *New File or Project*. When you create a project you have many choices of application templates. Qt Creator is capable of creating desktop, mobile applications. An application which uses Widgets or Qt Quick or Qt Quick and controls or even bare-bone projects. Also, a project for HTML5 and Python are supported. For a beginner, it is difficult to choose, so we pick three project types for you.

- **Applications / Qt Quick 2.0 UI**: This will create a QML/JS only project for you, without any C++ code. Take this if you want to sketch a new user interface or plan to create a modern UI application where the native parts are delivered by plug-ins.
- **Libraries / Qt Quick 2.0 Extension Plug-in**: Use this wizard to create a stub for a plug-in for your Qt Quick UI. A plug-in is used to extend Qt Quick with native elements.
- **Other Project / Empty Qt Project**: A bare-bones empty project. Take this if you want to code your application with c++ from scratch. Be aware you need to know what you are doing here.

Note: During the first parts of the book, we will mainly use the Qt Quick 2.0 UI project type. Later to describe some c++ aspects we will use the Empty-Qt-Project type or something similar. For extending Qt Quick with our own native plug-ins we will use the *Qt Quick 2.0 Extension Plug-in* wizard type.

3.4 Using the Editor

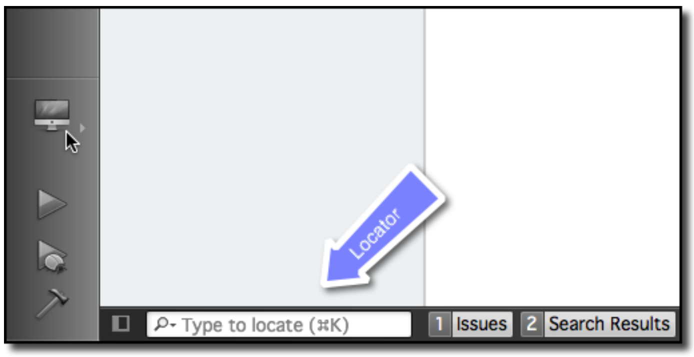
When you open a project or you just created a new project Qt Creator will switch to the edit mode. You should see on the left of your project files and in the center area the code editor. Selecting files on the left will open them in the editor. The editor provides syntax highlighting, code-completion, and quick-fixes. Also, it supports several commands for code refactoring. When working with the editor you will have the feeling that everything reacts immediately. This is thanks to the developers of Qt Creator which made the tool feel really snappy.



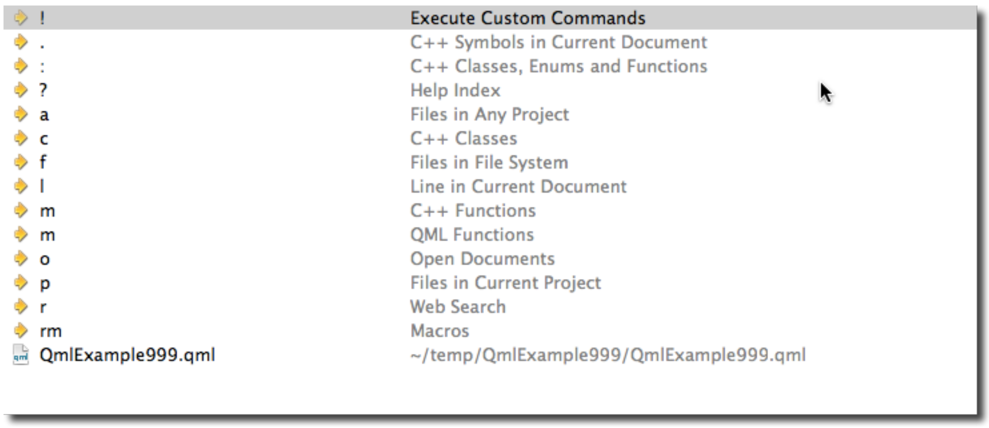
```
import QtQuick 2.12
import QtQuick.Window 2.12

Window {
    visible: true
    width: 640
    height: 480
    title: qsTr("Hello World")
}
```

3.5 Locator

The locator is a central component inside Qt Creator. It allows developers to navigate fast to specific locations inside the source code or inside the help. To open the locator press `Ctrl+K`.



A pop-up is coming from the bottom left and shows a list of options. If you just search a file inside your project just hit the first letter from the file name. The locator also accepts wild-cards, so `*main.qml` will also work. Otherwise, you can prefix your search to search for the specific content type.



!	Execute Custom Commands
.	C++ Symbols in Current Document
:	C++ Classes, Enums and Functions
?	Help Index
a	Files in Any Project
c	C++ Classes
f	Files in File System
l	Line in Current Document
m	C++ Functions
m	QML Functions
o	Open Documents
p	Files in Current Project
r	Web Search
rm	Macros
QmlExample999.qml	~/temp/QmlExample999/QmlExample999.qml

Please try it out. For example to open the help for the QML element Rectangle open the locator and type `? rectangle`. While you type the locator will update the suggestions until you found the reference you are looking for.

3.6 Debugging

Qt Creator comes with C++ and QML debugging support.

Note: Hmm, I just realized I have not used debugging a lot. I hope this is a good sign. Need to ask someone to help me out here. In the meantime have a look at the Qt Creator documentation.

3.7 Shortcuts

Shortcuts are the difference between a nice-to-use editor and a professional editor. As a professional you spend hundreds of hours in front of your application. Each shortcut which makes your work-flow faster counts. Luckily the developers of Qt Creator think the same and have added literally hundreds of shortcuts to the application.

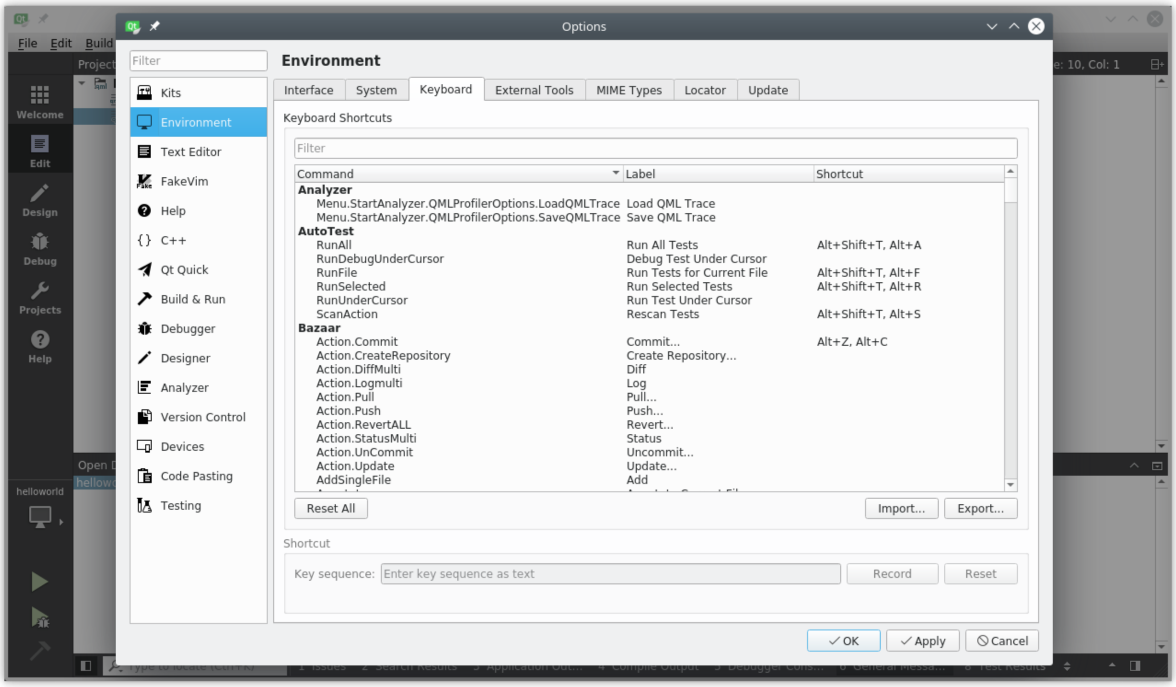
To get started we have collection some basic shortcuts (in Windows notation):

- `Ctrl+B` - Build project
- `Ctrl+R` - Run Project
- `Ctrl+Tab` - Switch between open documents

- `Ctrl+K` - Open Locator
- `Esc` - Go back (hit several times and you are back in the editor)
- `F2` - Follow Symbol under cursor
- `F4` - Switch between header and source (only useful for c++ code)

List of Qt Creator shortcuts from the documentation.

Note: You can edit the shortcuts from inside creator using the settings dialog.



Command	Label	Shortcut
Analyzer		
Menu.StartAnalyzer.QMLProfilerOptions.LoadQMLTrace	Load QML Trace	
Menu.StartAnalyzer.QMLProfilerOptions.SaveQMLTrace	Save QML Trace	
AutoTest		
RunAll	Run All Tests	Alt+Shift+T, Alt+A
RunDebugUnderCursor	Debug Test Under Cursor	
RunFile	Run Tests for Current File	Alt+Shift+T, Alt+F
RunSelected	Run Selected Tests	Alt+Shift+T, Alt+R
RunUnderCursor	Run Test Under Cursor	
ScanAction	Rescan Tests	Alt+Shift+T, Alt+S
Bazaar		
Action.Commit	Commit...	Alt+Z, Alt+C
Action.CreateRepository	Create Repository...	
Action.DiffMulti	Diff	
Action.Logmulti	Log	
Action.Pull	Pull...	
Action.Push	Push...	
Action.RevertALL	Revert...	
Action.StatusMulti	Status	
Action.UnCommit	Uncommit...	
Action.Update	Update...	
AddSingleFile	Add	

CHAPTER

FOUR

QUICK STARTER

Section author: jryannel@LinkedIn

Note: Last Build: December 07, 2020 at 10:50 CET

The source code for this chapter can be found in the assets folder.

This chapter provides an overview of QML, the declarative user interface language used in Qt 5. We will discuss the QML syntax, which is a tree of elements, followed by an overview of the most important basic elements. Later we will briefly look at how to create our own elements, called components and how to transform elements using property manipulations. Towards the end, we will look at how to arrange elements together in a layout and finally have a look at elements where the user can provide input.

4.1 QML Syntax

QML is a declarative language used to describe the user interface of your application. It breaks down the user interface into smaller elements, which can be combined into components. QML describes the look and the behavior of these user interface elements. This user interface description can be enriched with JavaScript code to provide simple but also more complex logic. In this perspective, it follows the HTML-JavaScript pattern but QML is designed from the ground up to describe user interfaces, not text-documents.

In its simplest way, QML is a hierarchy of elements. Child elements inherit the coordinate system from the parent. An `x,y` coordinate is always relative to the parent.

Let's start with a simple example of a QML file to explain the different syntax.

```
// RectangleExample.qml

import QtQuick 2.5

// The root element is the Rectangle
Rectangle {
    // name this element root
    id: root

    // properties: <name>: <value>
    width: 120; height: 240

    // color property
    color: "#4A4A4A"

    // Declare a nested element (child of root)
    Image {
        id: triangle

        // reference the parent
```

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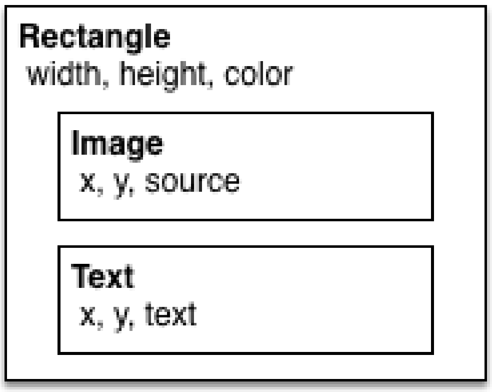

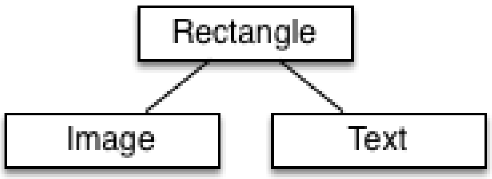

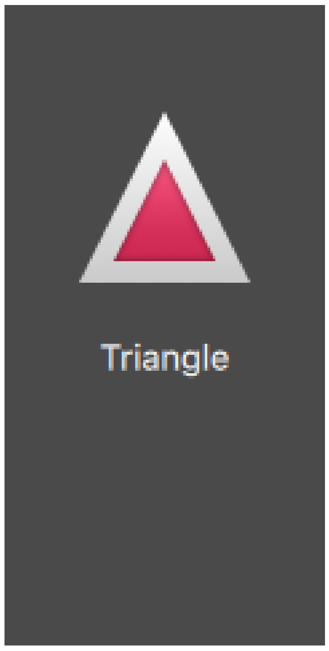

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```
        x: (parent.width - width)/2; y: 40

        source: 'assets/triangle_red.png'
    }

    // Another child of root
    Text {
        // un-named element

        // reference element by id
        y: triangle.y + triangle.height + 20

        // reference root element
        width: root.width

        color: 'white'
        horizontalAlignment: Text.AlignHCenter
        text: 'Triangle'
    }
}
```

- The `import` statement imports a module in a specific version.
- Comments can be made using `//` for single line comments or `/* */` for multi-line comments. Just like in C/C++ and JavaScript
- Every QML file needs to have exactly one root element, like HTML
- An element is declared by its type followed by `{ }`
- Elements can have properties, they are in the form `` name: value``
- Arbitrary elements inside a QML document can be accessed by using their `id` (an unquoted identifier)
- Elements can be nested, meaning a parent element can have child elements. The parent element can be accessed using the `parent` keyword

The `import` statement you import a specific version of a module. For the QML modules that comes with Qt the version is linked to the Qt version you intend to use. The lower the version number, the earlier Qt version can be used. The minor version of the `import` statement matches the minor version of the Qt release, so Qt 5.11 corresponds to `QtQuick` 2.11, Qt 5.12 to `QtQuick` 2.12 and so on. Prior to Qt 5.11, the QML modules shipped with Qt had their own versioning sequences, meaning that `QtQuick` followed the Qt versions, while `QtQuick.Controls` started with version 2.0 at Qt 5.7 and was at version 2.4 by Qt 5.11.

Tip: Often you want to access a particular element by id or a parent element using the `parent` keyword. So it's good practice to name your root element "root" using `id: root`. Then you don't have to think about how the root element is named in your QML document.

Hint: You can run the example using the Qt Quick runtime from the command line from your OS like this:

```
$ $QTDIR/bin/qmlscene RectangleExample.qml
```

Where you need to replace the *$QTDIR* to the path to your Qt installation. The *qmlscene* executable initializes the Qt Quick runtime and interprets the provided QML file.

In Qt Creator, you can open the corresponding project file and run the document `RectangleExample.qml`.

4.1.1 Properties

Elements are declared by using their element name but are defined by using their properties or by creating custom properties. A property is a simple key-value pair, e.g. `width : 100`, `text: 'Greetings'`, `color: '#FF0000'`. A property has a well-defined type and can have an initial value.

```
    Text {
        // (1) identifier
        id: thisLabel

        // (2) set x- and y-position
        x: 24; y: 16

        // (3) bind height to 2 * width
        height: 2 * width

        // (4) custom property
        property int times: 24

        // (5) property alias
        property alias anotherTimes: thisLabel.times

        // (6) set text appended by value
        text: "Greetings " + times

        // (7) font is a grouped property
        font.family: "Ubuntu"
        font.pixelSize: 24

        // (8) KeyNavigation is an attached property
        KeyNavigation.tab: otherLabel

        // (9) signal handler for property changes
        onHeightChanged: console.log('height:', height)

        // focus is need to receive key events
        focus: true
```

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```
        // change color based on focus value
        color: focus?"red":"black"
    }
```

Let's go through the different features of properties:

1. `id` is a very special property-like value, it is used to reference elements inside a QML file (called "document" in QML). The `id` is not a string type but rather an identifier and part of the QML syntax. An `id` needs to be unique inside a document and it can't be reset to a different value, nor may it be queried. (It behaves much like a reference in the C++ world.)
2. A property can be set to a value, depending on its type. If no value is given for a property, an initial value will be chosen. You need to consult the documentation of the particular element for more information about the initial value of a property.
3. A property can depend on one or many other properties. This is called *binding*. A bound property is updated when its dependent properties change. It works like a contract, in this case, the `height` should always be two times the `width`.
4. Adding own properties to an element is done using the `property` qualifier followed by the type, the name and the optional initial value (`property <type> <name> : <value>`). If no initial value is given a system initial value is chosen.

   Note: You can also declare one property to be the default property if no property name is given by prepending the property declaration with the `default` keyword. This is used for example when you add child elements, the child elements are added automatically to the default property `children` of type list if they are visible elements.

5. Another important way of declaring properties is using the `alias` keyword (`property alias <name>: <reference>`). The `alias` keyword allows us to forward a property of an object or an object itself from within the type to an outer scope. We will use this technique later when defining components to export the inner properties or element ids to the root level. A property alias does not need a type, it uses the type of the referenced property or object.
6. The `text` property depends on the custom property `times` of type int. The `int` based value is automatically converted to a `string` type. The expression itself is another example of binding and results in the text being updated every time the `times` property changes.
7. Some properties are grouped properties. This feature is used when a property is more structured and related properties should be grouped together. Another way of writing grouped properties is `font { family: "Ubuntu"; pixelSize: 24 }`.
8. Some properties are attached to the element itself. This is done for global relevant elements which appear only once in the application (e.g. keyboard input). The writing is `<Element>.<property>: <value>`.
9. For every property, you can provide a signal handler. This handler is called after the property changes. For example, here we want to be notified whenever the height changes and use the built-in console to log a message to the system.

Warning: An element id should only be used to reference elements inside your document (e.g. the current file). QML provides a mechanism called dynamic-scoping where later loaded documents overwrite the element id's from earlier loaded documents. This makes it possible to reference element id's from earlier loaded documents if they are not yet overwritten. It's like creating global variables. Unfortunately, this frequently leads to really bad code in practice, where the program depends on the order of execution. Unfortunately, this can't be turned off. Please only use this with care or even better don't use this mechanism at all. It's better to export the element you want to provide to the outside world using properties on the root element of your document.

4.1.2 Scripting

QML and JavaScript (also known as ECMAScript) are best friends. In the *JavaScript* chapter we will go into more detail on this symbiosis. Currently, we just want to make you aware of this relationship.

```
    Text {
        id: label

        x: 24; y: 24

        // custom counter property for space presses
        property int spacePresses: 0

        text: "Space pressed: " + spacePresses + " times"

        // (1) handler for text changes
        onTextChanged: console.log("text changed to:", text)

        // need focus to receive key events
        focus: true

        // (2) handler with some JS
        Keys.onSpacePressed: {
            increment()
        }

        // clear the text on escape
        Keys.onEscapePressed: {
            label.text = ''
        }

        // (3) a JS function
        function increment() {
            spacePresses = spacePresses + 1
        }
    }
```

1. The text changed handler `onTextChanged` prints the current text every-time the text changed due to a space-bar key pressed
2. When the text element receives the space-bar key (because the user pressed the space-bar on the keyboard) we call a JavaScript function `increment()`.
3. Definition of a JavaScript function in the form of `function <name>(<parameters>) { ... }`, which increments our counter `spacePressed`. Every time `spacePressed` is incremented, bound properties will also be updated.

Note: The difference between the QML **:** (binding) and the JavaScript = (assignment) is, that the binding is a contract and keeps true over the lifetime of the binding, whereas the JavaScript assignment (=) is a one time value assignment. The lifetime of a binding ends, when a new binding is set to the property or even when a JavaScript value is assigned is to the property. For example, a key handler setting the text property to an empty string would destroy our increment display:

```
Keys.onEscapePressed: {
    label.text = ''
}
```

After pressing escape, pressing the space-bar will not update the display anymore as the previous binding of the `text` property (*text: "Space pressed: " + spacePresses + " times"*) was destroyed.

When you have conflicting strategies to change a property as in this case (text updated by a change to a property increment via a binding and text cleared by a JavaScript assignment) then you can't use bindings! You need to use assignment on both property change paths as the binding will be destroyed by the assignment (broken contract!).

4.2 Basic Elements

Elements can be grouped into visual and non-visual elements. A visual element (like the `Rectangle`) has a geometry and normally presents an area on the screen. A non-visual element (like a `Timer`) provides general functionality, normally used to manipulate the visual elements.

Currently, we will focus on the fundamental visual elements, such as `Item`, `Rectangle`, `Text`, `Image` and `MouseArea`. However, by using the Qt Quick Controls 2 module, it is possible to create user interfaces built from standard platform components such as buttons, labels and sliders.

4.2.1 Item Element

`Item` is the base element for all visual elements as such all other visual elements inherits from `Item`. It doesn't paint anything by itself but defines all properties which are common across all visual elements:

Group	Properties
Geometry	`x` and `y` to define the top-left position, `width` and `height` for the expansion of the element and also the `z` stacking order to lift elements up or down from their natural ordering
Layout handling	`anchors` (left, right, top, bottom, vertical and horizontal center) to position elements relative to other elements with their `margins`
Key handling	attached `Key` and `KeyNavigation` properties to control key handling and the input `focus` property to enable key handling in the first place
Transformation	`scale` and `rotate` transformation and the generic `transform` property list for *x,y,z* transformation and their `transformOrigin` point
Visual	`opacity` to control transparency, `visible` to show/hide elements, `clip` to restrain paint operations to the element boundary and `smooth` to enhance the rendering quality
State definition	`states` list property with the supported list of states and the current `state` property as also the `transitions` list property to animate state changes.

To better understand the different properties we will try to introduce them throughout this chapter in the context of the element presented. Please remember these fundamental properties are available on every visual element and work the same across these elements.

Note: The `Item` element is often used as a container for other elements, similar to the *div* element in HTML.

4.2.2 Rectangle Element

The `Rectangle` extends `Item` and adds a fill color to it. Additionally it supports borders defined by `border.color` and `border.width`. To create rounded rectangles you can use the `radius` property.

```
    Rectangle {
        id: rect1
        x: 12; y: 12
        width: 76; height: 96
        color: "lightsteelblue"
    }
    Rectangle {
        id: rect2
        x: 112; y: 12
```

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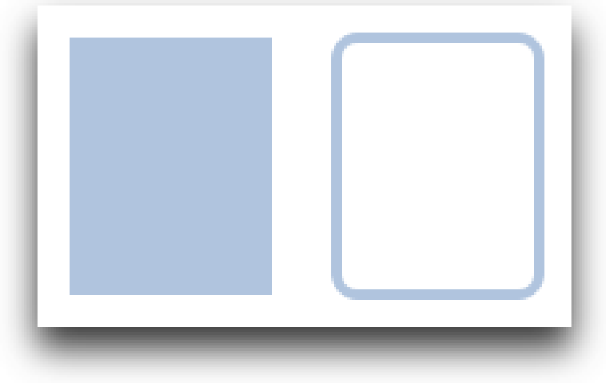
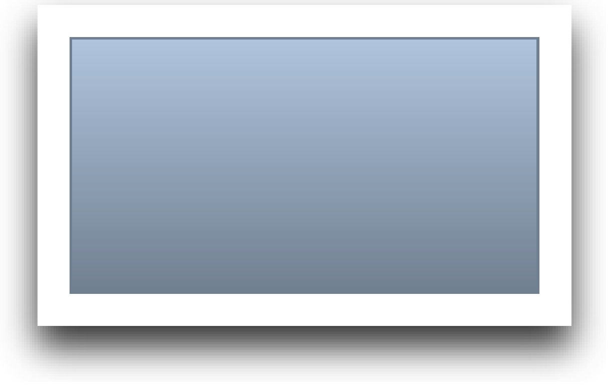
```
        width: 76; height: 96
        border.color: "lightsteelblue"
        border.width: 4
        radius: 8
    }
```



Note: Valid colors values are colors from the SVG color names (see http://www.w3.org/TR/css3-color/#svg-color). You can provide colors in QML in different ways, but the most common way is an RGB string ('#FF4444') or as a color name (e.g. 'white').

Besides a fill color and a border the rectangle also supports custom gradients.

```
    Rectangle {
        id: rect1
        x: 12; y: 12
        width: 176; height: 96
        gradient: Gradient {
            GradientStop { position: 0.0; color: "lightsteelblue" }
            GradientStop { position: 1.0; color: "slategray" }
        }
        border.color: "slategray"
    }
```



A gradient is defined by a series of gradient stops. Each stop has a position and a color. The position marks the position on the y-axis (0 = top, 1 = bottom). The color of the `GradientStop` marks the color at that position.

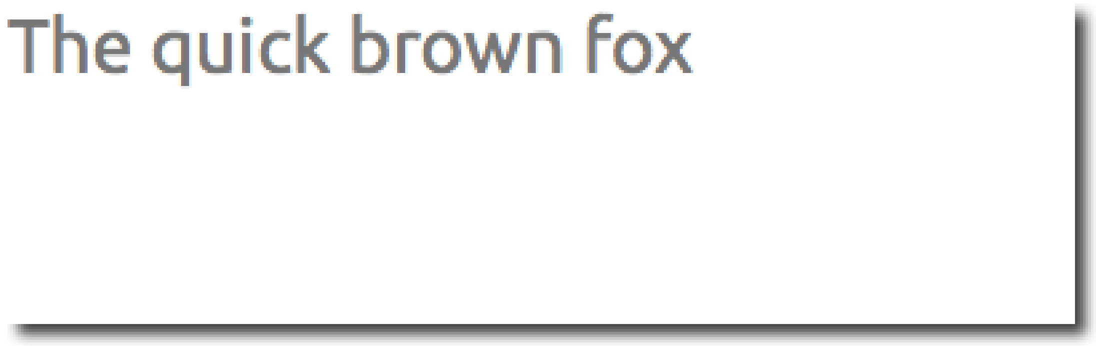
Note: A rectangle with no *width/height* set will not be visible. This happens often when you have several rectangles width (height) depending on each other and something went wrong in your composition logic. So watch out!

Note: It is not possible to create an angled gradient. For this, it's better to use predefined images. One possibility would be to just rotate the rectangle with the gradient, but be aware the geometry of a rotated rectangle will not change and thus will lead to confusion as the geometry of the element is not the same as the visible area. From the authors perspective, it's really better to use designed gradient images in that case.

4.2.3 Text Element

To display text, you can use the `Text` element. Its most notable property is the `text` property of type `string`. The element calculates its initial width and height based on the given text and the font used. The font can be influenced using the font property group (e.g. `font.family`, `font.pixelSize`, ...). To change the color of the text just use the color property.

```
    Text {
        text: "The quick brown fox"
        color: "#303030"
        font.family: "Ubuntu"
        font.pixelSize: 28
    }
```



Text can be aligned to each side and the center using the `horizontalAlignment` and `verticalAlignment` properties. To further enhance the text rendering you can use the `style` and `styleColor` property, which allows you render the text in outline, raised and sunken mode. For longer text, you often want to define a *break* position like *A very … long text*, this can be achieved using the `elide` property. The `elide` property allows you to set the elide position to the left, right or middle of your text. In case you don't want the '...' of the elide mode to appear but still want to see the full text you can also wrap the text using the `wrapMode` property (works only when the width is explicitly set):

```
Text {
    width: 40; height: 120
    text: 'A very long text'
    // '...' shall appear in the middle
    elide: Text.ElideMiddle
    // red sunken text styling
    style: Text.Sunken
    styleColor: '#FF4444'
    // align text to the top
    verticalAlignment: Text.AlignTop
```

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```
    // only sensible when no elide mode
    // wrapMode: Text.WordWrap
}
```

A `Text` element only displays the given text. It does not render any background decoration. Besides the rendered text the `Text` element is transparent. It's part of your overall design to provide a sensible background to the text element.

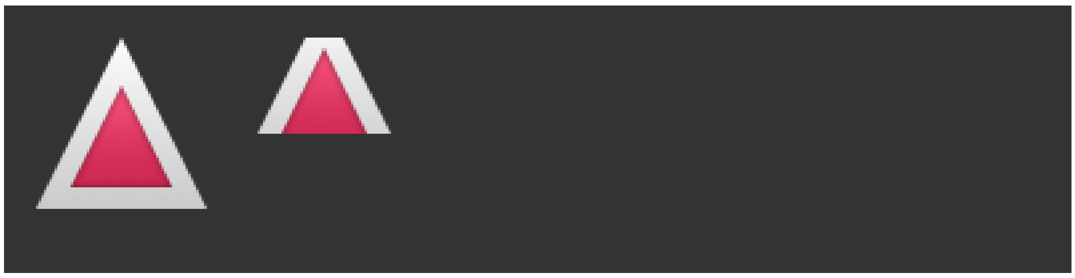
Note: Be aware a `Text` initial width (height) is depending on the text string and on the font set. A `Text` element with no width set and no text will not be visible, as the initial width will be 0.

Note: Often when you want to layout `Text` elements you need to differentiate between aligning the text inside the `Text` element boundary box or to align the element boundary box itself. In the former, you want to use the `horizontalAlignment` and `verticalAlignment` properties and in the latter case, you want to manipulate the element geometry or use anchors.

4.2.4 Image Element

An `Image` element is able to display images in various formats (e.g. PNG, JPG, GIF, BMP, WEBP). *For the full list of supported image formats, please consult the Qt documentation.* Besides the obvious `source` property to provide the image URL, it contains a `fillMode` which controls the resizing behavior.

```
    Image {
        x: 12; y: 12
        // width: 72
        // height: 72
        source: "assets/triangle_red.png"
    }
    Image {
        x: 12+64+12; y: 12
        // width: 72
        height: 72/2
        source: "assets/triangle_red.png"
        fillMode: Image.PreserveAspectCrop
        clip: true
    }
```



Note: A URL can be a local path with forward slashes ("./images/home.png") or a web-link (e.g. "http://example.org/home.png").

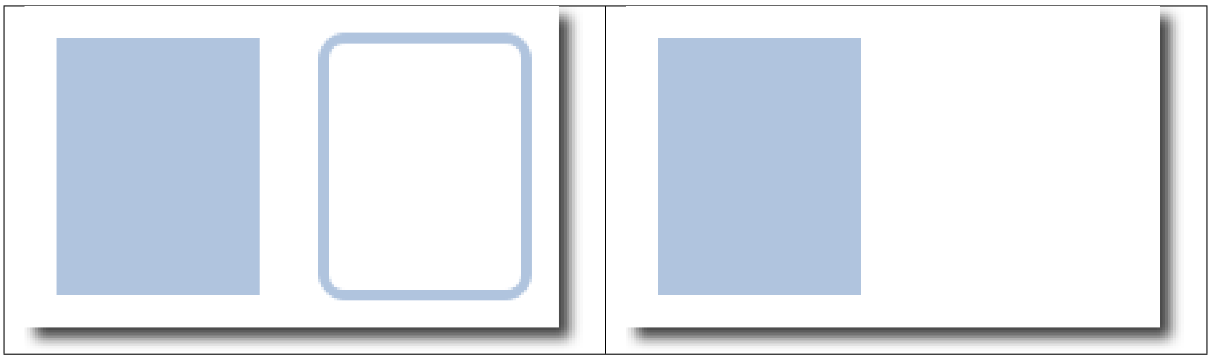
Note: `Image` elements using `PreserveAspectCrop` should also enable the clipping to avoid image data being rendered outside the `Image` boundaries. By default clipping is disabled (`` clip: false``). You need to enable clipping (`` clip: true``) to constrain the painting to the elements bounding rectangle. This can be used on any visual element.

Tip: Using C++ you are able to create your own image provider using QQuickImageProvider. This allows you to create images on the fly and threaded image loading.

4.2.5 MouseArea Element

To interact with these elements you often will use a `MouseArea`. It's a rectangular invisible item in where you can capture mouse events. The mouse area is often used together with a visible item to execute commands when the user interacts with the visual part.

```
    Rectangle {
        id: rect1
        x: 12; y: 12
        width: 76; height: 96
        color: "lightsteelblue"
        MouseArea {
            id: area
            width: parent.width
            height: parent.height
            onClicked: rect2.visible = !rect2.visible
        }
    }

    Rectangle {
        id: rect2
        x: 112; y: 12
        width: 76; height: 96
        border.color: "lightsteelblue"
        border.width: 4
        radius: 8
    }
```



Note: This is an important aspect of Qt Quick, the input handling is separated from the visual presentation. By this it allows you to show the user an interface element, but the interaction area can be larger.

Note: For more complex interaction, Qt Quick Input Handlers where introduced with Qt 5.12. They are intended to be used instead of elements such as `MouseArea` and `Flickable` and offer greater control and flexibility. The idea is to handle one interaction aspect in each handler instance instead of centralizing the handling of all events from a given source in a single element, which was the case before.

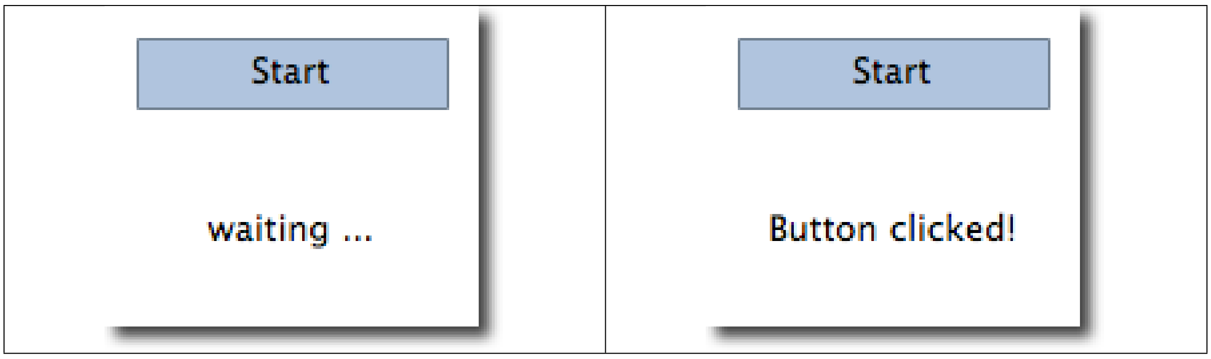
4.3 Components

A component is a reusable element and QML provides different ways to create components. Currently, we will look only at the simplest form - a file-based component. A file-based component is created by placing a QML element in a file and give the file an element name (e.g. `Button.qml`). You can use the component like every other element from the QtQuick module, in our case you would use this in your code as `Button { ... }`.

For example, let's create a rectangle containing a text component and a mouse area. This resembles a simple button and doesn't need to be more complicated for our purposes.

```
    Rectangle { // our inlined button ui
        id: button
        x: 12; y: 12
        width: 116; height: 26
        color: "lightsteelblue"
        border.color: "slategrey"
        Text {
            anchors.centerIn: parent
            text: "Start"
        }
        MouseArea {
            anchors.fill: parent
            onClicked: {
                status.text = "Button clicked!"
            }
        }
    }

    Text { // text changes when button was clicked
        id: status
        x: 12; y: 76
        width: 116; height: 26
        text: "waiting ..."
        horizontalAlignment: Text.AlignHCenter
    }
```

The UI will look similar to this. On the left the UI in the initial state, on the right after the button has been clicked.



Our task is now to extract the button UI in a reusable component. For this, we shortly think about a possible API for our button. You can do this by imagining how someone else should use your button. Here's what I came up with:

```
// minimal API for a button
Button {
    text: "Click Me"
    onClicked: { /* do something */ }
}
```

I would like to set the text using a `text` property and to implement my own click handler. Also, I would expect the button to have a sensible initial size, which I can overwrite (e.g. with `width: 240` for example).

To achieve this we create a `Button.qml` file and copy our button UI inside. Additionally, we need to export the properties a user might want to change on the root level.

```
// Button.qml

import QtQuick 2.5

Rectangle {
    id: root
    // export button properties
    property alias text: label.text
    signal clicked

    width: 116; height: 26
    color: "lightsteelblue"
    border.color: "slategrey"

    Text {
        id: label
        anchors.centerIn: parent
        text: "Start"
    }
    MouseArea {
        anchors.fill: parent
        onClicked: {
            root.clicked()
        }
    }
}
```

We have exported the text and clicked signal on the root level. Typically we name our root element root to make the referencing easier. We use the `alias` feature of QML, which is a way to export properties inside nested QML elements to the root level and make this available for the outside world. It is important to know, that only the root level properties can be accessed from outside this file by other components.

To use our new `Button` element we can simply declare it in our file. So the earlier example will become a little bit simplified.

```
    Button { // our Button component
        id: button
        x: 12; y: 12
        text: "Start"
        onClicked: {
            status.text = "Button clicked!"
        }
    }

    Text { // text changes when button was clicked
        id: status
        x: 12; y: 76
        width: 116; height: 26
        text: "waiting ..."
        horizontalAlignment: Text.AlignHCenter
    }
```

Now you can use as many buttons as you like in your UI by just using `Button { ... }`. A real button could be more complex, e.g providing feedback when clicked or showing a nicer decoration.

Note: If you want to, you could even go a step further and use an item as a root element. This prevents users to change the color of our designed button and provides us with more control about the exported API. The target should be to export a minimal API. Practically this means we would need to replace the root `Rectangle` with an `Item` and make the rectangle a nested element in the root item.

```
Item {
    id: root
    width: 116; height: 26

    property alias text: label.text
    signal clicked

    Rectangle {
        anchors.fill parent
        color: "lightsteelblue"
        border.color: "slategrey"
    }
    ...
}
```

With this technique, it is easy to create a whole series of reusable components.

4.4 Simple Transformations

A transformation manipulates the geometry of an object. QML Items can, in general, be translated, rotated and scaled. There is a simple form of these operations and a more advanced way.

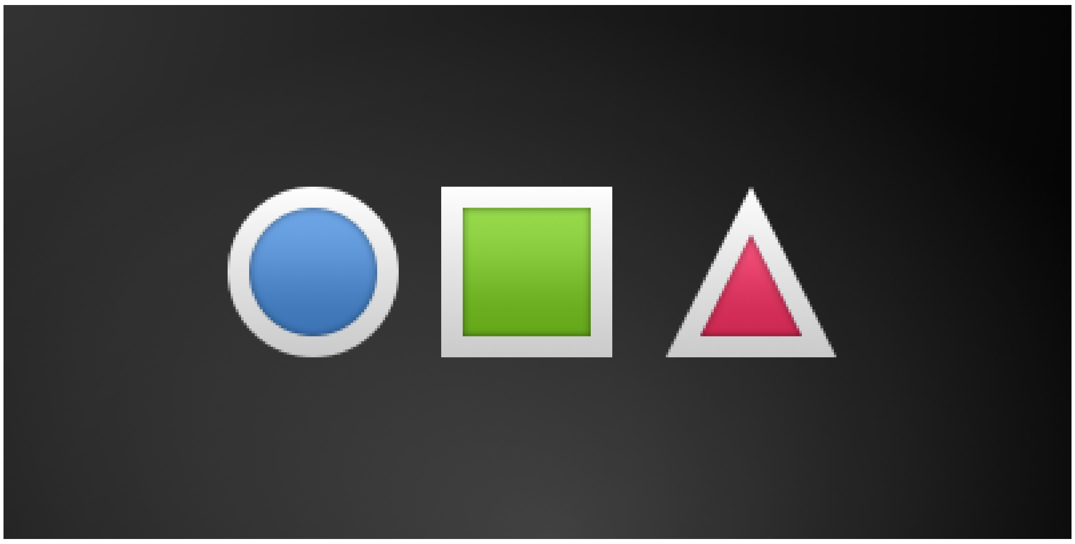
Let's start with the simple transformations. Here is our scene as our starting point.

A simple translation is done via changing the `x,y` position. A rotation is done using the `rotation` property. The value is provided in degrees (0 .. 360). A scaling is done using the `scale` property and a value <1 means the element is scaled down and `>1` means the element is scaled up. The rotation and scaling do not change your geometry. The items `x,y` and `width/height` haven't changed. Just the painting instructions are transformed.

Before we show off the example I would like to introduce a little helper: The `ClickableImage` element. The `ClickableImage` is just an image with a mouse area. This brings up a useful rule of thumb - if you have copied a chunk of code three times, extract it into a component.

```
// ClickableImage.qml

// Simple image which can be clicked

import QtQuick 2.5

Image {
    id: root
    signal clicked

    MouseArea {
        anchors.fill: parent
        onClicked: root.clicked()
    }
}
```

We use our clickable image to present three objects (box, circle, triangle). Each object performs a simple transformation when clicked. Clicking the background will reset the scene.



```
// transformation.qml


import QtQuick 2.5

Item {
    // set width based on given background
    width: bg.width
    height: bg.height

    Image { // nice background image
        id: bg
        source: "assets/background.png"
    }

    MouseArea {
        id: backgroundClicker
        // needs to be before the images as order matters
        // otherwise this mousearea would be before the other elements
        // and consume the mouse events
        anchors.fill: parent
        onClicked: {
            // reset our little scene
            circle.x = 84
            box.rotation = 0
            triangle.rotation = 0
            triangle.scale = 1.0
        }
    }

    ClickableImage {
        id: circle
        x: 84; y: 68
        source: "assets/circle_blue.png"
        antialiasing: true
        onClicked: {
            // increase the x-position on click
            x += 20
        }
    }

    ClickableImage {
```

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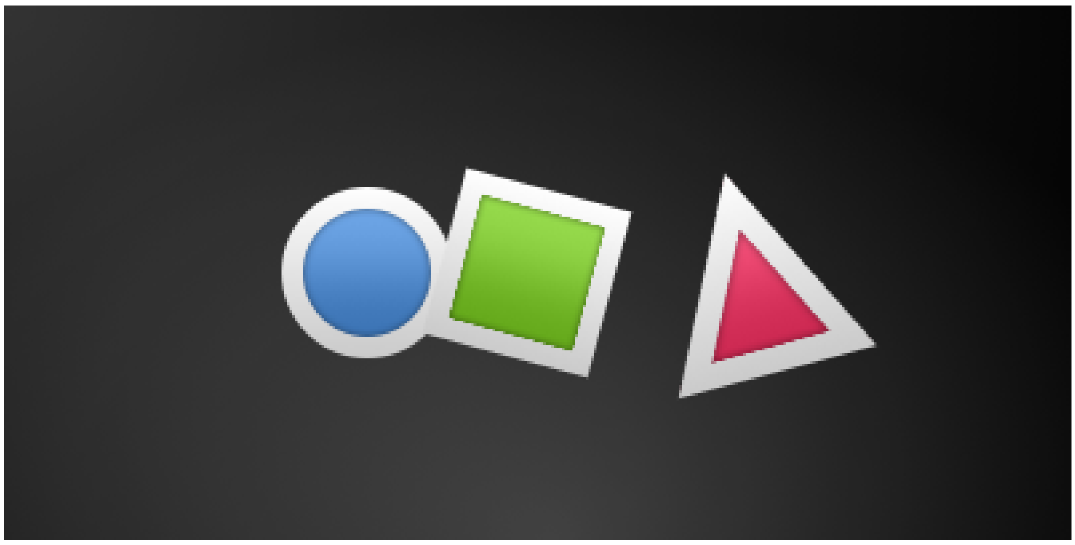
```
        id: box
        x: 164; y: 68
        source: "assets/box_green.png"
        antialiasing: true
        onClicked: {
            // increase the rotation on click
            rotation += 15
        }
    }

    ClickableImage {
        id: triangle
        x: 248; y: 68
        source: "assets/triangle_red.png"
        antialiasing: true
        onClicked: {
            // several transformations
            rotation += 15
            scale += 0.05
        }
    }

    function _test_transformed() {
        circle.x += 20
        box.rotation = 15
        triangle.scale = 1.2
        triangle.rotation = -15
    }

    function _test_overlap() {
        circle.x += 40
        box.rotation = 15
        triangle.scale = 2.0
        triangle.rotation = 45
    }

}
```

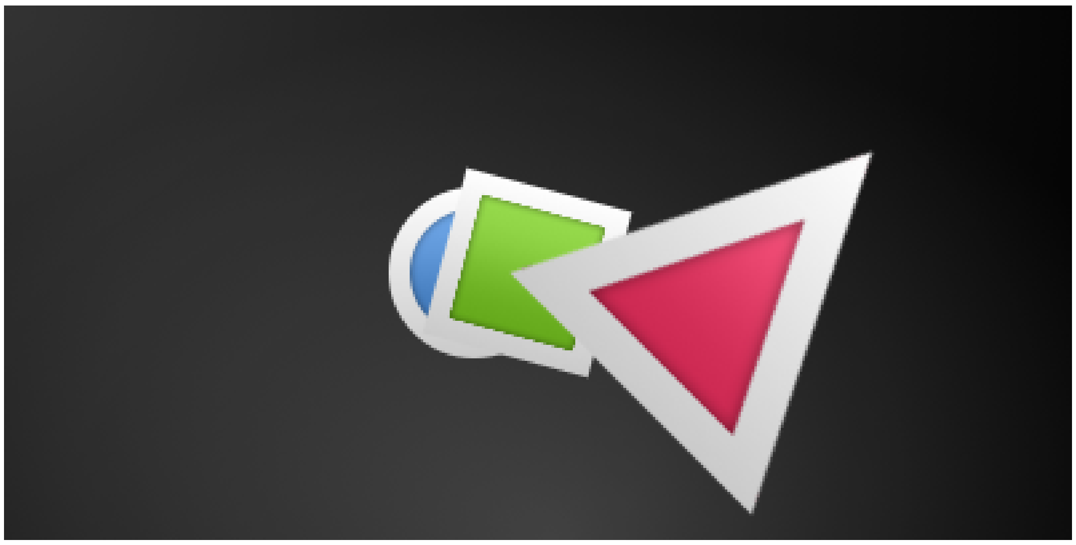


The circle increments the x-position on each click and the box will rotate on each click. The triangle will rotate and scale the image up on each click, to demonstrate a combined transformation. For the scaling and rotation operation we set `antialiasing: true` to enable anti-aliasing, which is switched off (same as the clipping property `clip`) for performance reasons. In your own work, when you see some rasterized edges in your graphics, then you should probably switch smoothly on.

Note: To achieve better visual quality when scaling images it is recommended to scale images down instead of up. Scaling an image up with a larger scaling factor will result in scaling artifacts (blurred image). When scaling an image you should consider using ‘‘ antialiasing: true‘‘ to enable the usage of a higher quality filter.

The background `MouseArea` covers the whole background and resets the object values.

Note: Elements which appear earlier in the code have a lower stacking order (called z-order). If you click long enough on `circle` you will see it moves below `box`. The z-order can also be manipulated by the `z-property` of an Item.



This is because `box` appears later in the code. The same applies also to mouse areas. A mouse area later in the code will overlap (and thus grab the mouse events) of a mouse area earlier in the code.

Please remember: *The order of elements in the document matters*.

4.5 Positioning Elements

There are a number of QML elements used to position items. These are called positioners and the following are provided in the QtQuick module `Row`, `Column`, `Grid` and `Flow`. They can be seen showing the same contents in the illustration below.

Note: Before we go into details, let me introduce some helper elements. The red, blue, green, lighter and darker squares. Each of these components contains a 48x48 pixels colorized rectangle. As a reference here is the source code for the `RedSquare`:

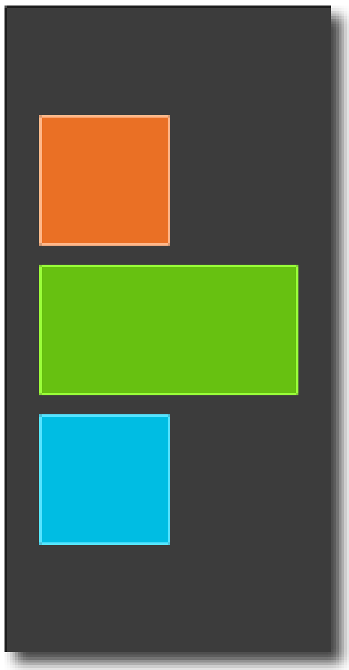
```
// RedSquare.qml

import QtQuick 2.5

Rectangle {
    width: 48
    height: 48
    color: "#ea7025"
    border.color: Qt.lighter(color)
}
```

Please note the use of `Qt.lighter(color)` to produce a lighter border color based on the fill color. We will use these helpers in the next examples to make the source code more compact and hopefully readable. Please remember, each rectangle is initial 48x48 pixels.

The `Column` element arranges child items into a column by stacking them on top of each other. The `spacing` property can be used to distance each of the child elements from each other.



```
// column.qml

import QtQuick 2.5

DarkSquare {
    id: root
    width: 120
    height: 240

    Column {
        id: row
        anchors.centerIn: parent
        spacing: 8
        RedSquare { }
        GreenSquare { width: 96 }
        BlueSquare { }
    }
}
```

The `Row` element places its child items next to each other, either from the left to the right or from the right to the left, depending on the `layoutDirection` property. Again, `spacing` is used to separate child items.

```
// row.qml

import QtQuick 2.5

BrightSquare {
    id: root
    width: 400; height: 120

```

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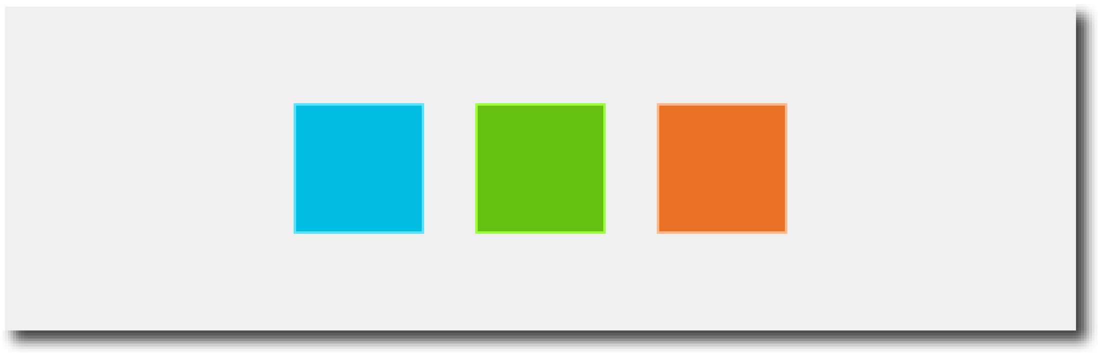

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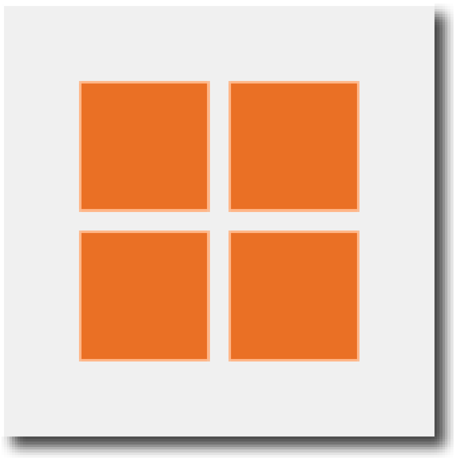
```
    Row {
        id: row
        anchors.centerIn: parent
        spacing: 20
        BlueSquare { }
        GreenSquare { }
        RedSquare { }
    }
}
```

The `Grid` element arranges its children in a grid, by setting the `rows` and `columns` properties, the number of rows or columns can be constrained. By not setting either of them, the other is calculated from the number of child items. For instance, setting rows to 3 and adding 6 child items will result in 2 columns. The properties `flow` and `layoutDirection` are used to control the order in which the items are added to the grid, while `spacing` controls the amount of space separating the child items.



```
// grid.qml

import QtQuick 2.5

BrightSquare {
    id: root
    width: 160
    height: 160

    Grid {
        id: grid
        rows: 2
        columns: 2
        anchors.centerIn: parent
```

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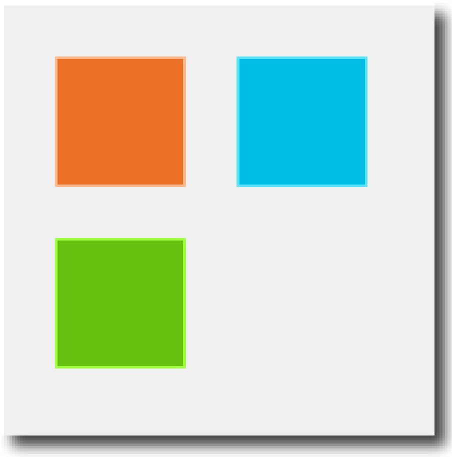
```
        spacing: 8
        RedSquare { }
        RedSquare { }
        RedSquare { }
        RedSquare { }
    }

}
```

The final positioner is `Flow`. It adds its child items in a flow. The direction of the flow is controlled using `flow` and `layoutDirection`. It can run sideways or from the top to the bottom. It can also run from left to right or in the opposite direction. As the items are added in the flow, they are wrapped to form new rows or columns as needed. In order for a flow to work, it must have a width or a height. This can be set either directly, or though anchor layouts.



```
// flow.qml

import QtQuick 2.5

BrightSquare {
    id: root
    width: 160
    height: 160

    Flow {
        anchors.fill: parent
        anchors.margins: 20
        spacing: 20
        RedSquare { }
        BlueSquare { }
        GreenSquare { }
    }
}
```

An element often used with positioners is the `Repeater`. It works like a for-loop and iterates over a model. In the simplest case a model is just a value providing the number of loops.

```
// repeater.qml

import QtQuick 2.5

DarkSquare {
    id: root
    width: 252
```

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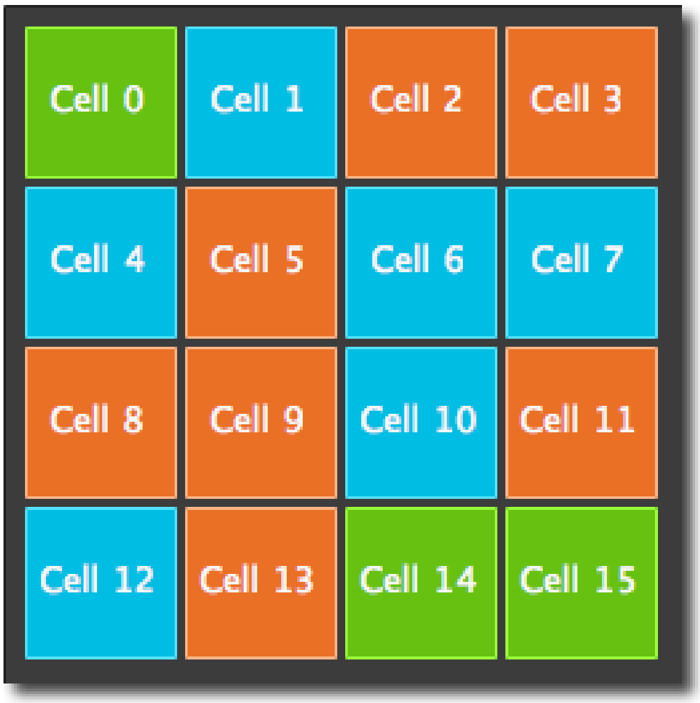

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```
    height: 252
    property variant colorArray: ["#00bde3", "#67c111", "#ea7025"]


    Grid{
        anchors.fill: parent
        anchors.margins: 8
        spacing: 4
        Repeater {
            model: 16
            Rectangle {
                width: 56; height: 56
                property int colorIndex: Math.floor(Math.random()*3)
                color: root.colorArray[colorIndex]
                border.color: Qt.lighter(color)
                Text {
                    anchors.centerIn: parent
                    color: "#f0f0f0"
                    text: "Cell " + index
                }
            }
        }
    }
}
```

In this repeater example, we use some new magic. We define our own color property, which we use as an array of colors. The repeater creates a series of rectangles (16, as defined by the model). For each loop, he creates the rectangle as defined by the child of the repeater. In the rectangle we chose the color by using JS math functions `Math.floor(Math.random()*3)`. This gives us a random number in the range from 0..2, which we use to select the color from our color array. As noted earlier, JavaScript is a core part of Qt Quick, as such the standard libraries are available for us.

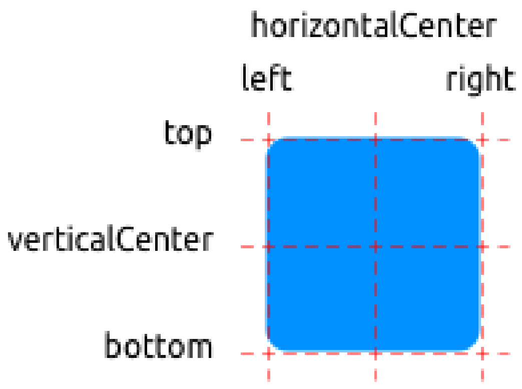
A repeater injects the `index` property into the repeater. It contains the current loop-index. (0,1,..15). We can use this to make our own decisions based on the index, or in our case to visualize the current index with the `Text` element.

Note: More advanced handling of larger models and kinetic views with dynamic delegates is covered in an own model-view chapter. Repeaters are best used when having a small amount of static data to be presented.

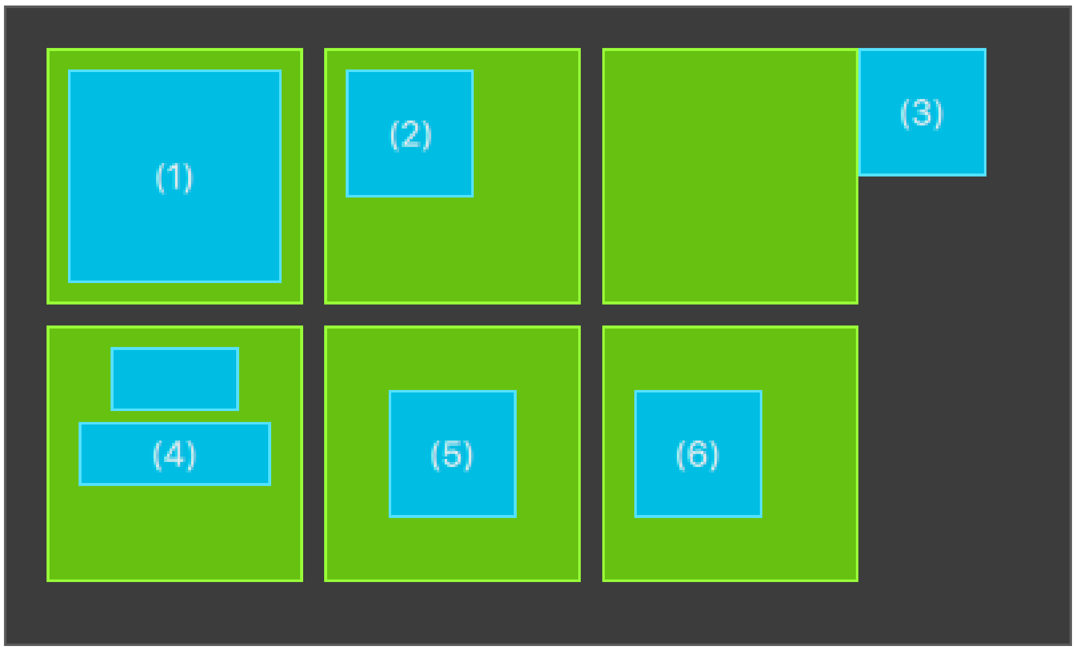
4.6 Layout Items

Todo: do we need to remove all uses of anchors earlier?

QML provides a flexible way to layout items using anchors. The concept of anchoring is part of the `Item` fundamental properties and available to all visual QML elements. Anchors act like a contract and are stronger than competing geometry changes. Anchors are expressions of relativeness, you always need a related element to anchor with.



An element has 6 major anchor lines (top, bottom, left, right, horizontalCenter, verticalCenter). Additional there is the baseline anchor for text in Text elements. Each anchor line comes with an offset. In the case of the top, bottom left and right they are called margins. For horizontalCenter, verticalCenter and baseline they are called offsets.



1. An element fills a parent element

```
GreenSquare {
    BlueSquare {
        width: 12
        anchors.fill: parent
        anchors.margins: 8
        text: '(1)'
    }
}
```

2. An element is left aligned to the parent

```
GreenSquare {
    BlueSquare {
        width: 48
        y: 8
        anchors.left: parent.left
        anchors.leftMargin: 8
        text: '(2)'
    }
}
```

3. An element left side is aligned to the parent's right side

```
GreenSquare {
    BlueSquare {
        width: 48
        anchors.left: parent.right
        text: '(3)'
    }
}
```

4. Center-aligned elements. `Blue1` is horizontally centered on the parent. `Blue2` is also horizontal centered but on `Blue1` and it's top is aligned to the `Blue1` bottom line.

```
GreenSquare {
    BlueSquare {
        id: blue1
        width: 48; height: 24
        y: 8
        anchors.horizontalCenter: parent.horizontalCenter
    }
    BlueSquare {
        id: blue2
        width: 72; height: 24
        anchors.top: blue1.bottom
        anchors.topMargin: 4
        anchors.horizontalCenter: blue1.horizontalCenter
        text: '(4)'
    }
}
```

5. An element is centered on a parent element

```
GreenSquare {
    BlueSquare {
        width: 48
        anchors.centerIn: parent
        text: '(5)'
    }
}
```

6. An element is centered with a left-offset on a parent element using horizontal and vertical center lines

```
        GreenSquare {
            BlueSquare {
                width: 48
                anchors.horizontalCenter: parent.horizontalCenter
                anchors.horizontalCenterOffset: -12
                anchors.verticalCenter: parent.verticalCenter
                text: '(6)'
            }
        }
```

Note: Our squares have been enhanced to enable dragging. Try the example and drag around some squares. You will see that (1) can't be dragged as it's anchored on all sides, sure you can drag the parent of (1) as it's not anchored at all. (2) can be vertically dragged as only the left side is anchored. Similar applies to (3). (4) can only be dragged vertically as both squares are horizontally centered. (5) is centered on the parent and as such can't be dragged, similar applies to (7). Dragging an element means changing their `x,y` position. As anchoring is stronger than geometry changes such as `x,y`, dragging is restricted by the anchored lines. We will see this effect later when we discuss animations.

4.7 Input Elements

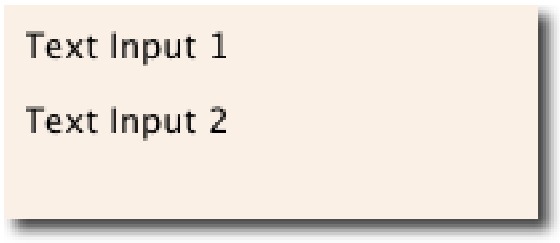
We have already used the `MouseArea` as a mouse input element. Next, we'll focus on keyboard input. We start off with the text editing elements: `TextInput` and `TextEdit`.

4.7.1 TextInput

The `TextInput` allows the user to enter a line of text. The element supports input constraints such as `validator`, `inputMask`, and `echoMode`.

```
// textinput.qml

import QtQuick 2.5

Rectangle {
    width: 200
    height: 80
    color: "linen"

    TextInput {
        id: input1
        x: 8; y: 8
        width: 96; height: 20
        focus: true
        text: "Text Input 1"
    }

    TextInput {
        id: input2
        x: 8; y: 36
        width: 96; height: 20
        text: "Text Input 2"
    }
}
```

The user can click inside a `TextInput` to change the focus. To support switching the focus by keyboard, we can use the `KeyNavigation` attached property.



```
// textinput2.qml

import QtQuick 2.5

Rectangle {
    width: 200
    height: 80
    color: "linen"

    TextInput {
        id: input1
        x: 8; y: 8
        width: 96; height: 20
        focus: true
        text: "Text Input 1"
        KeyNavigation.tab: input2
    }

    TextInput {
        id: input2
        x: 8; y: 36
        width: 96; height: 20
        text: "Text Input 2"
        KeyNavigation.tab: input1
    }
}
```

The `KeyNavigation` attached property supports a preset of navigation keys where an element id is bound to switch focus on the given key press.

A text input element comes with no visual presentation beside a blinking cursor and the entered text. For the user to be able to recognize the element as an input element it needs some visual decoration, for example, a simple rectangle. When placing the `TextInput` inside an element you need make sure you export the major properties you want others to be able to access.

We move this piece of code into our own component called `TLineEditV1` for reuse.

```
// TLineEditV1.qml

import QtQuick 2.5

Rectangle {
    width: 96; height: input.height + 8
    color: "lightsteelblue"
    border.color: "gray"

    property alias text: input.text
    property alias input: input

    TextInput {
        id: input
        anchors.fill: parent
```

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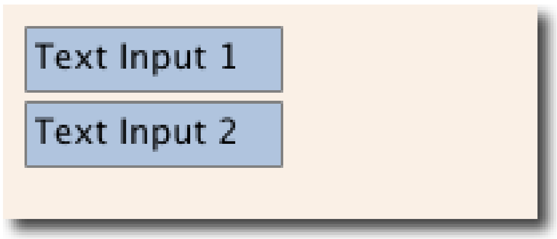
```
        anchors.margins: 4
        focus: true
    }
}
```

Note: If you want to export the `TextInput` completely, you can export the element by using `property alias input: input`. The first `input` is the property name, where the 2nd input is the element id.

We rewrite our `KeyNavigation` example with the new `TLineEditV1` component.

```
Rectangle {
    ...
    TLineEditV1 {
        id: input1
        ...
    }
    TLineEditV1 {
        id: input2
        ...
    }
}
```



And try the tab key for navigation. You will experience the focus does not change to `input2`. The simple use of `focus: true` is not sufficient. The problem arises, that the focus was transferred to the `input2` element the top-level item inside the `TlineEditV1` (our `Rectangle`) received focus and did not forward the focus to the `TextInput`. To prevent this QML offers the `FocusScope`.

4.7.2 FocusScope

A focus scope declares that the last child element with `focus: true` receives the focus if the focus scope receives the focus. So it's forward the focus to the last focus requesting child element. We will create a 2nd version of our TLineEdit component called TLineEditV2 using the focus scope as the root element.

```
// TLineEditV2.qml

import QtQuick 2.5

FocusScope {
    width: 96; height: input.height + 8
    Rectangle {
        anchors.fill: parent
        color: "lightsteelblue"
        border.color: "gray"

    }

    property alias text: input.text
    property alias input: input
```

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```
    TextInput {
        id: input
        anchors.fill: parent
        anchors.margins: 4
        focus: true
    }
}
```

Our example will now look like this:

```
Rectangle {
    ...
    TLineEditV2 {
        id: input1
        ...
    }
    TLineEditV2 {
        id: input2
        ...
    }
}
```

Pressing the tab key now successfully switches the focus between the 2 components and the correct child element inside the component is focused.

4.7.3 TextEdit

The `TextEdit` is very similar to `TextInput` and support a multi-line text edit field. It doesn't have the text constraint properties as this depends on querying the painted size of the text (`paintedHeight`, `paintedWidth`). We also create our own component called `TTextEdit` to provide an editing background and use the focus scope for better focus forwarding.

```
// TTextEdit.qml

import QtQuick 2.5

FocusScope {
    width: 96; height: 96
    Rectangle {
        anchors.fill: parent
        color: "lightsteelblue"
        border.color: "gray"

    }

    property alias text: input.text
    property alias input: input

    TextEdit {
        id: input
        anchors.fill: parent
        anchors.margins: 4
        focus: true
    }
}
```

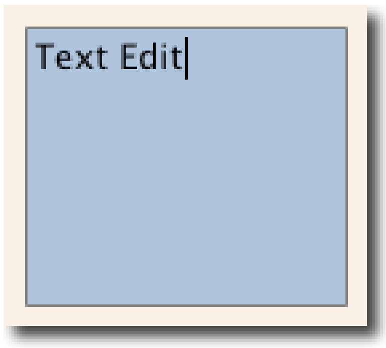
You can use it like the `TLineEdit` component

```
// textedit.qml

import QtQuick 2.5

Rectangle {
    width: 136
    height: 120
    color: "linen"

    TTextEdit {
        id: input
        x: 8; y: 8
        width: 120; height: 104
        focus: true
        text: "Text Edit"
    }
}
```



4.7.4 Keys Element

The attached property `Keys` allows executing code based on certain key presses. For example, to move a square around and scale we can hook into the up, down, left and right keys to translate the element and the plus, minus key to scale the element.

```
// keys.qml

import QtQuick 2.5

DarkSquare {
    width: 400; height: 200

    GreenSquare {
        id: square
        x: 8; y: 8
    }
    focus: true
    Keys.onLeftPressed: square.x -= 8
    Keys.onRightPressed: square.x += 8
    Keys.onUpPressed: square.y -= 8
    Keys.onDownPressed: square.y += 8
    Keys.onPressed: {
        switch(event.key) {
            case Qt.Key_Plus:
                square.scale += 0.2
                break;
            case Qt.Key_Minus:
                square.scale -= 0.2
```

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```
                    break;
            }

        }
}
```

4.8 Advanced Techniques

4.8.1 Performance of QML

QML and Javascript are interpreted languages. This means that they do not have to be processed by a compiler before being executed. Instead, they are being run inside an execution engine. However, as interpretation is a costly operation various techniques are used to improvide performance.

The QML engine uses just-in-time (JIT) compilation to improve performance. It also caches the intermediate output to avoid having to recompile. This works seamlessly for you as a developer. The only trace of this is that files ending with `qmlc` and `jsc` can be found next to the source files.

If you want to avoid the initial start-up penalty induced by the initial parsing you can also pre-compile your QML and Javascript. This requires you to put your code into a Qt resource file and is described in detail in the Compiling QML Ahead of Time chapter in the Qt documentation.

CHAPTER

FIVE

FLUID ELEMENTS

Section author: jryannel@LinkedIn

Note: Last Build: December 07, 2020 at 10:50 CET

The source code for this chapter can be found in the assets folder.

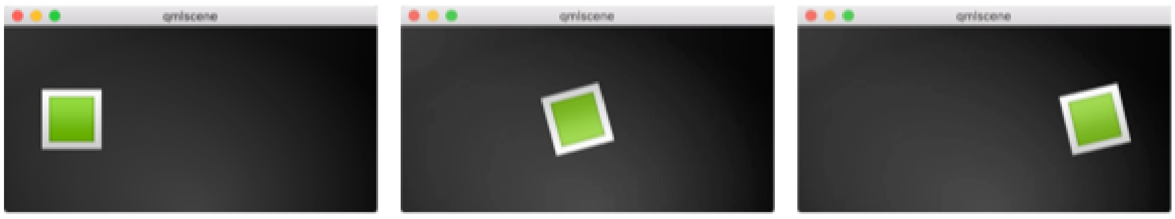
Till now, we have mostly looked at simple graphical elements and how to arrange and manipulate them. This chapter is about how to control these changes in a way that a value of a property not just changes instantly, it's more how the value changes over time: an animation. This technology is one of the key foundations for modern slick user interfaces and can be extended with a system to describe your user interface using states and transitions. Each state defines a set of property changes and can be combined with animations on state changes, called transitions.

5.1 Animations

Animations are applied to property changes. An animation defines the interpolation curve when for property value changes to create smooth transitions from one value to another. An animation is defined by a series of target properties to be animated, an easing curve for the interpolation curve and in the most cases a duration, which defines the time for the property change. All animations in Qt Quick are controlled by the same timer and are therefore synchronized. This improves the performance and visual quality of animations.

Note: Animations control how property changes, i.e. value interpolation. This is a fundamental concept. QML is based on elements, properties, and scripting. Every element provides dozens of properties, each property is waiting to get animated by you. In the book, you will see this is a spectacular playing field. You will catch yourself at looking at some animations and just admire their beauty and for sure also your creative genius. Please remember then: *Animations control property changes and every element has dozens of properties at your disposal*.

Unlock the power!



```
// animation.qml

import QtQuick 2.5
```

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```
Image {
    id: root
    source: "assets/background.png"

    property int padding: 40
    property int duration: 4000
    property bool running: false

    Image {
        id: box
        x: root.padding;
        y: (root.height-height)/2
        source: "assets/box_green.png"

        NumberAnimation on x {
            to: root.width - box.width - root.padding
            duration: root.duration
            running: root.running
        }
        RotationAnimation on rotation {
            to: 360
            duration: root.duration
            running: root.running
        }
    }

    MouseArea {
        anchors.fill: parent
        onClicked: root.running = true
    }

}
```

The example above shows a simple animation applied on the `x` and `rotation` property. Each animation has a duration of 4000 milliseconds (msec) and loops forever. The animation on x moves the x coordinate from the object gradually over to 240px. The animation on rotation runs from the current angle to 360 degrees. Both animations run in parallel and are started as soon as the UI is loaded.

Now you can play around with the animation by changing the `to` and `duration` property or you could add another animation for example on the `opacity` or even the `scale`. Combining these it could look like the object is disappearing into the deep space. Try it out!

5.1.1 Animation Elements

There are several types of animation elements, each optimized for a specific use case. Here is a list of the most prominent animations:

- `PropertyAnimation` - Animates changes in property values
- `NumberAnimation` - Animates changes in qreal-type values
- `ColorAnimation` - Animates changes in color values
- `RotationAnimation` - Animates changes in rotation values

Besides these basic and widely used animation elements, Qt Quick provides also more specialized animations for specific use cases:

- `PauseAnimation` - Provides a pause for an animation
- `SequentialAnimation` - Allows animations to be run sequentially
- `ParallelAnimation` - Allows animations to be run in parallel

- `AnchorAnimation` - Animates changes in anchor values
- `ParentAnimation` - Animates changes in parent values
- `SmoothedAnimation` - Allows a property to smoothly track a value
- `SpringAnimation` - Allows a property to track a value in a spring-like motion
- `PathAnimation` - Animates an item alongside a path
- `Vector3dAnimation` - Animates changes in QVector3d values

We will learn later how to create a sequence of animations. While working on more complex animations there comes up the need to change a property or to run a script during an ongoing animation. For this Qt Quick offers the action elements, which can be used everywhere where the other animation elements can be used:

- `PropertyAction` - Specifies immediate property changes during animation
- `ScriptAction` - Defines scripts to be run during an animation

The major animation types will be discussed in this chapter using small focused examples.

5.1.2 Applying Animations

Animation can be applied in several ways:

- *Animation on property* - runs automatically after the element is fully loaded
- *Behavior on property* - runs automatically when the property value changes
- *Standalone Animation* - runs when the animation is explicitly started using `start()` or `running` is set to true (e.g. by a property binding)

Later we see also how animations can be used inside state transitions.

Extended ClickableImage Version 2

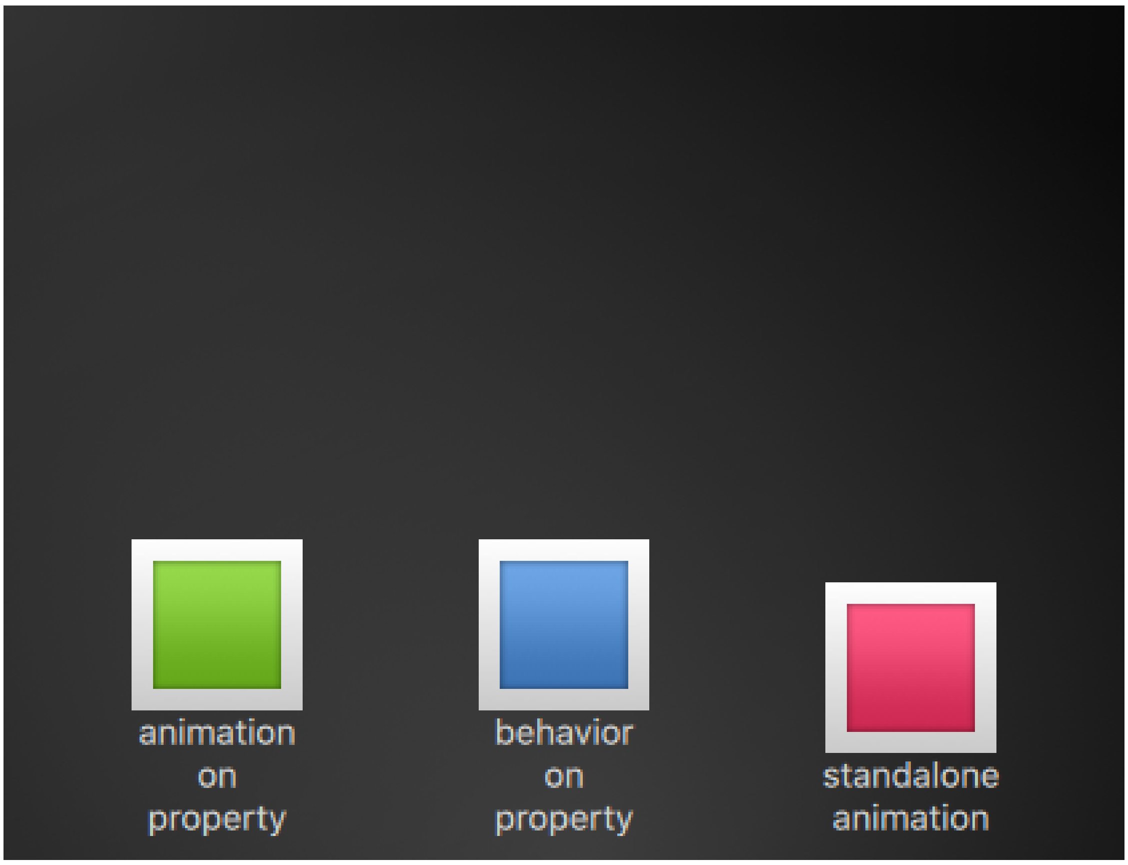
To demonstrate the usage of animations we reuse our `ClickableImage` component from an earlier chapter and extended it with a text element.

```
// ClickableImageV2.qml
// Simple image which can be clicked

import QtQuick 2.5

Item {
    id: root
    width: container.childrenRect.width
    height: container.childrenRect.height
    property alias text: label.text
    property alias source: image.source
    signal clicked

    Column {
        id: container
        Image {
            id: image
        }
        Text {
            id: label
            width: image.width
            horizontalAlignment: Text.AlignHCenter
            wrapMode: Text.WordWrap
            color: "#ececec"
        }
    }

    MouseArea {
        anchors.fill: parent
        onClicked: root.clicked()
    }
}
```

To organize the element below the image we used a `Column` positioner and calculated the width and height based on the column's `childrenRect` property. We exposed two properties: `text` and the image `source` as also the `clicked` signal. We also wanted that the text is as wide as the image and it should wrap. We achieve the latter by using the `Text` elements `wrapMode` property.

Note: Due to the inversion of the geometry-dependency (parent geometry depends on child geometry), we can't set a width/height on the `ClickableImageV2`, as this will break our width/height binding. This is a limitation on our internal design and as a designer of components, you should be aware of this. Normally you should prefer the child's geometry to depend on the parent's geometry.

The objects ascending.



The three objects are all at the same y-position (`y=200`). They need to travel all to `y=40`. Each of them using a different method with different side-effects and features.

```
    ClickableImageV2 {
        id: greenBox
        x: 40; y: root.height-height
        source: "assets/box_green.png"
        text: "animation on property"
        NumberAnimation on y {
            to: 40; duration: 4000
        }
    }
```

First object

The first object travels using the `Animation on <property>` strategy. The animation starts immediately. When an object is clicked their y-position is reset to the start position, this applies to all objects. On the first object, the reset does not have any effect as long as the animation is running. It's even disturbing as the y-position is set for a fraction of a second to a new value before the animation starts. *Such competing property changes should be avoided.*

```
    ClickableImageV2 {
        id: blueBox
        x: (root.width-width)/2; y: root.height-height
        source: "assets/box_blue.png"
        text: "behavior on property"
        Behavior on y {
            NumberAnimation { duration: 4000 }
        }

        onClicked: y = 40
        // random y on each click
//        onClicked: y = 40+Math.random()*(205-40)
    }
```

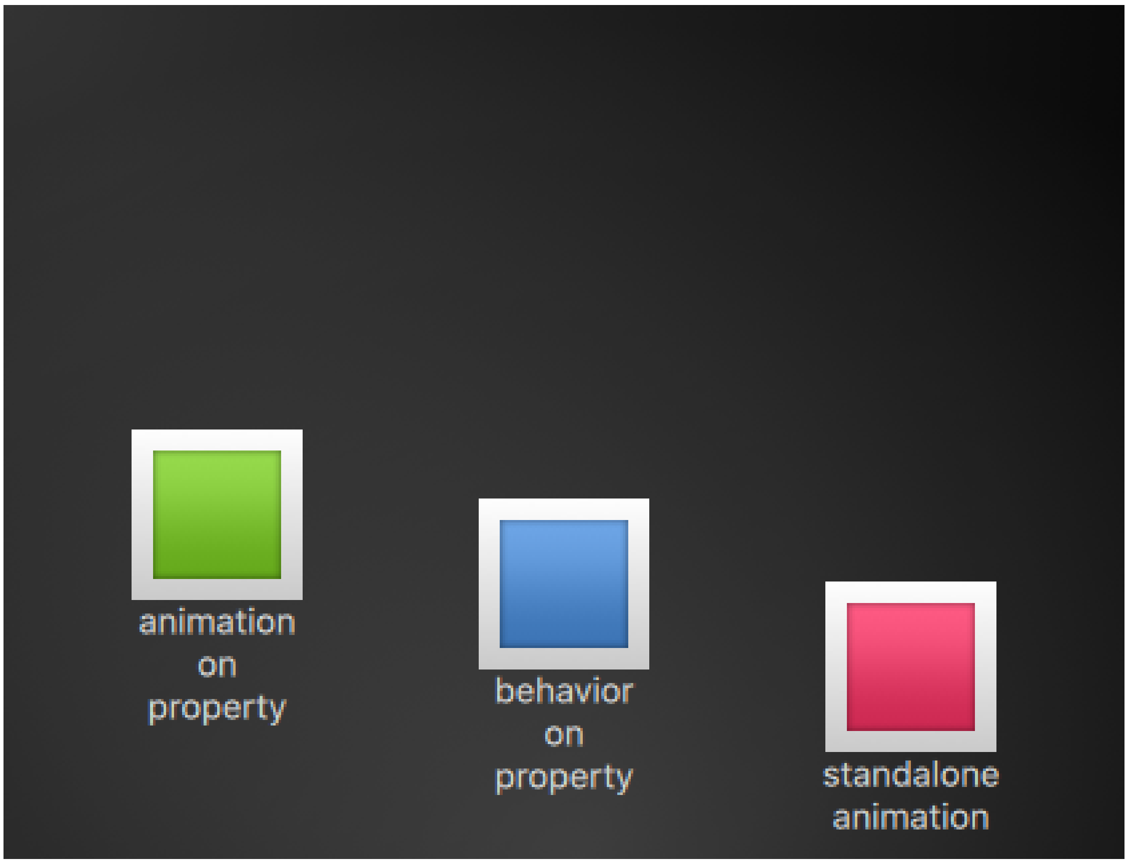
Second object

The second object travels using a `behavior on` animation. This behavior tells the property, every time the property value changes, it changes through this animation. The behavior can be disabled by `enabled : false` on the `Behavior` element. The object will start traveling when you click it (y-position is then set to 40). Another click has no influence as the position is already set. You could try to use a random value (e.g. `40+(Math.random()*(205-40))` for the y-position. You will see that the object will always animate to the new position and adapt its speed to match the 4 seconds to the destination defined by the duration of the animation.

```
    ClickableImageV2 {
        id: redBox
        x: root.width-width-40; y: root.height-height
        source: "assets/box_red.png"
        onClicked: anim.start()
//        onClicked: anim.restart()

        text: "standalone animation"

        NumberAnimation {
            id: anim
            target: redBox
            properties: "y"
            to: 40
            duration: 4000
        }
    }
```

Third object

The third object uses a `standalone animation`. The animation is defined as its own element and could be everywhere in the document. The click will start the animation using the animations function `start()`. Each animation has a start(), stop(), resume(), restart() function. The animation itself contains much more information than the other animation types earlier. We need to define the target and properties to declare the target element to be animated and which properties we want to animate. We need to define a `to` value and in this case, we define also a `from` value to allow a restart of the animation.



A click on the background will reset all objects to their initial position. The first object cannot be restarted except by re-starting the program which triggers the re-loading of the element.

Note: Another way to start/stop an animation is to bind a property to the `running` property of an animation. This is especially useful when the user-input is in control of properties:

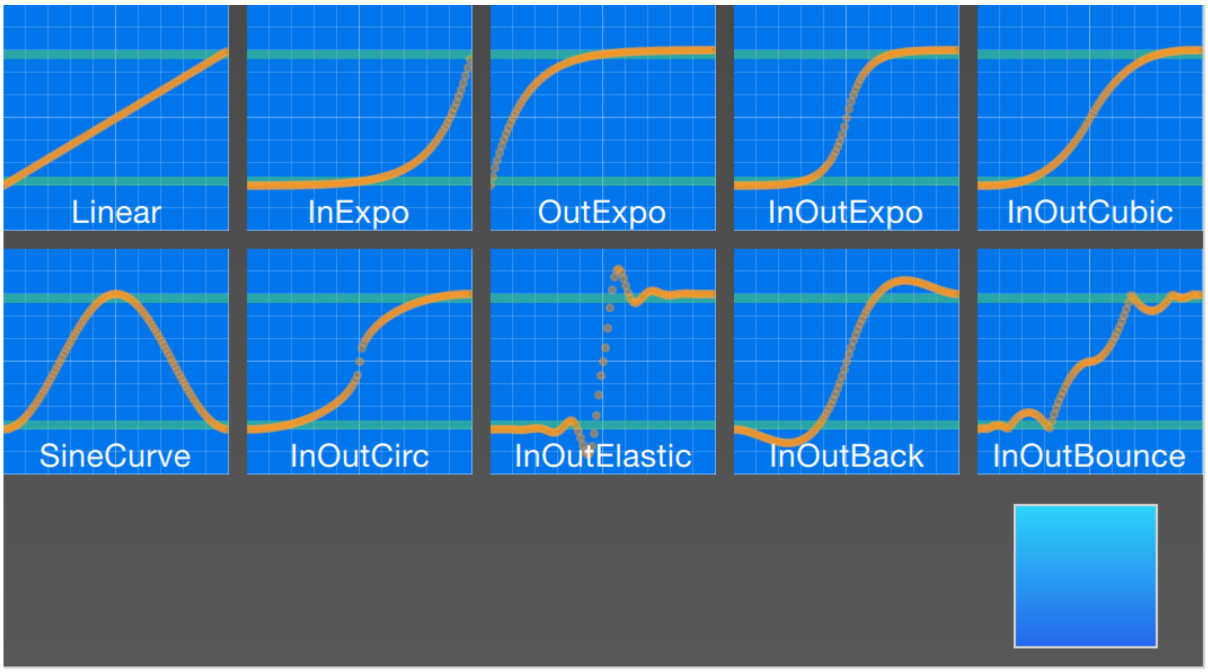
```
NumberAnimation {
    ...
    // animation runs when mouse is pressed
    running: area.pressed
}
MouseArea {
    id: area
}
```

5.1.3 Easing Curves

The value change of a property can be controlled by an animation. Easing attributes allows influencing the interpolation curve of a property change. All animations we have defined by now use a linear interpolation because the initial easing type of an animation is `Easing.Linear`. It's best visualized with a small plot, where the y-axis is the property to be animated and the x-axis is the time (*duration*). A linear interpolation would draw a straight line from the `from` value at the start of the animation to the `to` value at the end of the animation. So the easing type defines the curve of change. Easing types are carefully chosen to support a natural fit for a moving object, for example when a page slides out. Initially, the page should slide out slowly and then gain the speed to finally slide out at high speed, similar to turning the page of a book.

Note: Animations should not be overused. As other aspects of UI design also animations should be designed carefully and support the UI flow and not dominate it. The eye is very sensitive to moving objects and animations can easily distract the user.

In the next example, we will try some easing curves. Each easing curve is displayed by a click-able image and, when clicked, will set a new easing type on the `square` animation and then trigger a `restart()` to run the animation with the new curve.



The code for this example was made a little bit more complicated. We first create a grid of `EasingTypes` and a `Box` which is controlled by the easing types. An easing type just displays the curve which the box shall use for its animation. When the user clicks on an easing curve the box moves in a direction according to the easing curve. The animation itself is a standalone-animation with the target set to the box and configured for x-property animation with a duration of 2 secs.

Note: The internals of the EasingType renders the curve in real time and the interested reader can look it up in the `EasingCurves` example.

```
// EasingCurves.qml

import QtQuick 2.5
import QtQuick.Layouts 1.2

Rectangle {
    id: root
    width: childrenRect.width
    height: childrenRect.height

    color: '#4a4a4a'
    gradient: Gradient {
        GradientStop { position: 0.0; color: root.color }
        GradientStop { position: 1.0; color: Qt.lighter(root.color, 1.2) }
    }

    ColumnLayout {

        Grid {
            spacing: 8
```

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```
            columns: 5
            EasingType {
                easingType: Easing.Linear
                title: 'Linear'
                onClicked: {
                    animation.easing.type = easingType
                    box.toggle = !box.toggle
                }
            }
            EasingType {
                easingType: Easing.InExpo
                title: "InExpo"
                onClicked: {
                    animation.easing.type = easingType
                    box.toggle = !box.toggle
                }
            }
            EasingType {
                easingType: Easing.OutExpo
                title: "OutExpo"
                onClicked: {
                    animation.easing.type = easingType
                    box.toggle = !box.toggle
                }
            }
            EasingType {
                easingType: Easing.InOutExpo
                title: "InOutExpo"
                onClicked: {
                    animation.easing.type = easingType
                    box.toggle = !box.toggle
                }
            }
            EasingType {
                easingType: Easing.InOutCubic
                title: "InOutCubic"
                onClicked: {
                    animation.easing.type = easingType
                    box.toggle = !box.toggle
                }
            }
            EasingType {
                easingType: Easing.SineCurve
                title: "SineCurve"
                onClicked: {
                    animation.easing.type = easingType
                    box.toggle = !box.toggle
                }
            }
            EasingType {
                easingType: Easing.InOutCirc
                title: "InOutCirc"
                onClicked: {
                    animation.easing.type = easingType
                    box.toggle = !box.toggle
                }
            }
            EasingType {
                easingType: Easing.InOutElastic
                title: "InOutElastic"
                onClicked: {
```

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```
                    animation.easing.type = easingType
                    box.toggle = !box.toggle
                }
            }
            EasingType {
                easingType: Easing.InOutBack
                title: "InOutBack"
                onClicked: {
                    animation.easing.type = easingType
                    box.toggle = !box.toggle
                }
            }
            EasingType {
                easingType: Easing.InOutBounce
                title: "InOutBounce"
                onClicked: {
                    animation.easing.type = easingType
                    box.toggle = !box.toggle
                }
            }
        }
        Item {
            height: 80
            Layout.fillWidth: true
            Box {
                id: box
                property bool toggle
                x: toggle?20:root.width-width-20
                anchors.verticalCenter: parent.verticalCenter
                gradient: Gradient {
                    GradientStop { position: 0.0; color: "#2ed5fa" }
                    GradientStop { position: 1.0; color: "#2467ec" }
                }
                Behavior on x {
                    NumberAnimation {
                        id: animation
                        duration: 500
                    }
                }
            }
        }
    }
}
```

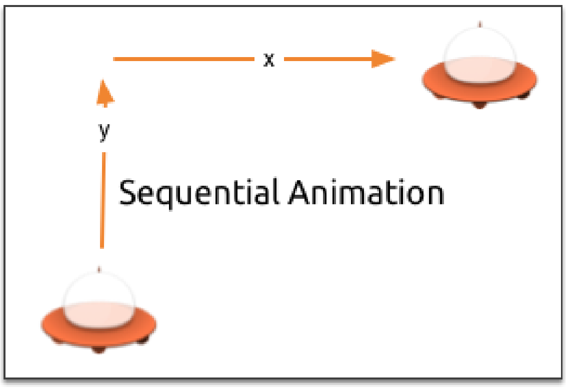
Please play with it, please observe the change of speed during an animation. Some animations feel more natural for the object and some feel irritating.

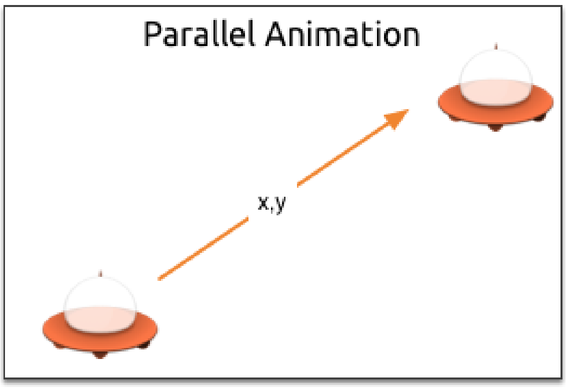
Besides the `duration` and `easing.type` you are able to fine tune animations. For example, the general `PropertyAnimation` where most animation inherits from additionally supports an `easing.amplitude`, `easing.overshoot` and `easing.period` property which allows you to fine-tune the behavior of particular easing curves. Not all easing curves support these parameters. Please consult the easing table from the `PropertyAnimation` documentation to check if an easing parameter has an influence on an easing curve.

Note: Choosing the right animation for the element in the user interface context is crucial for the outcome. Remember the animation shall support the UI flow; not irritate the user.

5.1.4 Grouped Animations

Often animations will be more complex than just animating one property. You might want to run several animations at the same time or one after another or even execute a script between two animations. For this, the grouped animation offer you a possibility. As the named suggests it's possible to group animations. Grouping can be done in two ways: parallel or sequential. You can use the `SequentialAnimation` or the `ParallelAnimation` element, which act as animation containers for other animation elements. These grouped animations are animations themselves and can be used exactly as such.





All direct child animations of a parallel animation will run in parallel when started. This allows you to animate different properties at the same time.

```
// parallelanimation.qml
import QtQuick 2.5

BrightSquare {
    id: root
    width: 600
    height: 400
    property int duration: 3000
    property Item ufo: ufo

    Image {
        anchors.fill: parent
        source: "assets/ufo_background.png"
    }


    ClickableImageV3 {
        id: ufo
        x: 20; y: root.height-height
        text: 'ufo'
        source: "assets/ufo.png"
        onClicked: anim.restart()
    }

    ParallelAnimation {
        id: anim
        NumberAnimation {
            target: ufo
            properties: "y"
            to: 20
            duration: root.duration
        }
        NumberAnimation {
            target: ufo
            properties: "x"
```

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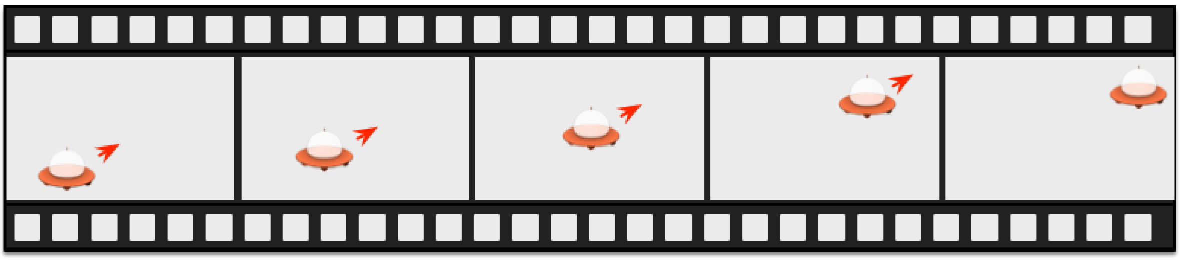
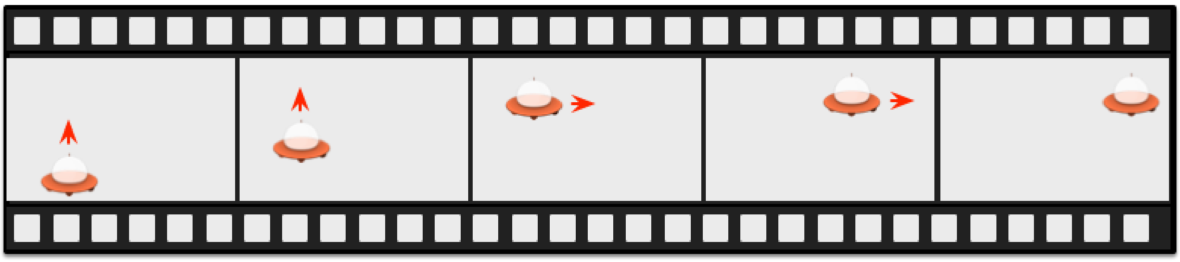
```
            to: 160
            duration: root.duration
        }
    }
}
```

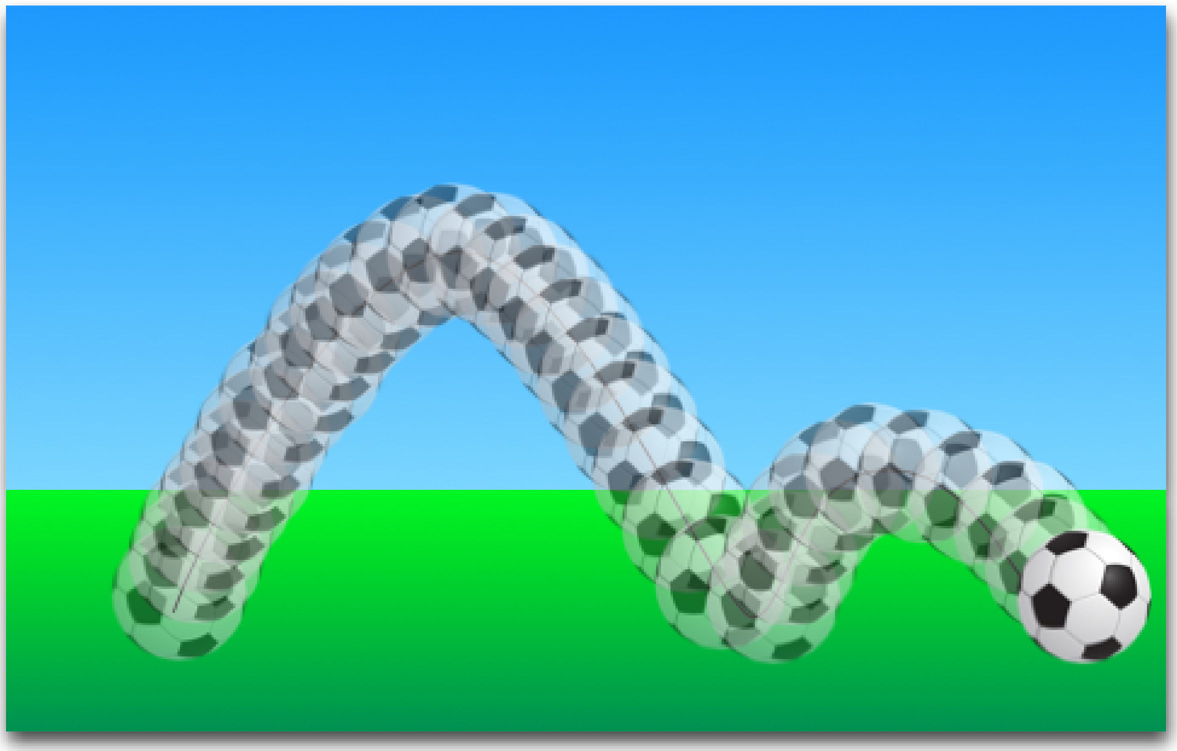


A sequential animation will first run the first child animation and then continue from there.

```
// SequentialAnimationExample.qml
import QtQuick 2.5

BrightSquare {
    id: root
    width: 600
    height: 400
    property int duration: 3000

    property Item ufo: ufo

    Image {
        anchors.fill: parent
        source: "assets/ufo_background.png"
    }

    ClickableImageV3 {
        id: ufo
        x: 20; y: root.height-height
        text: 'rocket'
        source: "assets/ufo.png"
        onClicked: anim.restart()
    }

    SequentialAnimation {
        id: anim
        NumberAnimation {
            target: ufo
            properties: "y"
            to: 20
            // 60% of time to travel up
            duration: root.duration*0.6
        }
        NumberAnimation {
            target: ufo
            properties: "x"
            to: 400
            // 40% of time to travel sideways
            duration: root.duration*0.4
        }
    }
}
```



Grouped animation can also be nested, for example, a sequential animation can have two parallel animations as child animations, and so on. We can visualize this with a soccer ball example. The idea is to throw a ball from left to right an animate its behavior.



To understand the animation we need to dissect it into the integral transformations of the object. We need to remember animation do animate property changes. Here are the different transformations:

- An x-translation from left-to-right (`X1`)
- An y-translation from down to up (`Y1`) followed by a translation from up to down (`Y2`) with some bouncing
- A rotation over 360 over the whole animation duration (`ROT1`)

The whole duration of the animation should take three seconds.

We start with an empty item as the root element of the width of 480 and height of 300.

```
import QtQuick 2.5

Item {
    id: root
    width: 480
    height: 300
    property int duration: 3000

```

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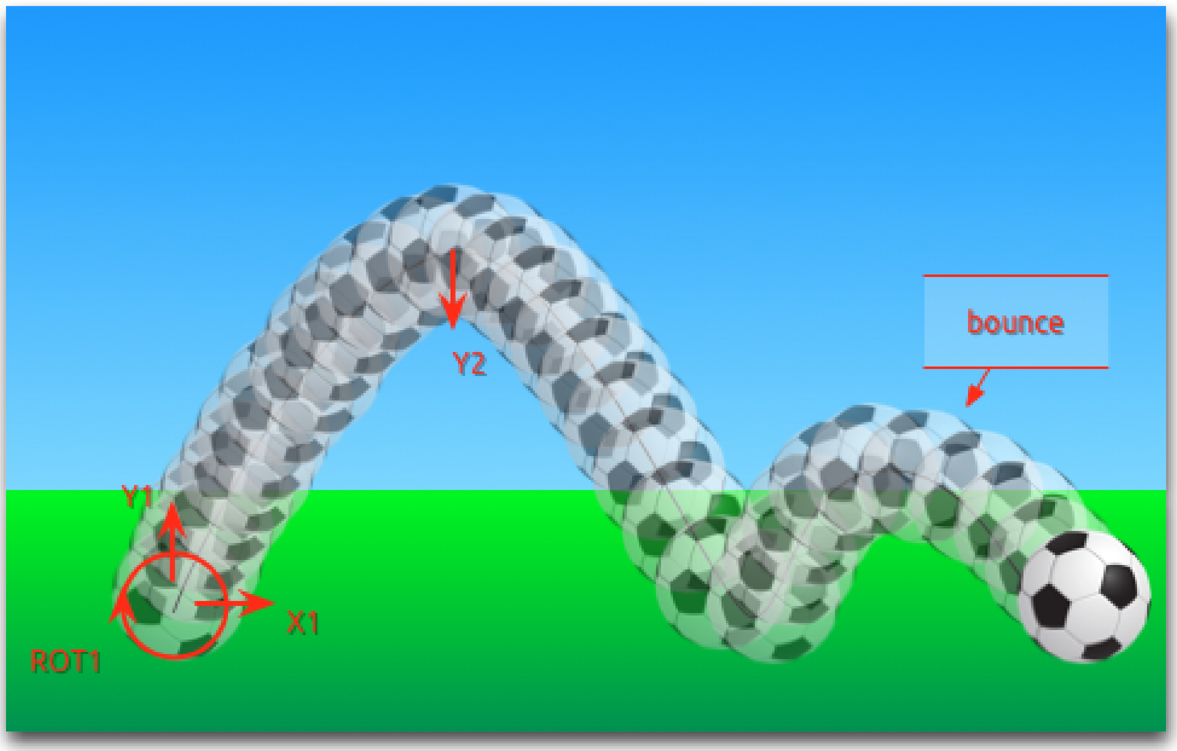

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```
    ...
}
```

We have defined our total animation duration as a reference to better synchronize the animation parts.

The next step would be to add the background, which in our case are 2 rectangles with a green and blue gradients.

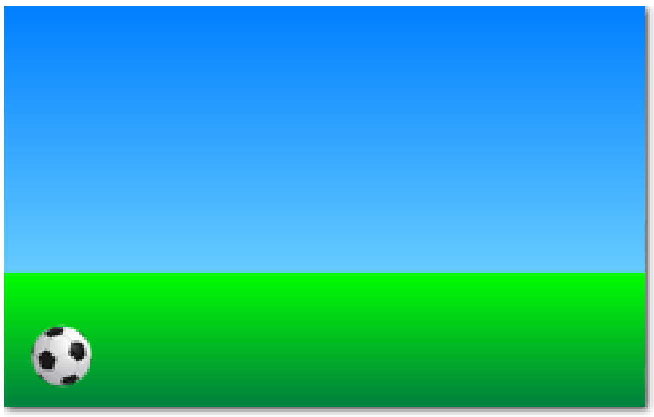
```
    Rectangle {
        id: sky
        width: parent.width
        height: 200
        gradient: Gradient {
            GradientStop { position: 0.0; color: "#0080FF" }
            GradientStop { position: 1.0; color: "#66CCFF" }
        }
    }
    Rectangle {
        id: ground
        anchors.top: sky.bottom
        anchors.bottom: root.bottom
        width: parent.width
        gradient: Gradient {
            GradientStop { position: 0.0; color: "#00FF00" }
            GradientStop { position: 1.0; color: "#00803F" }
        }
    }
```

The upper blue rectangle takes 200 pixels of the height and the lower one is anchored to the top of the sky and to the bottom on the root element.

Let's bring the soccer ball onto the green. The ball is an image, stored under "assets/soccer_ball.png". For the beginning, we would like to position it in the lower left corner, near the edge.

```
    Image {
        id: ball
        x: 0; y: root.height-height
        source: "assets/soccer_ball.png"

        MouseArea {
            anchors.fill: parent
            onClicked: {
                ball.x = 0;
                ball.y = root.height-ball.height;
                ball.rotation = 0;
                anim.restart()
            }
        }
    }
```



The image has a mouse area attached to it. If the ball is clicked the position of the ball will reset and the animation restarted.

Let’s start with a sequential animation for the two y translations first.

```
SequentialAnimation {
    id: anim
    NumberAnimation {
        target: ball
        properties: "y"
        to: 20
        duration: root.duration * 0.4
    }
    NumberAnimation {
        target: ball
```

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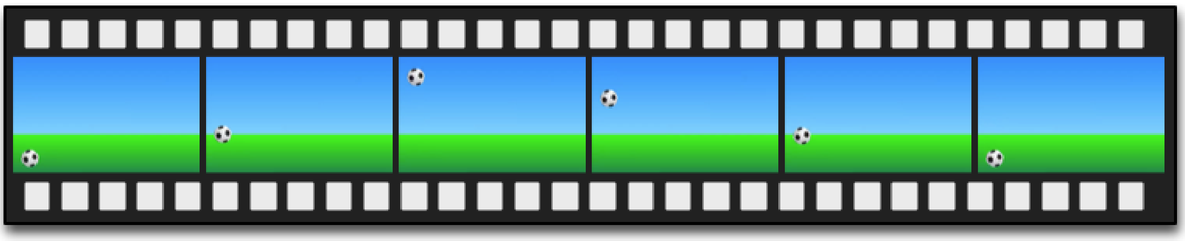
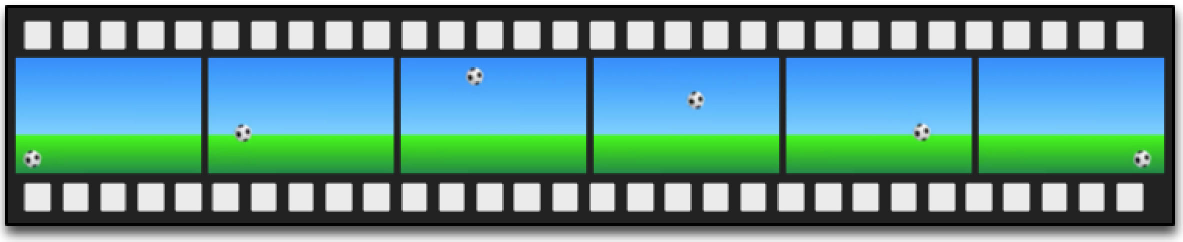
```
        properties: "y"
        to: 240
        duration: root.duration * 0.6
    }
}
```



This specifies that 40% of the total animation duration is the up animation and 60% the down animation. One animation after another as a sequence. The transformations are animated on a linear path but there is no curving currently. Curves will be added later using the easing curves, at the moment we're concentrating on getting the transformations animated.

Next, we need to add the x-translation. The x-translation shall run in parallel with the y-translation so we need to encapsulate the sequence of y-translations into a parallel animation together with the x-translation.

```
ParallelAnimation {
    id: anim
    SequentialAnimation {
        // ... our Y1, Y2 animation
    }
    NumberAnimation { // X1 animation
        target: ball
        properties: "x"
        to: 400
        duration: root.duration
    }
}
```



In the end, we would like the ball to be rotating. For this, we need to add another animation to the parallel animation. We choose the `RotationAnimation` as it's specialized for rotation.

```
ParallelAnimation {
    id: anim
    SequentialAnimation {
        // ... our Y1, Y2 animation
    }
    NumberAnimation { // X1 animation
        // X1 animation
    }
    RotationAnimation {
        target: ball
        properties: "rotation"
```

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```
        to: 720
        duration: root.duration
    }
}
```

That's the whole animation sequence. The one thing left is to provide the correct easing curves for the movements of the ball. For the *Y1* animation I use a `Easing.OutCirc` curve as this should look more like a circular movement. *Y2* is enhanced using an `Easing.OutBounce` as the ball should bounce and the bouncing should happen at the end (try an `Easing.InBounce` and you see the bouncing will start right away). The *X1* and *ROT1* animation are left as is with a linear curve.

Here is the final animation code for your reference:

```
    ParallelAnimation {
        id: anim
        SequentialAnimation {
            NumberAnimation {
                target: ball
                properties: "y"
                to: 20
                duration: root.duration * 0.4
                easing.type: Easing.OutCirc
            }
            NumberAnimation {
                target: ball
                properties: "y"
                to: root.height-ball.height
                duration: root.duration * 0.6
                easing.type: Easing.OutBounce
            }
        }
        NumberAnimation {
            target: ball
            properties: "x"
            to: root.width-ball.width
            duration: root.duration
        }
        RotationAnimation {
            target: ball
            properties: "rotation"
            to: 720
            duration: root.duration
        }
    }
```

5.2 States and Transitions

Often parts of a user interface can be described in states. A state defines a set of property changes and can be triggered by a certain condition. Additional these state switches can have a transition attached which defines how these changes should be animated or any additional actions shall be applied. Actions can also be applied when a state is entered.

5.2.1 States

You define states in QML with the `State` element, which needs to be bound to the `states` array of any item element. A state is identified through a state name and consist, in its simplest form, of a series of property changes on elements. The default state is defined by the initial properties of the element and is named `""` (the empty string).

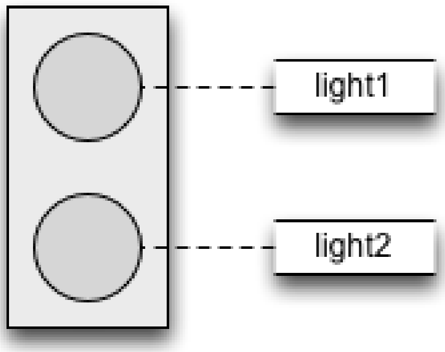
```
Item {
    id: root
    states: [
        State {
            name: "go"
            PropertyChanges { ... }
        },
        State {
            name: "stop"
            PropertyChanges { ... }
        }
    ]
}
```

A state is changed by assigning a new state name to the `state` property of the element with the states defined.

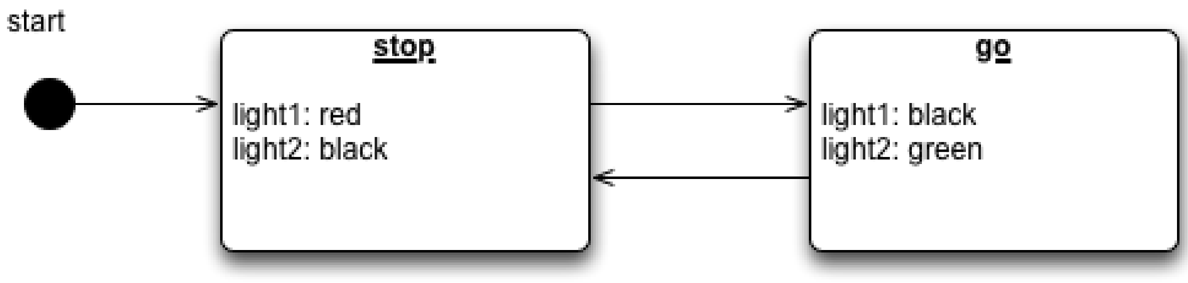
Note: Another way to switch states is using the `when` property of the `State` element. The `when` property can be set to an expression that evaluates to true when the state should be applied.

```
Item {
    id: root
    states: [
        ...
    ]

    Button {
        id: goButton
        ...
        onClicked: root.state = "go"
    }
}
```



For example, a traffic light might have two signaling lights. The upper one signaling stop with a red color and the lower one signaling go with a green color. In this example, both lights should not shine at the same time. Let's have a look at the state chart diagram.



When the system is switched on it goes automatically into the stop mode as the default state. The stop state changes the `light1` to red and `light2` to black (off). An external event can now trigger a state switch to the `"go"` state. In the go state, we change the color properties from `light1` to black (off) and `light2` to green to indicate the passers may walk now.

To realize this scenario we start sketching our user interface for the 2 lights. For simplicity, we use 2 rectangles with the radius set to the half of the width (and the width is the same as the height, which means it's a square).

```
    Rectangle {
        id: light1
        x: 25; y: 15
        width: 100; height: width
        radius: width/2
        color: root.black
        border.color: Qt.lighter(color, 1.1)
    }

    Rectangle {
        id: light2
        x: 25; y: 135
        width: 100; height: width
        radius: width/2
        color: root.black
        border.color: Qt.lighter(color, 1.1)
    }
```

As defined in the state chart we want to have two states one the `"go"` state and the other the `"stop"` state, where each of them changes the traffic lights respective to red or green. We set the `state` property to `stop` to ensure the initial state of our traffic light is the `stop` state.

Note: We could have achieved the same effect with only a `"go"` state and no explicit `"stop"` state by setting the color of `light1` to red and the color of `light2` to black. The initial state `""` defined by the initial property values would then act as the `"stop"` state.

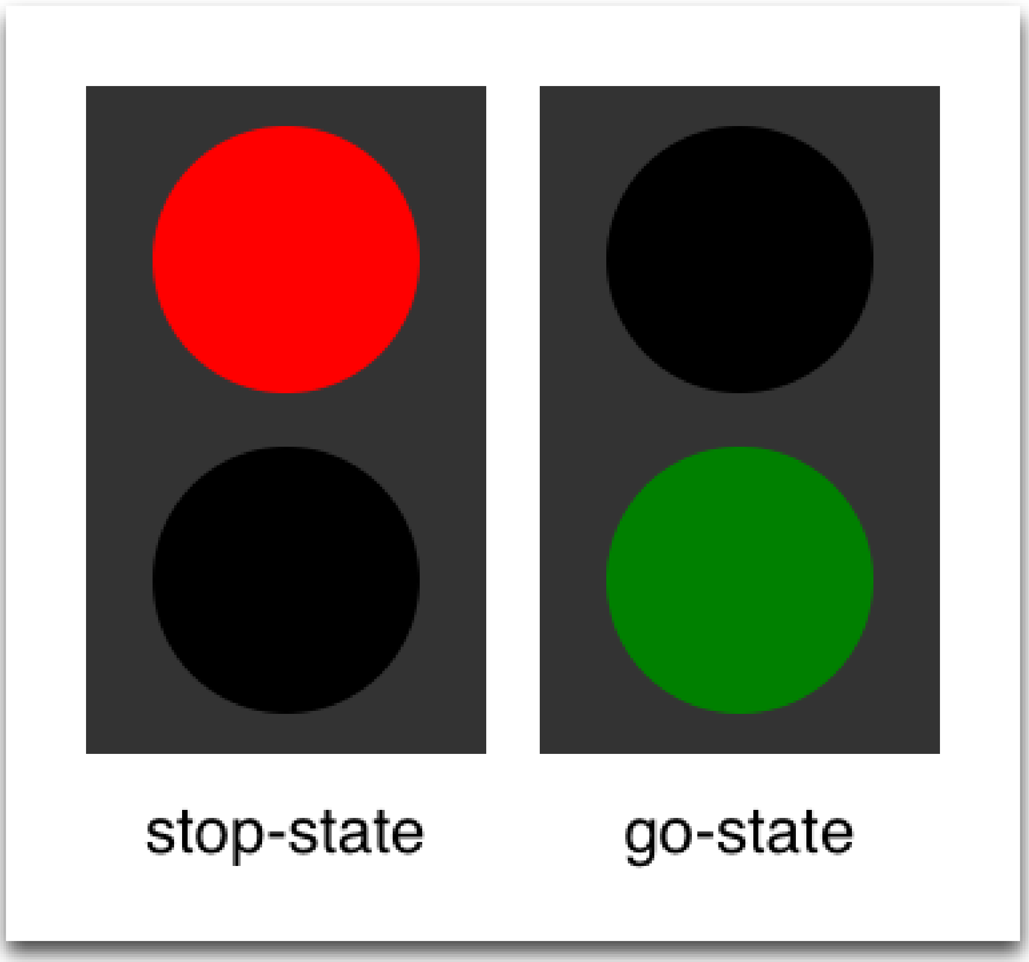
```
    state: "stop"

    states: [
        State {
            name: "stop"
            PropertyChanges { target: light1; color: root.red }
            PropertyChanges { target: light2; color: root.black }
        },
        State {
            name: "go"
            PropertyChanges { target: light1; color: root.black }
            PropertyChanges { target: light2; color: root.green }
        }
    ]
```

Using `PropertyChanges { target:  light2; color:  "black" }` is not really required in this examples as the initial color of `light2` is already black. In a state, it's only necessary to describe how the properties shall change from their default state (and not from the previous state).

A state change is triggered using a mouse area which covers the whole traffic light and toggles between the go- and stop-state when clicked.

```
    MouseArea {
        anchors.fill: parent
        onClicked: parent.state = (parent.state == "stop"? "go" : "stop")
    }
```


stop-state
go-state

We are now able to successfully change the state of the traffic lamp. To make the UI more appealing and look natural we should add some transitions with animation effects. A transition can be triggered by a state change.

Note: It's possible to create a similar logic using scripting instead of QML states. Developers can easily fall into the trap of writing more a JavaScript program than a QML program.

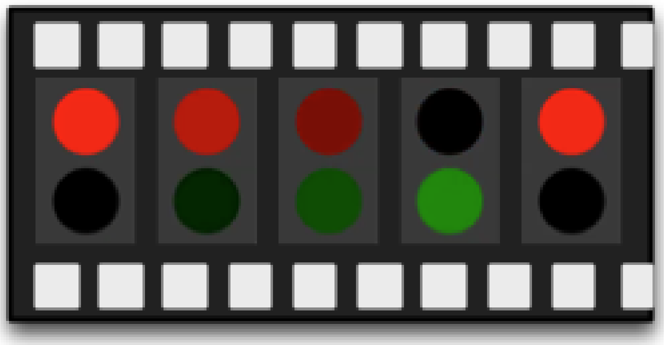
5.2.2 Transitions

A series of transitions can be added to every item. A transition is executed by a state change. You can define on which state change a particular transition can be applied using the `from:` and `to:` properties. These two properties act like a filter when the filter is true the transition will be applied. You can also use the wild-cast "*" which means "any state". For example `from:"*"; to:"*"` means from any state to any other state and is the default value for `from` and `to`, which means the transition is applied to every state switch.

For this example, we would like to animate the color changes when switching state from "go" to "stop". For the other reversed state change ("stop" to "go") we want to keep an immediate color change and don't apply a transition. We restrict the transition with the `from` and `to` properties to filter only the state change from "go" to "stop". Inside the transition, we add two color animations for each light, which shall animate the property changes defined in the state description.

```
    transitions: [
        Transition {
            from: "stop"; to: "go"
//              from: "*"; to: "*"
            ColorAnimation { target: light1; properties: "color"; duration: 2000 }
            ColorAnimation { target: light2; properties: "color"; duration: 2000 }
        }
    ]
```

You can change the state though clicking the UI. The state is applied immediately and will also change the state while a transition is running. So try to click the UI while the state is in the transition from "stop" to "go". You will see the change will happen immediately.



You could play around with this UI by, for example, scaling the inactive light down to highlight the active light. For this, you would need to add another property change for scaling to the states and also handle the animation for the scaling property in the transition. Another option would be to add an "attention" state where the lights are blinking yellow. For this, you would need to add a sequential animation to the transition for one second going to yellow ("to" property of the animation and one sec going to "black"). Maybe you would also want to change the easing curve to make it more visually appealing.

5.3 Advanced Techniques

Todo: To be written

CHAPTER

SIX

QT QUICK CONTROLS 2

Section author: e8johan

Note: Last Build: December 07, 2020 at 10:50 CET

The source code for this chapter can be found in the assets folder.

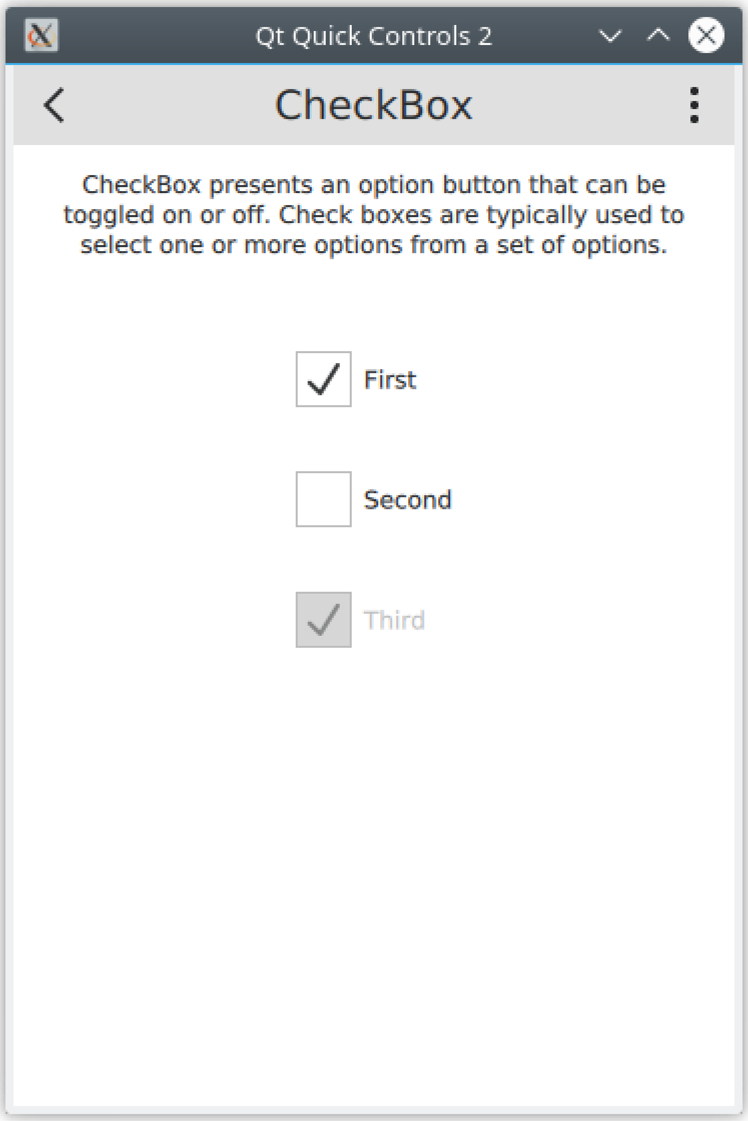
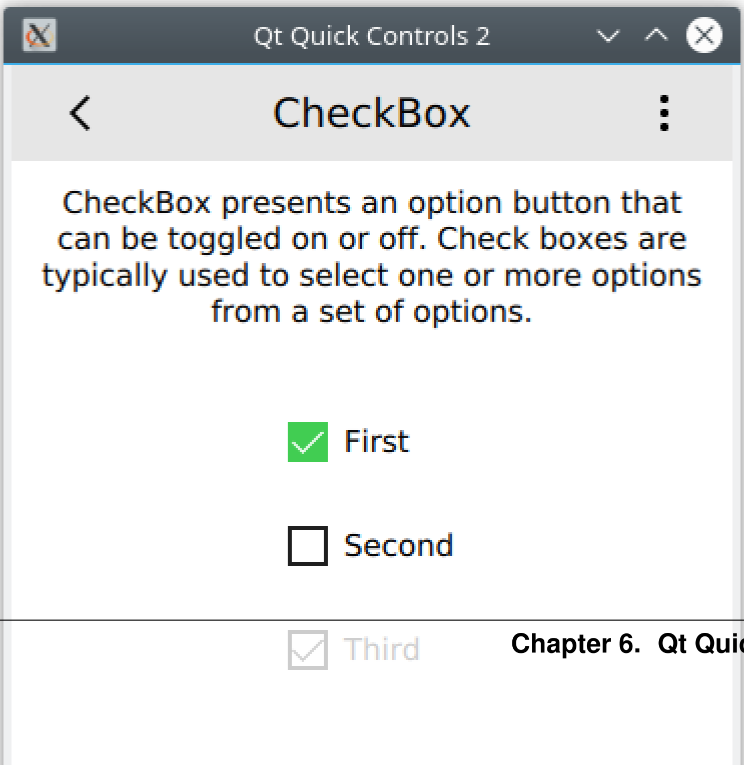
This chapter introduces how to use Qt Quick Controls 2 to create a user interface built from standard components such as buttons, labels, sliders and so on. We will look at how various styles can be used to move user interfaces between platforms before diving into custom styling.

6.1 Introduction to Controls

Using Qt Quick from scratch gives you primited graphical and interaction elements from which you can build your user interfaces. Using Qt Quick Controls 2 you start from a slightly more structured set of controls to build from. The controls range from simple text labels and buttons to more complex ones such as sliders and dials. These element are handy if you want to create a user interface based on classic interaction patterns as they provide a foundation to stand on.

The Qt Quick Controls 2 comes with a number of styles out of the box that are shown in the table below. The *Default* style is a basic flat style. The *Universal* style is based on the Microsoft Universal Design Guidelines, while *Material* is based on Google's Material Design Guidelines, and the *Fusion* style is a desktop oriented style.

Some of the styles can be tweaked by tweaking the used palette. The *Imagine* is a style based on image assets, this allows a graphical designer to create a new style without writing any code at all, not even for palette colour codes.

Style	Example
Default	 CheckBox presents an option button that can be toggled on or off. Check boxes are typically used to select one or more options from a set of options.
	 CheckBox presents an option button that can be toggled on or off. Check boxes are typically used to select one or more options from a set of options.

The Qt Quick Controls 2 is available from the `QtQuick.Controls` import module. In this module you will find the basic controls such as buttons, labels, checkboxes, sliders and so on. In addition to these controls, the following modules are also of interest:

Module	Description
`QtQuick.Controls`	The basic controls.
`QtQuick.Templates`	Provides the non-visual part of the controls.
`QtQuick.Dialogs`	Provides standard dialogs for showing messages, picking files, picking colours, and picking fonts, as well as the base for custom dialogs.
`QtQuick.Controls.Universal`	Universal style theming support.
`QtQuick.Controls.Material`	Material style theming support.
`Qt.labs.calendar`	Controls for supporting date picking and other calendar related interactions.
`Qt.labs.platform`	Support for platform native dialogs for common tasks such as picking files, colours, etc, as well as system tray icons and standard paths.

Notice that the `Qt.labs` modules are experimental, meaning that their APIs can have breaking changes between Qt versions.

Note: The `QtQuick.Dialogs` module is a Qt Quick Controls 1 module, but it is also the only way to do dialogs without depending on the `QtWidgets` module. See below for more details.

6.2 An Image Viewer

Let's look at a larger example of how Qt Quick Controls 2 is used. For this, we will create a simple image viewer.

First, we create it for desktop using the Fusion style, then we will refactor it for a mobile experience before having a look at the final code base.

6.2.1 The Desktop Version

The desktop version is based around a classic application window with a menu bar, a tool bar and a document area. The application can be seen in action below.

We use the Qt Creator project template for an empty Qt Quick application as a starting point. However, we replace the default `Window` element from the template with a `ApplicationWindow` from the `QtQuick.Controls` module. The code below shows `main.qml` where the window itself is created and setup with a default size and title.

```
import QtQuick 2.0
import QtQuick.Controls 2.4
import QtQuick.Dialogs 1.2

ApplicationWindow {
    visible: true
    width: 640
    height: 480

    // ...
```

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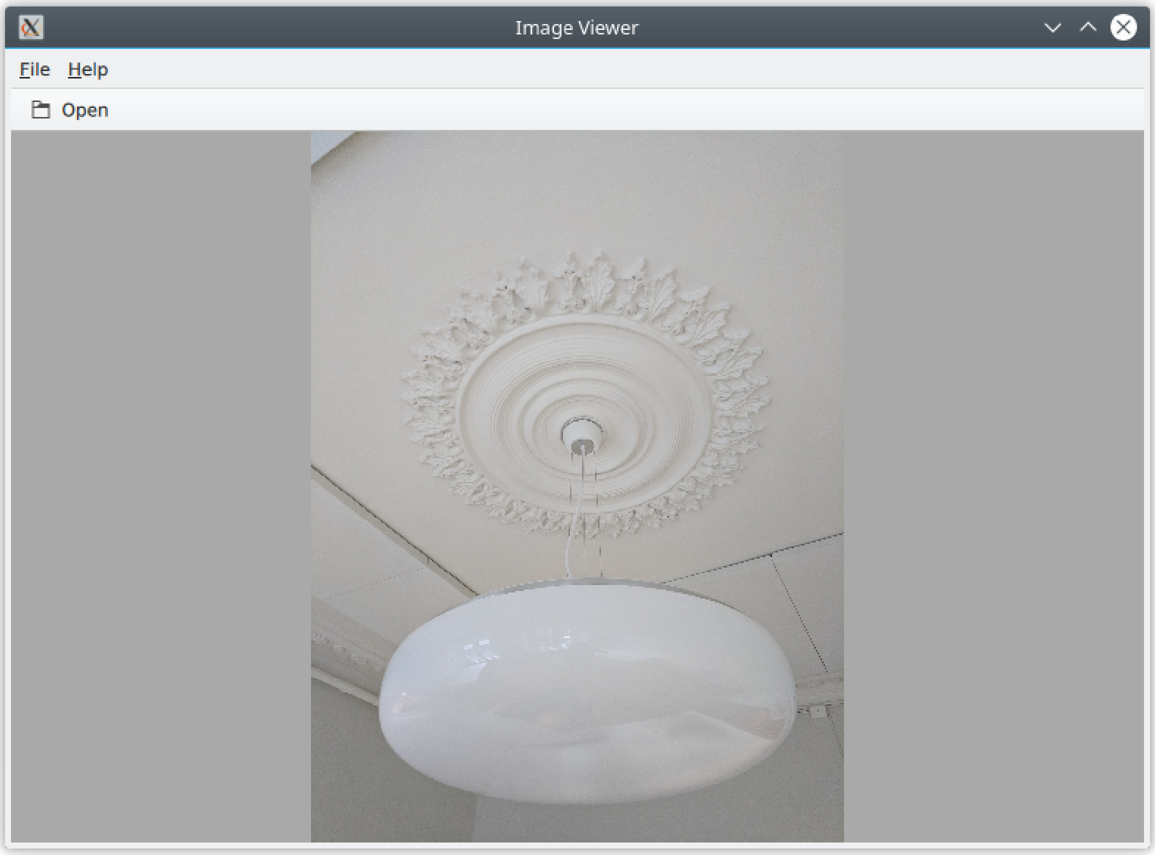

Fig. 1: The image viewer main window.

(continued from previous page)

```
}
```

The ApplicationWindow consists of four main areas as shown below. The menu bar, tool bar and status bar are usually populated by instances of MenuBar, ToolBar or TabBar controls, while the contents area is where the children of the window goes. Notice that the image viewer application does not feature a status bar, that is why it is missing from the code show here, as well as from the figure above.

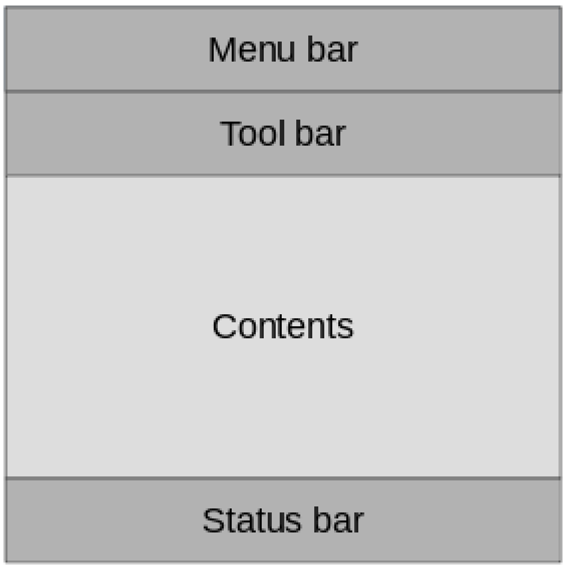

Fig. 2: The main areas of the ApplicationWindow

As we are targetting desktop, we enforce the use of the *Fusion* style. This can be done via environment variables, command line arguments, or programmatically in the C++ code. We do it the latter way by adding the following line to the main.cpp:

```
QQuickStyle::setStyle("Fusion");
```

We then start building the user interface in main.qml by adding an Image element as the contents. This element will hold the images when the user opens them, so for now it is just a place holder. The background property is used to provide an element to the window to place behind the contents. This will be shown when there is no image loaded, and as borders around the image if the aspect ratio down not let it fill the contents area of the window.

```
ApplicationWindow {

    // ...

    background: Rectangle {
        color: "darkGray"
    }

    Image {
        id: image
        anchors.fill: parent
        fillMode: Image.PreserveAspectFit
        asynchronous: true
    }

    // ...

}
```

We then continue by adding the `ToolBar`. This is done using the `toolBar` property of the window. Inside the tool bar we add a `Flow` element which will let the contents fill the width of the control before overflowing to a new row. Inside the flow we place a `ToolButton`.

The `ToolButton` has a couple of interesting properties. The `text` is straight forward. However, the `icon.name` is taken from the freedesktop.org Icon Naming Specification. In that document, a list of standard icons are listed by name. By refering to such a name, Qt will pick out the correct icon from the current desktop theme.

In the `onClicked` signal handler of the `ToolButton` is the final piece of code. It calls the `open` method on the `fileOpenDialog` element.

```
ApplicationWindow {

    // ...

    header: ToolBar {
        Flow {
            anchors.fill: parent
            ToolButton {
                text: qsTr("Open")
                icon.name: "document-open"
                onClicked: fileOpenDialog.open()
            }
        }
    }

    // ...

}
```

The `fileOpenDialog` element is a `FileDialog` control from the `QtQuick.Dialogs` module. The file dialog can be used to open or save files, as well as picking directories.

Note: The `QtQuick.Dialogs` module is a Qt Quick Controls 1 module, but it is also the only way to do dialogs without depending on the `QtWidgets` module. See how to implement native dialogs using `Qt.labs.platform` further down.

In the code we start by assigning a `title`. Then we set the starting folder using the `shortcut` property. The `shortcut` property holds links to common folders such as the user's home, documents, and such. After that we set a name filter that controls what files the user can see and pick using the dialog.

Finally, we reach the `onAccepted` signal handler where the `Image` element that holds the window contents is set to show the the selected file. There is an `onRejected` signal as well, but we do not need to handle it in the image viewer application.

```
ApplicationWindow {

    // ...

    FileDialog {
        id: fileOpenDialog
        title: "Select an image file"
        folder: shortcuts.documents
        nameFilters: [
            "Image files (*.png *.jpeg *.jpg)",
        ]
        onAccepted: {
            image.source = fileOpenDialog.fileUrl
        }
    }

```

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```
    // ...

}
```

We then continue with the `MenuBar`. To create a menu, one puts `Menu` elements inside the menu bar, and then populate each `Menu` with `MenuItem` elements.

In the code below, we create two menus, *File* and *Help*. Under *File*, we place *Open* using the same icon and action as the tool button in the tool bar. Under *Help* you find *About* which triggers a call to the `open` method of the `aboutDialog` element.

Notice that the ampersands ("&") in the `title` property of the `Menu` and the `text` property of the `MenuItem` turns the following character into a keyboard shortcut, e.g. you reach the file menu by pressing *Alt+F*, followed by *Alt+O* to trigger the open item.

```
ApplicationWindow {

    // ...

    menuBar: MenuBar {
        Menu {
            title: qsTr("&File")
            MenuItem {
                text: qsTr("&Open...")
                icon.name: "document-open"
                onTriggered: fileOpenDialog.open()
            }
        }

        Menu {
            title: qsTr("&Help")
            MenuItem {
                text: qsTr("&About...")
                onTriggered: aboutDialog.open()
            }
        }
    }

    // ...

}
```

The `aboutDialog` element is based on the `Dialog` control from the `QtQuick.Controls` module, which is the base for custom dialogs. The dialog we are about to create is shown in the figure below.

The code for the `aboutDialog` can be split into three parts. First, we setup the dialog window with a title. Then we provide some contents for the dialog – in this case, a `Label` control. Finally, we opt to use a standard *Ok* button to close the dialog.

```
ApplicationWindow {

    // ...

    Dialog {
        id: aboutDialog
        title: qsTr("About")
        Label {
            anchors.fill: parent
            text: qsTr("QML Image Viewer\nA part of the QmlBook\nhttp://qmlbook.org
↪")
            horizontalAlignment: Text.AlignHCenter
```

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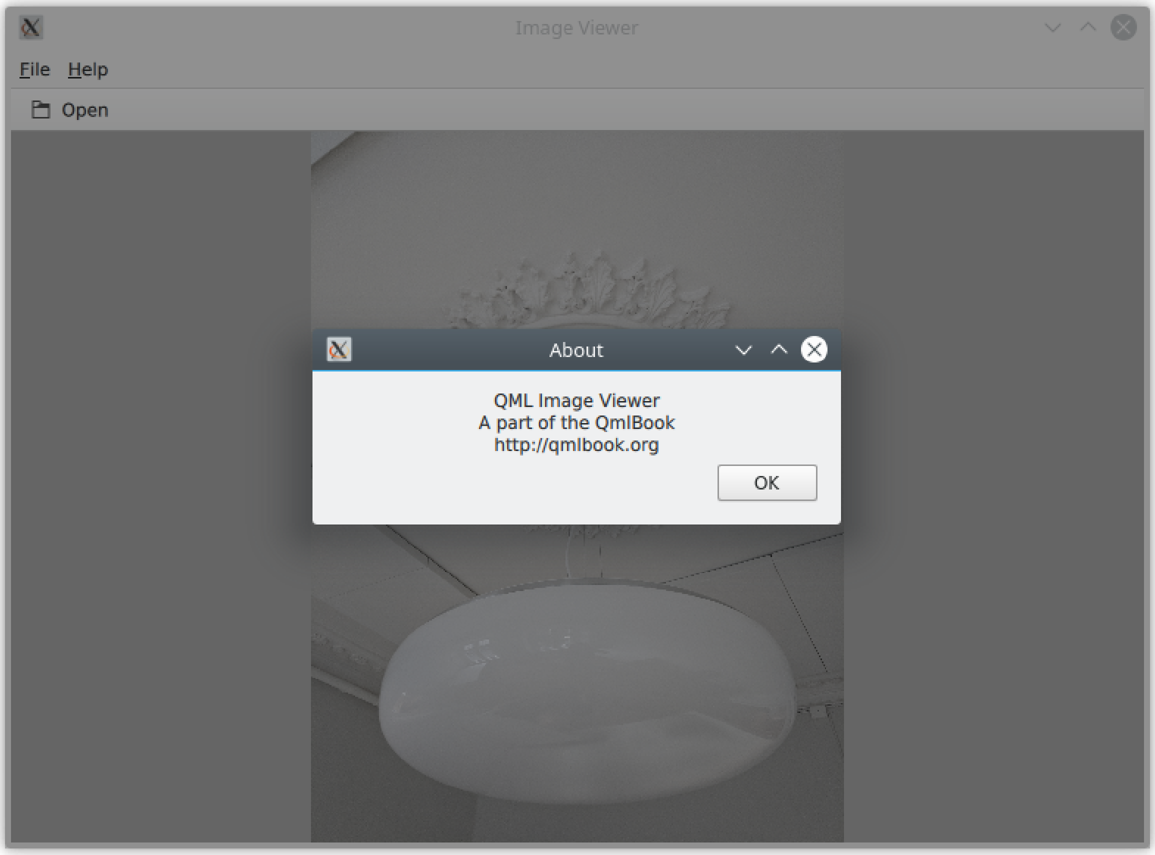

QML Image Viewer
A part of the QmlBook
http://qmlbook.org

Fig. 3: The about dialog.

(continued from previous page)

```
        }

        standardButtons: StandardButton.Ok
    }

    // ...

}
```

The end result of all this is an, albeit simple, desktop application for viewing images.

6.2.2 Moving to Mobile

There are a number of differences in how a user interface is expected to look an behave on a mobile device compared to a desktop application. The biggest difference for our application is how the actions are accessed. Instead of a menu bar and a tool bar, we will use a drawer from which the user can pick the actions. The drawer can swiped in from the side, but we also offer a hamburger button in the header. The resulting application with the drawer open can be seen below.

First of all, we need to change the style that is set in `main.cpp` from *Fusion* to *Material*:

```
QQuickStyle::setStyle("Material");
```

Then we start adapting the user interface. We start by replacing the menu with a drawer. In the code below, the `Drawer` component is added as a child to the `ApplicationWindow`. Inside the drawer, we put a `ListView` containing `ItemDelegate` instances. It also contains a `ScrollIndicator` used to show what part of a long list that is shown. As our list only consists of two items, this is not visible in this example.

The drawer `ListView` is populated from a `ListModel` where each `ListItem` corresponds to a menu item. Each time an item is clicked, in the `onClicked` method, the `triggered` method of the corresponding `ListItem` is called. This way, we can use a single delegate to trigger different actions.

```
ApplicationWindow {

    // ...

    id: window

    Drawer {
        id: drawer

        width: Math.min(window.width, window.height) / 3 * 2
        height: window.height

        ListView {
            focus: true
            currentIndex: -1
            anchors.fill: parent

            delegate: ItemDelegate {
                width: parent.width
                text: model.text
                highlighted: ListView.isCurrentItem
                onClicked: {
                    drawer.close()
                    model.triggered()
                }
            }

            model: ListModel {
```

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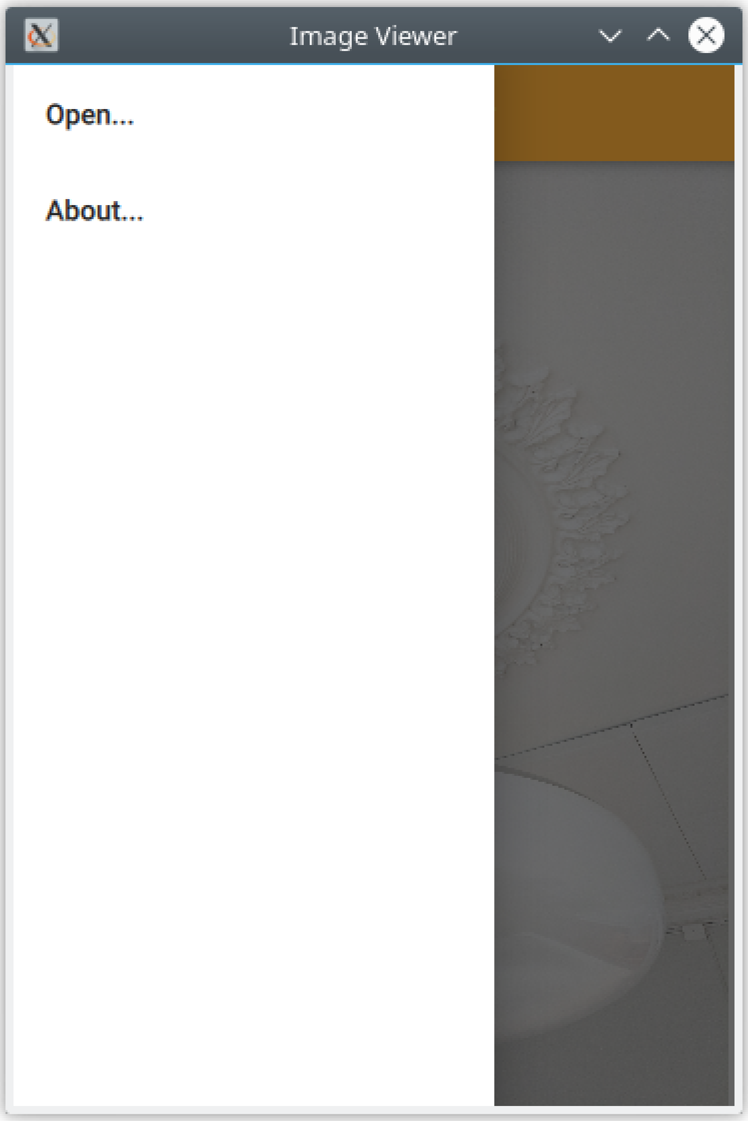

Fig. 4: The image viewer with a drawer menu.

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```
                ListElement {
                    text: qsTr("Open...")
                    triggered: function(){ fileOpenDialog.open(); }
                }
                ListElement {
                    text: qsTr("About...")
                    triggered: function(){ aboutDialog.open(); }
                }
            }

            ScrollIndicator.vertical: ScrollIndicator { }
        }
    }

    // ...

}
```

The next change is the `header` in the `ApplicationWindow`. Instead of a desktop style toolbar, we add a button to open the drawer and the title of our application.

The `ToolBar` contains a two child child elements: a `ToolButton` and a `Label`.

The `ToolButton` control opens the drawer. The corresponding close call can be found in the `ListView` delegate. When an item has been selected the drawer is closed. The icon used for the `ToolButton` comes from the Material Design Icons page.

```
ApplicationWindow {

    // ...

    header: ToolBar {
        ToolButton {
            id: menuButton
            anchors.left: parent.left
            anchors.verticalCenter: parent.verticalCenter
            icon.source: "images/baseline-menu-24px.svg"
            onClicked: drawer.open()
        }
        Label {
            anchors.centerIn: parent
            text: "Image Viewer"
            font.pixelSize: 20
            elide: Label.ElideRight
        }
    }

    // ...

}
```

Finally we make the background of the toolbar pretty — or at least orange. To do this, we alter the `Material.background` attached property. This comes from the `QtQuick.Controls.Material 2.1` module and only affects the Material style.

```
import QtQuick.Controls.Material 2.1

ApplicationWindow {

    // ...

```

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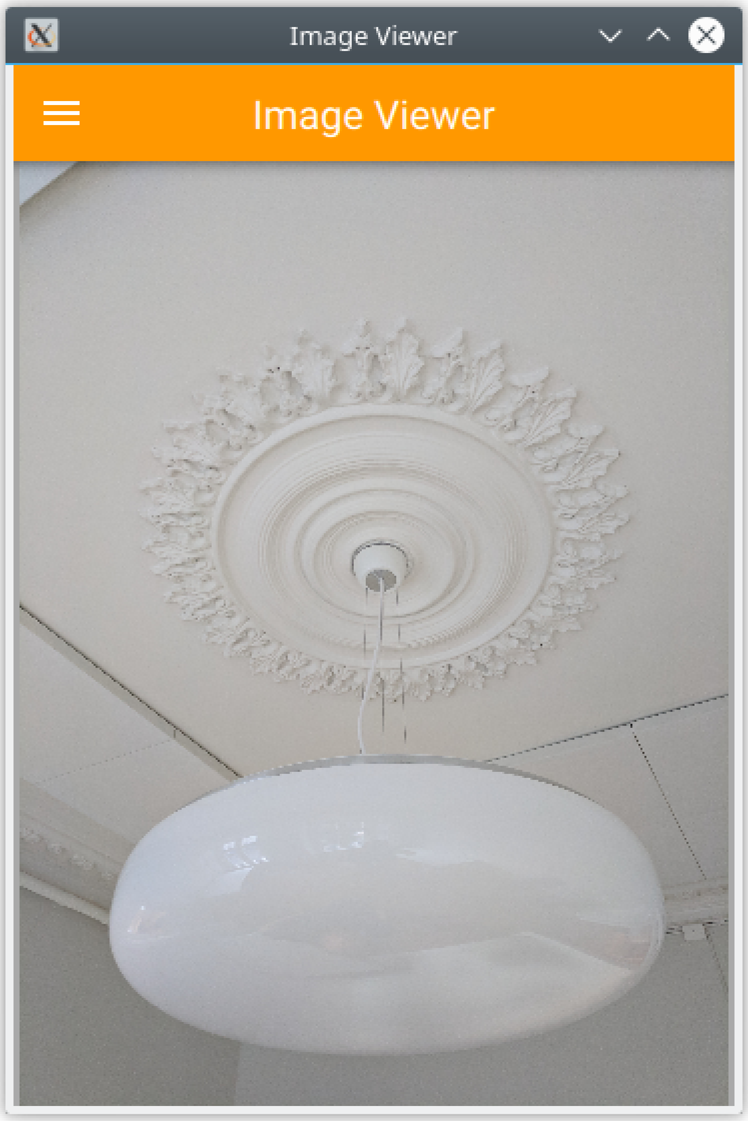

Fig. 5: The image viewer with the mobile header.

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```
    header: ToolBar {
        Material.background: Material.Orange

    // ...

}
```

With these few changes we have converted our desktop image viewer to a mobile friendly version.

6.2.3 A Shared Codebase

In the past two sections we have looked at an image viewer developed for desktop use and then adapted it to mobile.

Looking at the code base, much of the code is still shared. The parts that are shared are mostly associated with the document of the application, i.e. the image. The changes has affected individual interaction patterns of desktop and mobile respectively. Naturally, we would want to unify these code bases. QML supports this through the use of *file selectors*.

A file selector lets us replace individual files based on which selectors are active. The Qt documentation maintains a list of selectors in the documentation for the `QFileSelector` class (link). In our case we will make the desktop version the default and replace selected files when the *android* selector is encountered. During the development you can set the environment variable `QT_FILE_SELECTORS` to `android` to simulate this.

Note: The file selector works by replacing files with an alternative when a *selector* is present.

By creating a directory named `+selector`, where `selector` represents the name of a selector, in parallel to the files that you want to replace, you can then place files with the same name as the file you want to replace inside the directory. When the selector is present, the file in the directory will be picked instead of the original file.

The selectors are based on the platform, e.g. android, ios, osx, linux, qnx, and so on. They can also include the name of the Linux distribution used (if identified), e.g. debian, ubuntu, fedora. Finally, they also include the locale, e.g. en_US, sv_SE, etc.

It is also possible to add your own, custom, selectors.

The first step to do this change is to isolate the shared code. We do this by creating the `ImageViewerWindow` element which will be used instead of the `ApplicationWindow` for both our variants. This will consist of the dialogs, the `Image` element and the background. In order to make the open methods of the dialogs available to the platform specific code, we need to expose them through the functions `openFileDialog` and `openAboutDialog`.

```
import QtQuick 2.0
import QtQuick.Controls 2.4
import QtQuick.Dialogs 1.2

ApplicationWindow {
    function openFileDialog() { fileOpenDialog.open(); }
    function openAboutDialog() { aboutDialog.open(); }

    visible: true
    title: qsTr("Image Viewer")

    background: Rectangle {
        color: "darkGray"
    }

    Image {
        id: image
```

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```
        anchors.fill: parent
        fillMode: Image.PreserveAspectFit
        asynchronous: true
    }

    FileDialog {
        id: fileOpenDialog

        // ...

    }

    Dialog {
        id: aboutDialog

        // ...

    }
}
```

Next, we create a new `main.qml` for our default style *Fusion*, i.e. the desktop version of the user interface.

Here, we base the user interface around the `ImageViewerWindow` instead of the `ApplicationWindow`. Then we add the platform specific parts to it, e.g. the `MenuBar` and `ToolBar`. The only changes to these is that the calls to open the respective dialogs are made to the new functions instead of directly to the dialog controls.

```
import QtQuick 2.0
import QtQuick.Controls 2.4

ImageViewerWindow {
    id: window

    width: 640
    height: 480

    menuBar: MenuBar {
        Menu {
            title: qsTr("&File")
            MenuItem {
                text: qsTr("&Open...")
                icon.name: "document-open"
                onTriggered: window.openFileDialog()
            }
        }

        Menu {
            title: qsTr("&Help")
            MenuItem {
                text: qsTr("&About...")
                onTriggered: window.openAboutDialog()
            }
        }
    }

    header: ToolBar {
        Flow {
            anchors.fill: parent
            ToolButton {
                text: qsTr("Open")
                icon.name: "document-open"
                onClicked: window.openFileDialog()
```

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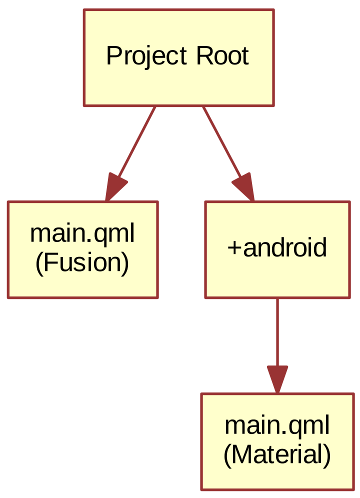
```
                }
            }
        }
}
```

Next, we have to create a mobile specific `main.qml`. This will be based around the *Material* theme. Here, we keep the `Drawer` and the mobile specific toolbar. Again, the only change is how the dialogs are opened.

```
import QtQuick 2.0
import QtQuick.Controls 2.4
import QtQuick.Controls.Material 2.1

ImageViewerWindow {
    id: window

    width: 360
    height: 520

    Drawer {
        id: drawer

        // ...

        ListView {

            // ...

            model: ListModel {
                ListElement {
                    text: qsTr("Open...")
                    triggered: function(){ window.openFileDialog(); }
                }
                ListElement {
                    text: qsTr("About...")
                    triggered: function(){ window.openAboutDialog(); }
                }
            }

            // ...

        }
    }

    header: ToolBar {

        // ...

    }
}
```

The two `main.qml` files are placed in the file system as shown below. This lets the file selector that the QML engine automatically creates pick the right file. By default, the *Fusion* `main.qml` is loaded, unless the `android` selector is present. Then the *Material* `main.qml` is loaded instead.



Until now the style has been set in in `main.cpp`. We could continue doing this and use `#ifdef` expressions to set different styles for different platform. Instead we will use the file selector mechanism again and set the style using a configuration file. Below, you can see the file for the *Material* style, but the *Fusion* file is equally simple.

```
[Controls]
Style=Material
```

These changes has given us a joined codebase where all the document code is shared and only the differences in user interaction patterns differ. There are different ways to do this, e.g. keeping the document in a specific component that is included in the platform specific interfaces, or as in this example, by creating a common base that is extended by each platform. The best approach is best determined when you know how your specific code base looks and can decide how to separate the common from the unique.

6.2.4 Native Dialogs

When using the image viewer you will notice that it uses a non-standard file selector dialog. This makes it look out of place.

The `Qt.labs.platform` module can help us solve this. It provides QML bindings to native dialogs such as the file selector, font selector and colour selector. It also provides APIs to create system tray icons, as well as system global menus that sits on top of the screen (e.g. as in OS X). The cost of this is a dependency on the `QtWidgets` module, as the widget based dialog is used as a fallback where the native support is missing.

In order to integrate a native file dialog into the image viewer, we need to import the `Qt.labs.platform` module. As this module has name clashes with the module it replaces, `QtQuick.Dialogs`, it is important to remove the old import statement.

In the actual file dialog element, we have to change how the `folder` property is set, and ensure that the `onAccepted` handler uses the `file` property instead of the `fileUrl` property. Apart from these details, the usage is identical to the `FileDialog` from `QtQuick.Dialogs`.

```
import QtQuick 2.0
import QtQuick.Controls 2.4
import Qt.labs.platform 1.0

ApplicationWindow {

```

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```
    // ...

    FileDialog {
        id: fileOpenDialog
        title: "Select an image file"
        folder: StandardPaths.writableLocation(StandardPaths.DocumentsLocation)
        nameFilters: [
            "Image files (*.png *.jpeg *.jpg)",
        ]
        onAccepted: {
            image.source = fileOpenDialog.file
        }
    }

    // ...

}
```

In addition to the QML changes, we also need to alter the project file of the image viewer to include the `widgets` module.

```
QT += quick quickcontrols2 widgets
```

And we need to update `main.qml` to instantiate a `QApplication` object instead of a `QGuiApplication` object. This is because the `QGuiApplication` class contains the minimal environment needed for a graphical application, while `QApplication` extends `QGuiApplication` with features needed to support `QtWidgets`.

```
#include <QApplication>

// ...

int main(int argc, char *argv[])
{
    QApplication app(argc, argv);

    // ...

}
```

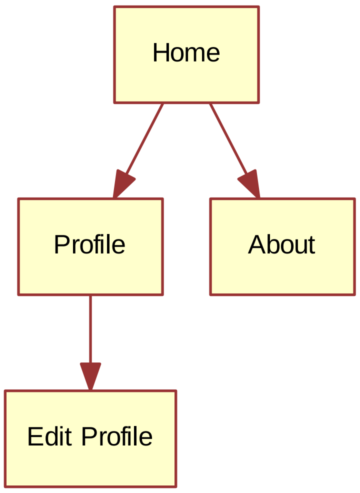
With these changes, the image viewer will now use native dialogs on most platforms. The platforms supported are iOS, Linux (with a GTK+ platform theme), macOS, Windows and WinRT. For Android, it will use a default Qt dialog provided by the `QtWidgets` module.

6.3 Common Patterns

There a number of common user interface patterns that can be implemented using Qt Quick Controls 2. In this section, we try to demonstrate how some of the more common ones can be built.

6.3.1 Nested Screens

For this example we will create a tree of pages that can be reached from the previous level of screens. The structure is pictured below.



The key component in this type of user interface is the `StackView`. It allows us to place pages on a stack which then can be poped when the user wants to go back. In the example here, we will show how this can be implemented.

The initial home screen of the application is shown in the figure below.

The application start in `main.qml` where we have an `ApplicationWindow` containing a `ToolBar`, a `Drawer`, a `StackView` and a home page element, `Home`. We will look into each of the components below.

```
import QtQuick 2.9
import QtQuick.Controls 2.2

ApplicationWindow {

    // ...

    header: ToolBar {

        // ...

    }

    Drawer {

        // ...

    }

    StackView {
        id: stackView
        anchors.fill: parent
        initialItem: Home {}
    }
}
```

The home page, `Home.qml` consists of a `Page`, which is an control element that support headers and footers. In this example we simply center a `Label` with the text *Home Screen* on the page. This works because the contents of a `StackView` automatically fills the stack view, so the page has the right size for this to work.

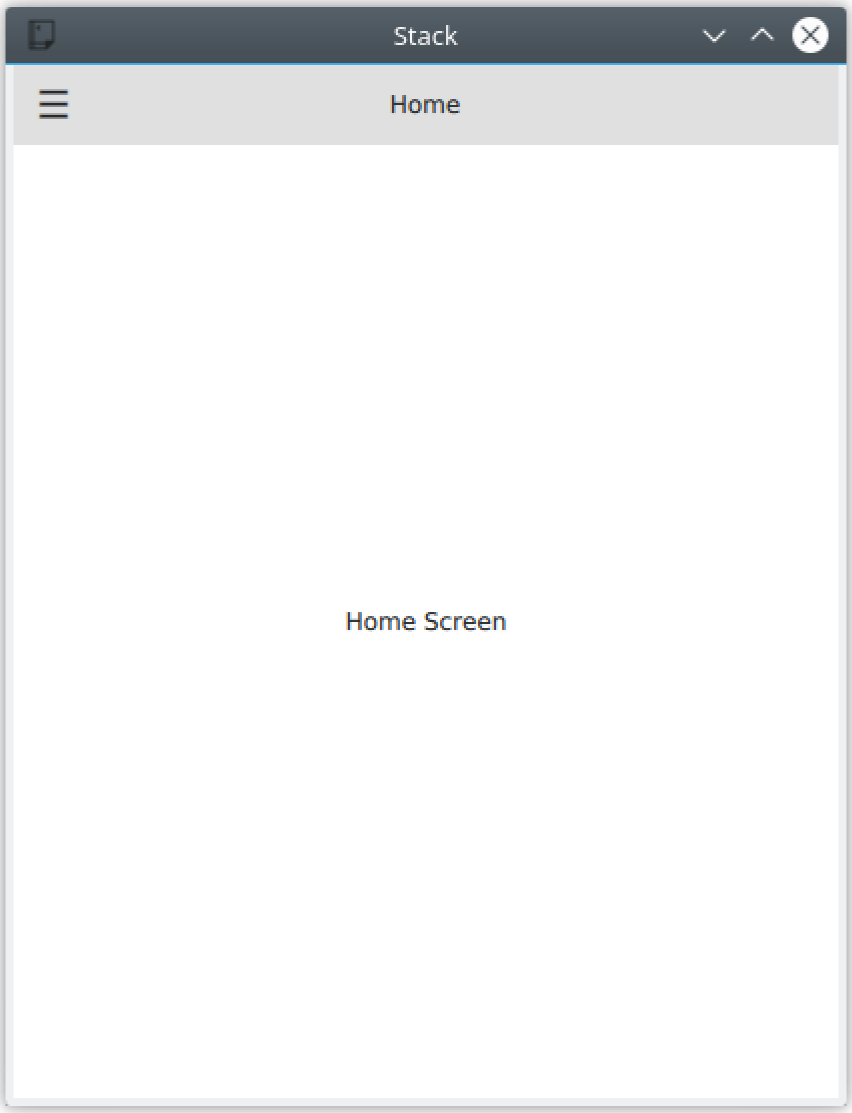


Fig. 6: The home screen page.

```
import QtQuick 2.9
import QtQuick.Controls 2.2

Page {
    title: qsTr("Home")

    Label {
        anchors.centerIn: parent
        text: qsTr("Home Screen")
    }
}
```

Returning back to the `main.qml`, we now look at the drawer part. This is where the navigation to the pages begin. The active parts of the user interface is the `ÌtemDelegate` items. In the `onClicked` handler, the next page is pushed onto the `stackView`.

As shown in the code below, it possible to push either a `Component` or a reference to a specific QML file. Either way results in that a new instance is created and is pushed onto the stack.

```
ApplicationWindow {

    // ...

    Drawer {
        id: drawer
        width: window.width * 0.66
        height: window.height

        Column {
            anchors.fill: parent

            ItemDelegate {
                text: qsTr("Profile")
                width: parent.width
                onClicked: {
                    stackView.push("Profile.qml")
                    drawer.close()
                }
            }
            ItemDelegate {
                text: qsTr("About")
                width: parent.width
                onClicked: {
                    stackView.push(aboutPage)
                    drawer.close()
                }
            }
        }
    }

    // ...

    Component {
        id: aboutPage

        About {}
    }

    // ...

}
```

The other half of the puzzle is the toolbar. The idea is that a back button is shown when the `stackView` contains more than one page, otherwise a menu button is shown. The logic for this can be seen on the `text` property where the `"\u..."` strings represents the unicode symbols that we need.

In the `onClicked` handler, we can see that when there is more than one page on the stack, the stack is poped, i.e. the top page is removed. If the stack contains only one item, i.e. the home screen, the drawer is opened.

Below the `ToolBar`, you find a `Label`. This element shows the title of each page in the center of the header.

```
ApplicationWindow {

    // ...

    header: ToolBar {
        contentHeight: toolButton.implicitHeight

        ToolButton {
            id: toolButton
            text: stackView.depth > 1 ? "\u25C0" : "\u2630"
            font.pixelSize: Qt.application.font.pixelSize * 1.6
            onClicked: {
                if (stackView.depth > 1) {
                    stackView.pop()
                } else {
                    drawer.open()
                }
            }
        }

        Label {
            text: stackView.currentItem.title
            anchors.centerIn: parent
        }
    }

    // ...

}
```

Now we've seen how to reach the *About* and *Profile* pages, but we also want to make it possible to reach the *Edit Profile* page from the *Profile* page. This is done via the `Button` on the *Profile* page. When the button is clicked, the `EditProfile.qml` file is pushed onto the `StackView`.

```
import QtQuick 2.9
import QtQuick.Controls 2.2

Page {
    title: qsTr("Profile")

    Column {
        anchors.centerIn: parent
        spacing: 10
        Label {
            anchors.horizontalCenter: parent.horizontalCenter
            text: qsTr("Profile")
        }
        Button {
            anchors.horizontalCenter: parent.horizontalCenter
            text: qsTr("Edit");
            onClicked: stackView.push("EditProfile.qml")
        }
    }
}
```

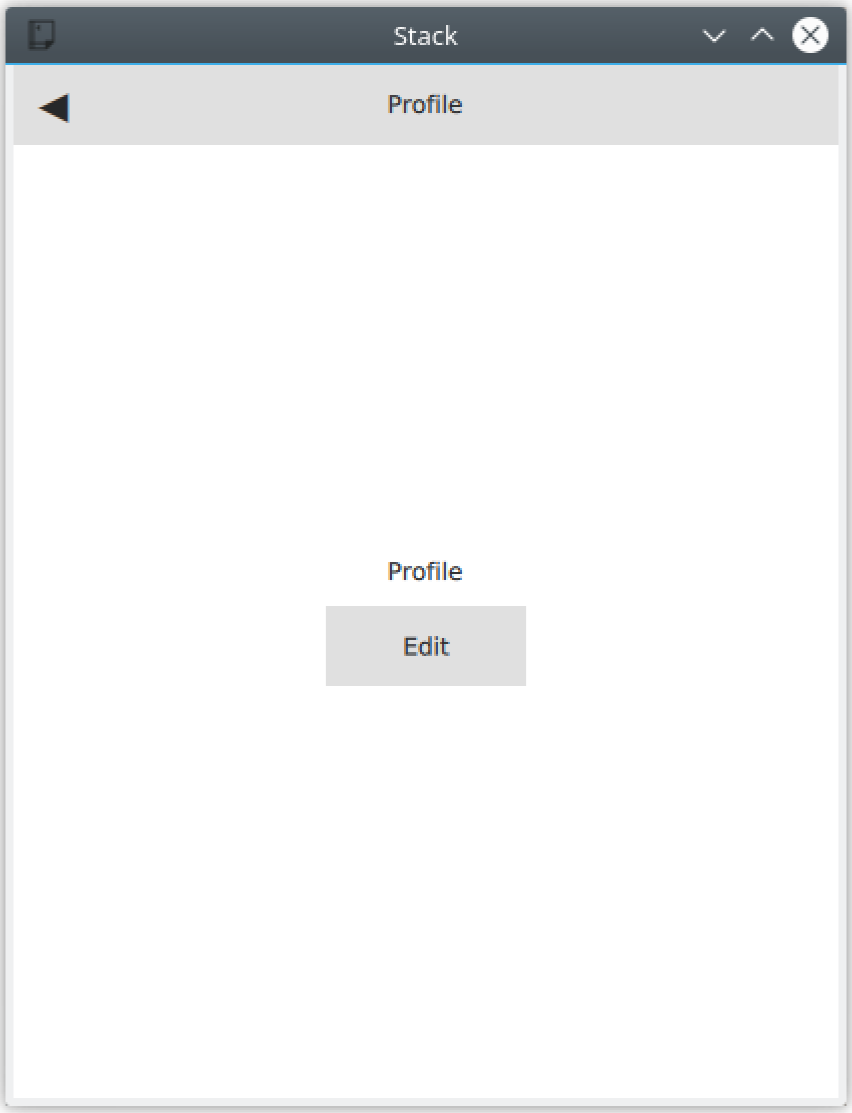
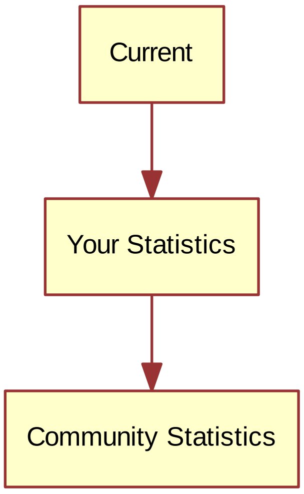


Fig. 7: The profile page with the *Edit* button.

6.3.2 Side by Side Screens

For this example we create a user interface consisting of three pages that the user can shift through. The pages are shown in the diagram below. This could be the interface of a health tracking app, tracking the current state, the user's statistics and the overall statistics.



The illustration below shows how the *Current* page looks in the application. The main part of the screen is managed by a `SwipeView`, which is what enables the side by side screens interaction pattern. The title and text shown in the figure come from the page inside the `SwipeView`, while the `PageIndicator` (the three dots at the bottom) come from `main.qml` and sit under the `SwipeView`. The page indicator shows the user which page that is currently active, helping when navigating.

Diving into `main.qml`, it consists of an `ApplicationWindow` with the `SwipeView`.

```
import QtQuick 2.9
import QtQuick.Controls 2.2

ApplicationWindow {
    visible: true
    width: 640
    height: 480

    title: qsTr("Side-by-side")

    SwipeView {

        // ...

    }

    // ...

}
```

Inside the `SwipeView` each of the child pages are instantiated in the order they are to appear. They are `Current`, `UserStats` and `TotalStats`.

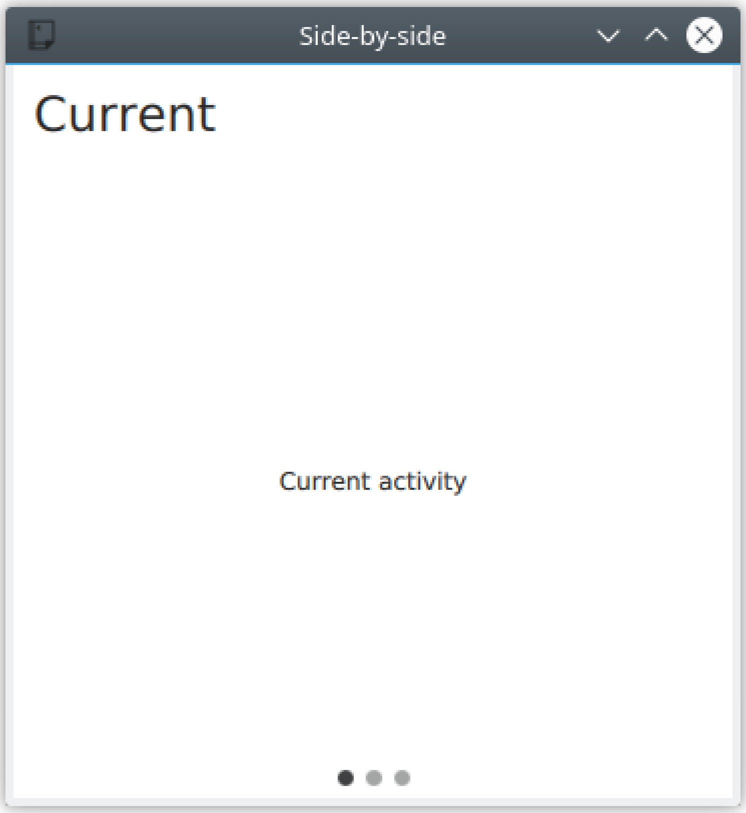


Fig. 8: The *Current* page in the side-by-side app.

```
ApplicationWindow {

    // ...

    SwipeView {
        id: swipeView
        anchors.fill: parent

        Current {
        }

        UserStats {
        }

        TotalStats {
        }
    }

    // ...

}
```

Finally the `count` and `currentIndex` properties of the `SwipeView` are bound to the `PageIndicator` element. This completes the structure around the pages.

```
ApplicationWindow {

    // ...

    SwipeView {
        id: swipeView

        // ...

    }

    PageIndicator {
        anchors.bottom: parent.bottom
        anchors.horizontalCenter: parent.horizontalCenter

        currentIndex: swipeView.currentIndex
        count: swipeView.count
    }
}
```

Each page consists of a `Page` with a `header` consisting of a `Label` and some contents. For the *Current* and *User Stats* pages the contents is a simple `Label`, but for the *Community Stats* page, a back button is included.

```
import QtQuick 2.9
import QtQuick.Controls 2.2

Page {
    header: Label {
        text: qsTr("Community Stats")
        font.pixelSize: Qt.application.font.pixelSize * 2
        padding: 10
    }

    // ...

}
```

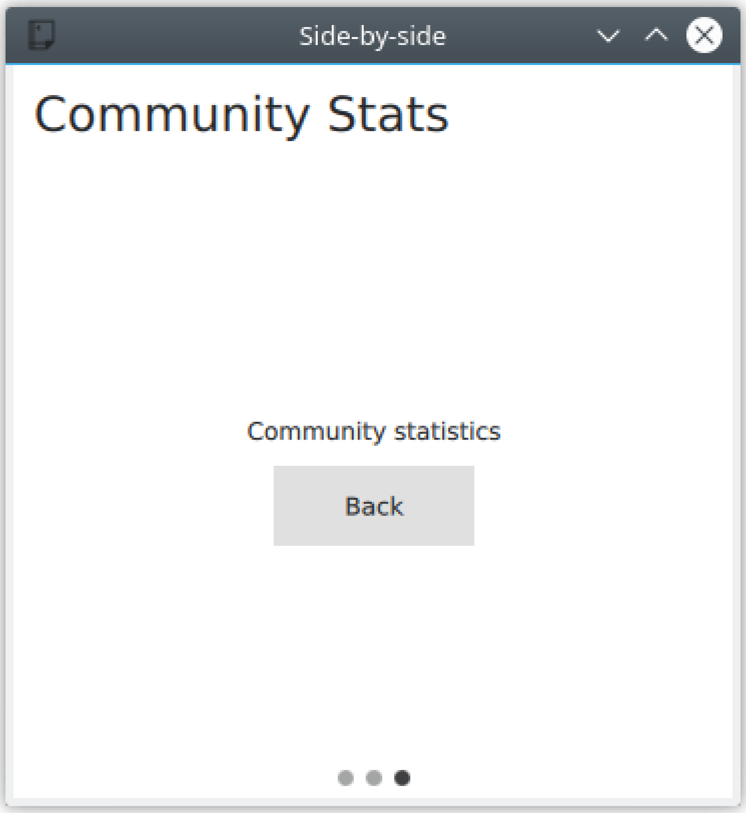


Fig. 9: The *Back* button in the side-by-side app.

The back button explicitly calls the `setCurrentIndex` of the `SwipeView` to set the index to zero, returning the user directly to the *Current* page. During each transition between pages the `SwipeView` provides a transition, so even when explicitly changing the index the user is given a sense of direction.

Note: When navigating in a `SwipeView` programatically it is important not to set the `currentIndex` by assignment in Javascript. This is because doing so will break any QML bindings it overrides. Instead use the methods `setCurrentIndex`, `incrementCurrentIndex`, and `decrementCurrentIndex`. This preserves the QML bindings.

```
Page {

    // ...

    Column {
        anchors.centerIn: parent
        spacing: 10
        Label {
            anchors.horizontalCenter: parent.horizontalCenter
            text: qsTr("Community statistics")
        }
        Button {
            anchors.horizontalCenter: parent.horizontalCenter
            text: qsTr("Back")
            onClicked: swipeView.setCurrentIndex(0);
        }
    }
}
```

6.3.3 Document Windows

This example shows how to implement a desktop oriented, document centric user interface. The idea is to have one window per document. When opening a new document, a new window is opened. To the user, each window is a self contained world with a single document.

The code starts from an `ApplicationWindow` with a *File* menu with the standard operations: *New*, *Open*, *Save* and *Save As*. We put this in the file `DocumentWindow.qml`.

We import the `Qt.labs.platform` for native dialogs and have made the subsequent changes to the project file and `main.cpp` as described in the section on native dialogs above.

```
import QtQuick 2.0
import QtQuick.Controls 2.4
import Qt.labs.platform 1.0 as NativeDialogs

ApplicationWindow {
    id: root

    // ...

    menuBar: MenuBar {
        Menu {
            title: qsTr("&File")
            MenuItem {
                text: qsTr("&New")
                icon.name: "document-new"
                onTriggered: root.newDocument()
            }
            MenuSeparator {}
            MenuItem {
```

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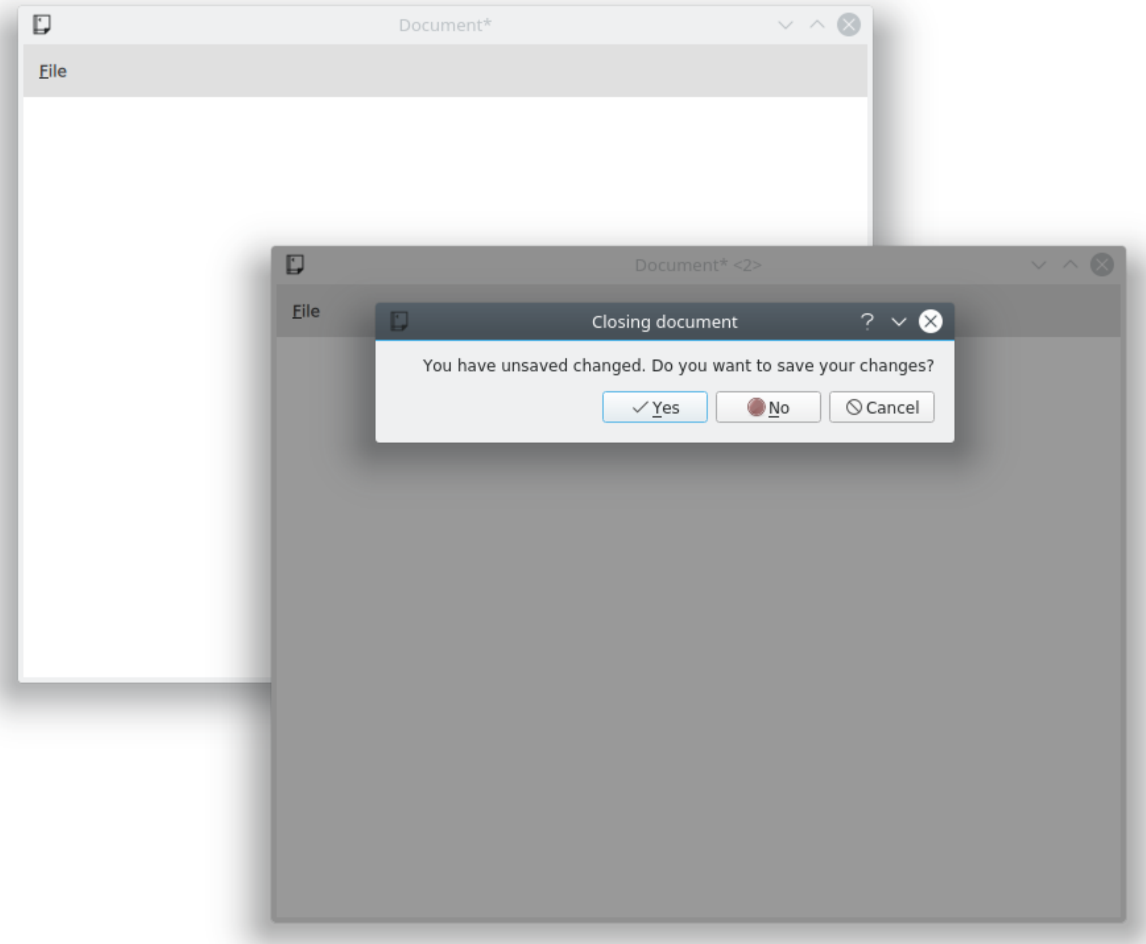

You have unsaved changed. Do you want to save your changes?

Fig. 10: Two document windows and the close warning dialog.

(continued from previous page)

```
                text: qsTr("&Open")
                icon.name: "document-open"
                onTriggered: openDocument()
            }
            MenuItem {
                text: qsTr("&Save")
                icon.name: "document-save"
                onTriggered: saveDocument()
            }
            MenuItem {
                text: qsTr("Save &As...")
                icon.name: "document-save-as"
                onTriggered: saveAsDocument()
            }
        }
    }

    // ...

}
```

To bootstrap the program, we create the first `DocumentWindow` instance from the `main.qml`, which is the entrypoint of the application.

```
import QtQuick 2.0

DocumentWindow {
    visible: true
}
```

In the example at the beginning of this chapter, each `MenuItem` results in a call to a corresponding function when triggered. Let's start with the *New* item, which ends up in the `newDocument` function.

The function, in turn, relies on the `_createNewDocument` function, which dynamically creates a new element instance from the `DocumentWindow.qml` file, i.e. a new `DocumentWindow` instance. The reason for breaking out this part of the new function is that we use it when opening documents as well.

Notice that we do not provide a parent element when creating the new instance using `createObject`. This way, we create new top level elements. If we would have provided the current document as parent to the next, the destruction of the parent window would lead to the destruction of the child windows.

```
ApplicationWindow {

    // ...

    function _createNewDocument()
    {
        var component = Qt.createComponent("DocumentWindow.qml");
        var window = component.createObject();
        return window;
    }

    function newDocument()
    {
        var window = _createNewDocument();
        window.show();
    }

    // ...

}
```

Looking at the *Open* item results in a call to `openDocument` function. The function simply opens the `openDialog` which let's the user pick a file to open. As we don't have a document format, file extension or anything like that, the dialog has most properties set to their default value. In a real world application, this would be better configured.

In the `onAccepted` handler a new document window is instantiated using the `_createNewDocument` method, but then a file name is set before the window is shown. In this case, no real loading takes place.

Note: We imported the `Qt.labs.platform` module as `NativeDialogs`. This is because it provides a `MenuItem` that clashes with the `MenuItem` provided by the `QtQuick.Controls` module.

```
ApplicationWindow {

    // ...

    function openDocument(fileName)
    {
        openDialog.open();
    }

    NativeDialogs.FileDialog {
        id: openDialog
        title: "Open"
        folder: NativeDialogs.StandardPaths.writableLocation(NativeDialogs.
↪StandardPaths.DocumentsLocation)
        onAccepted: {
            var window = root._createNewDocument();
            window._fileName = openDialog.file;
            window.show();
        }
    }

    // ...

}
```

The file name belongs to a pair of properties describing the document: `_fileName` and `_isDirty`. The `_fileName` holds the file name of the document name and `_isDirty` is set when the document has unsaved changes. This is used by the save and save as logic, which is shown below.

When trying to save a document without a name, the `saveAsDocument` is invoked. This results in a round-trip over the `saveAsDialog`, which sets a file name and then tries to save again in the `onAccepted` handler.

Notice that the `saveAsDocument` and `saveDocument` functions correspond to the *Save As* and *Save* menu items.

After having saved the document, in the `saveDocument` function, the `_tryingToClose` property is checked. This flag is set if the save is the result of the user wanting to save a document when the window is being closed. As a consequence, the window is closed after the save operation has been performed. Again, no actual saving takes place in this example.

```
ApplicationWindow {

    // ...

    property bool _isDirty: true        // Has the document got unsaved changes?
    property string _fileName           // The filename of the document
    property bool _tryingToClose: false // Is the window trying to close (but␣
↪needs a file name first)?

    // ...
```

(continues on next page)

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```
    function saveAsDocument()
    {
        saveAsDialog.open();
    }

    function saveDocument()
    {
        if (_fileName.length === 0)
        {
            root.saveAsDocument();
        }
        else
        {
            // Save document here
            console.log("Saving document")
            root._isDirty = false;

            if (root._tryingToClose)
                root.close();
        }
    }

    NativeDialogs.FileDialog {
        id: saveAsDialog
        title: "Save As"
        folder: NativeDialogs.StandardPaths.writableLocation(NativeDialogs.
↪StandardPaths.DocumentsLocation)
        onAccepted: {
            root._fileName = saveAsDialog.file
            saveDocument();
        }
        onRejected: {
            root._tryingToClose = false;
        }
    }

    // ...

}
```

This leads us to the closing of windows. When a window is being closed, the `onClosing` handler is invoked. Here, the code can choose not to accept the request to close. If the document has unsaved changes, we open the `closeWarningDialog` and reject the request to close.

The `closeWarningDialog` asks the user if the changes should be changed, but the user also has the option to cancel the close operation. The cancelling, handeled in `onRejected`, is the easiest case, as we rejected the closing when the dialog was opened.

When the user does not want to save the changes, i.e. in `onNoClicked`, the `_isDirty` flag is set to `false` and the window is closed again. This time around, the `onClosing` will accept the closing as the `_isDirty` is false.

Finally, when the user wants to save the changes, we set the `_tryingToClose` flag to true before calling save. This leads us to the save - save as logic.

```
ApplicationWindow {

    // ...

    onClosing: {
        if (root._isDirty) {
```

(continues on next page)

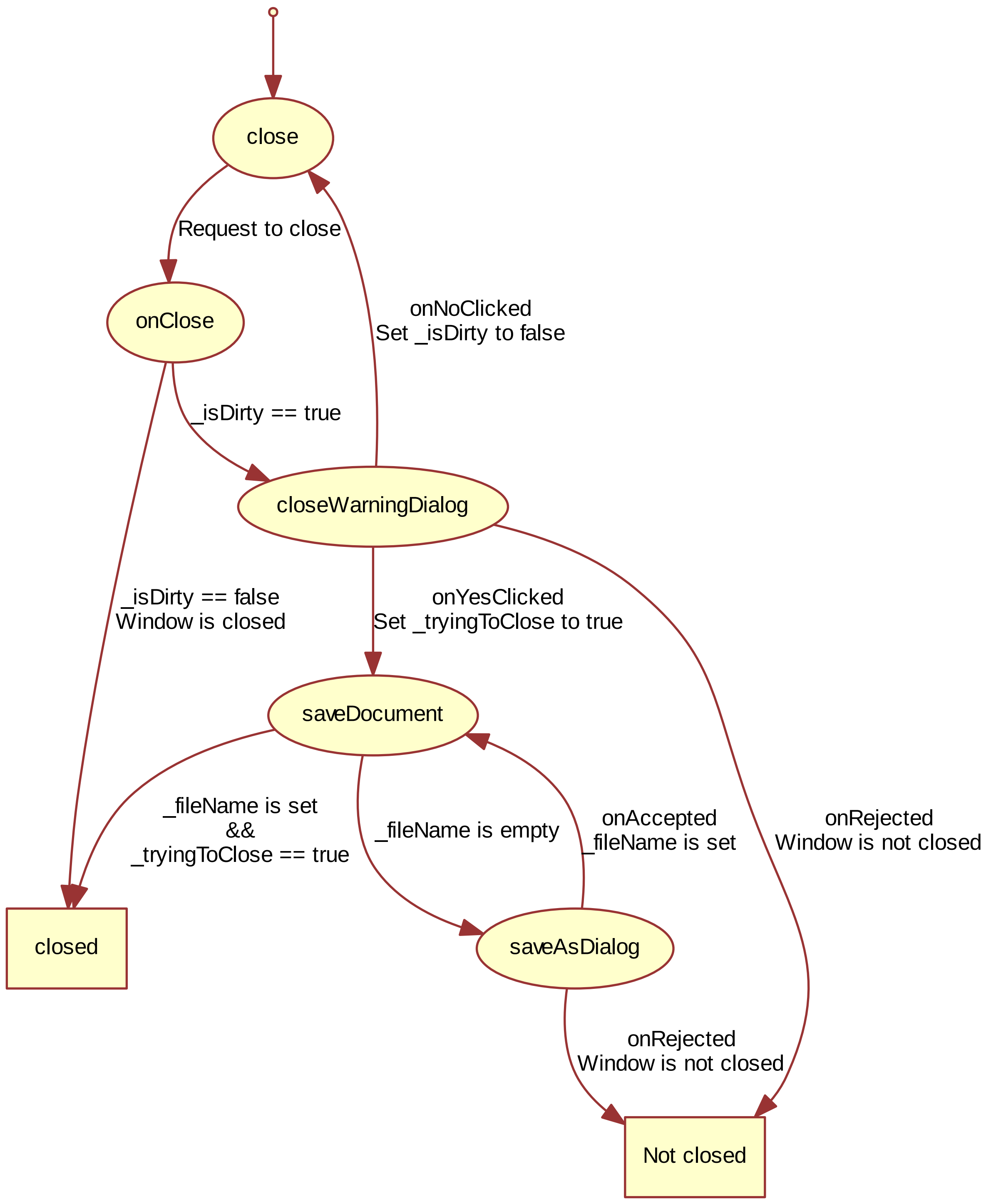
(continued from previous page)

```
            closeWarningDialog.open();
            close.accepted = false;
        }
    }

    NativeDialogs.MessageDialog {
        id: closeWarningDialog
        title: "Closing document"
        text: "You have unsaved changed. Do you want to save your changes?"
        buttons: NativeDialogs.MessageDialog.Yes | NativeDialogs.MessageDialog.No␣
↪| NativeDialogs.MessageDialog.Cancel
        onYesClicked: {
            // Attempt to save the document
            root._tryingToClose = true;
            root.saveDocument();
        }
        onNoClicked: {
            // Close the window
            root._isDirty = false;
            root.close()
        }
        onRejected: {
            // Do nothing, aborting the closing of the window
        }
    }
}
```

The entire flow for the close and save - save as logic is shown below. The system is entered at the *close* state, while *closed* and *not closed* states are outcomes.

This looks complicated compared to implementing this using `QtWidgets` and C++. This is because the dialogs are not blocking to QML. This means that we cannot wait for the outcome of a dialog in a `switch` statement. Instead we need to remember the state and continue the operation in the respective `onYesClicked`, `onNoClicked`, `onAccepted`, and `onRejected` handlers.



The final piece of the puzzle is the window title. It is composed form the `_fileName` and `_isDirty`.

```
ApplicationWindow {

    // ...
```

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```
    title: (_fileName.length===0?qsTr("Document"):_fileName) + (_isDirty?"*":"")

    // ...

}
```

This example is far from complete. For instance, the document is never loaded or saved. Another missing piece is handling the case of closing all the windows in one go, i.e. exiting the application. For this function, a singleton maintaining a list of all current `DocumentWindow` instances is needed. However, this would only be another way to trigger the closing of a window, so the logic flow shown here is still valid.

6.4 The Imagine Style

One of the goals with Qt Quick Controls 2 is to separate the logic of a control from its appearance. For most of the styles, the implementation of the appearance consists of a mix of QML code and graphical assets. However, using the *Imagine* style, it is possible to customize the appearance of a Qt Quick Controls 2 based application using only graphical assets.

The imagine style is based on 9-patch images. This allows the images to carry information on how they are stretched and what parts are to be considered as a part of the element and what is outside, e.g. a shadow. For each control, the style supports several elements, and for each element a large number of states are available. By providing assets for certain combinations of these elements and states, you can control the appearance of each control in detail.

The details of 9-patch images, and how each control can be styled is covered in great detail in the Imagine style documentation. Here, we will create a custom style to an imaginary device interface to demonstrate how the style is used.

The application consists of a custom style of the `ApplicationWindow` and `Button` controls. For the buttons, the normal case, as well as *pressed* and *checked* are handled. The demonstration application is shown below.

The code for this uses a `Column` for the clickable buttons, and a `Grid` for the checkable ones. The clickable buttons also stretch with the window width.

```
ApplicationWindow {

    // ...

    Column {

        // ...

        Repeater {
            model: 5
            delegate: Button {
                width: parent.width
                height: 70
                text: qsTr("Click me!")
            }
        }
    }

    Grid {

        // ...

        Repeater {
            model: 10
```

(continues on next page)

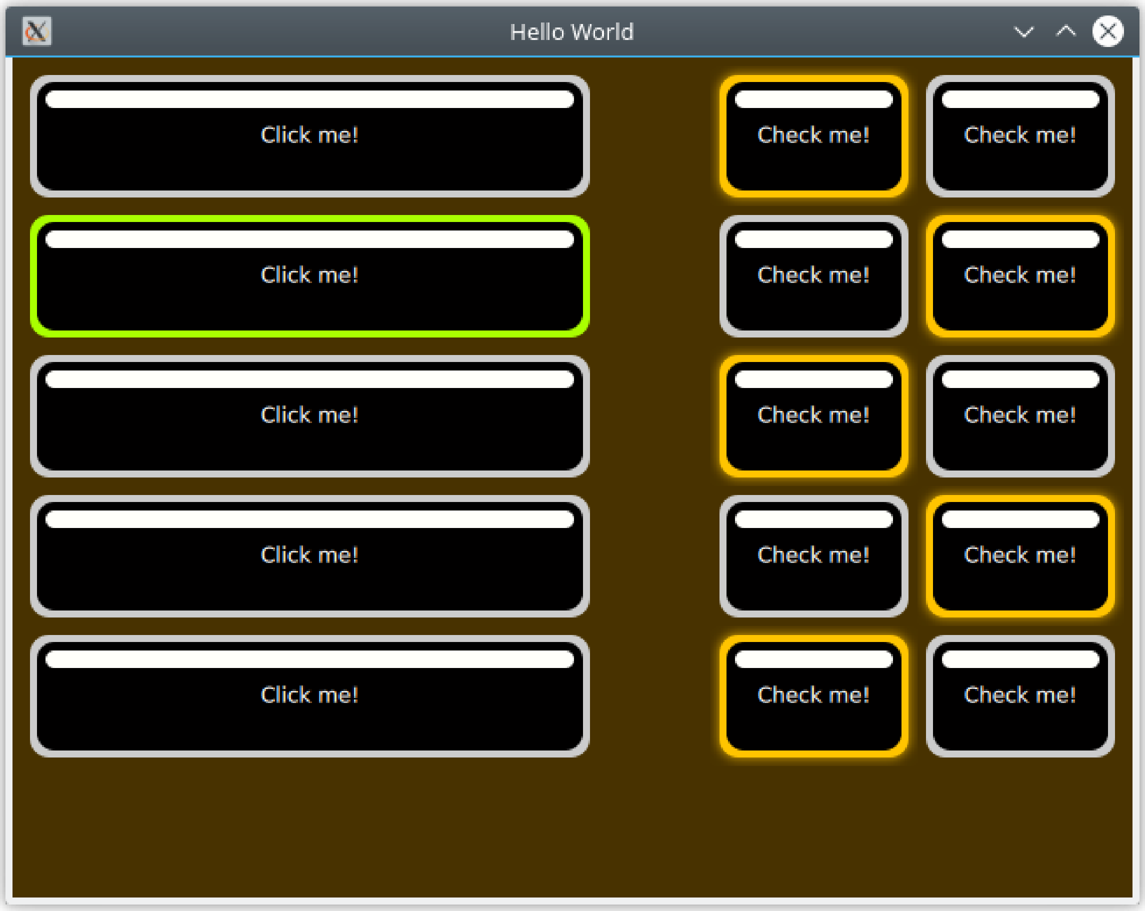


Fig. 11: The custom imagine button style.

(continued from previous page)

```
            delegate: Button {
                height: 70
                text: qsTr("Check me!")
                checkable: true
            }
        }
    }
}
```

As we are using the *Imagine* style, all controls that we want to use needs to be styled using a graphical asset. The easiest is the background for the `ApplicationWindow`. This is a single pixel texture defining the background colour. By naming the file `applicationwindow-background.png` and then pointing the style to it using the `qtquickcontrols2.conf` file, the file is picked up.

In the `qtquickcontrols2.conf` file shown below, you can see how we set the `Style` to `Imagine`, and then setup a `Path` for the style where it can look for the assets. Finally we set some palette properties as well. The available palette properties can be found on the palette QML Basic Type page.

```
[Controls]
Style=Imagine

[Imagine]
Path=:images/imagine

[Imagine\Palette]
Text=#ffffff
ButtonText=#ffffff
BrightText=#ffffff
```

The assets for the `Button` control are `button-background.9.png`, `button-background-pressed.9.png` and `button-background-checked.9.png`. These follow the *control-element-state* pattern. The stateless file, `button-background.9.png` is used for all states without a specific asset. According to the Imagine style element reference table, a button can have the following states:

- disabled
- pressed
- checked
- checkable
- focused
- highlighted
- flat
- mirrored
- hovered

Which ones that are needed depends on your user interface. For instance, the hovered style is never used for touch based interfaces.

Looking at an enlarged version of `button-background-checked.9.png` above you can see the 9-patch guide lines along the sides. The purple background has been added for visibility reasons. This area is actually transparent in the asset used in the example.

The pixels along the edges of the image can be either white/transparent, black, or red. These have different meanings that we will go through one by one.

- **Black** lines along the **left** and **top** sides of the asset mark the stretchable parts of the image. This means that the rounded corners and the white marker in the example are not affected when the button is stretched.

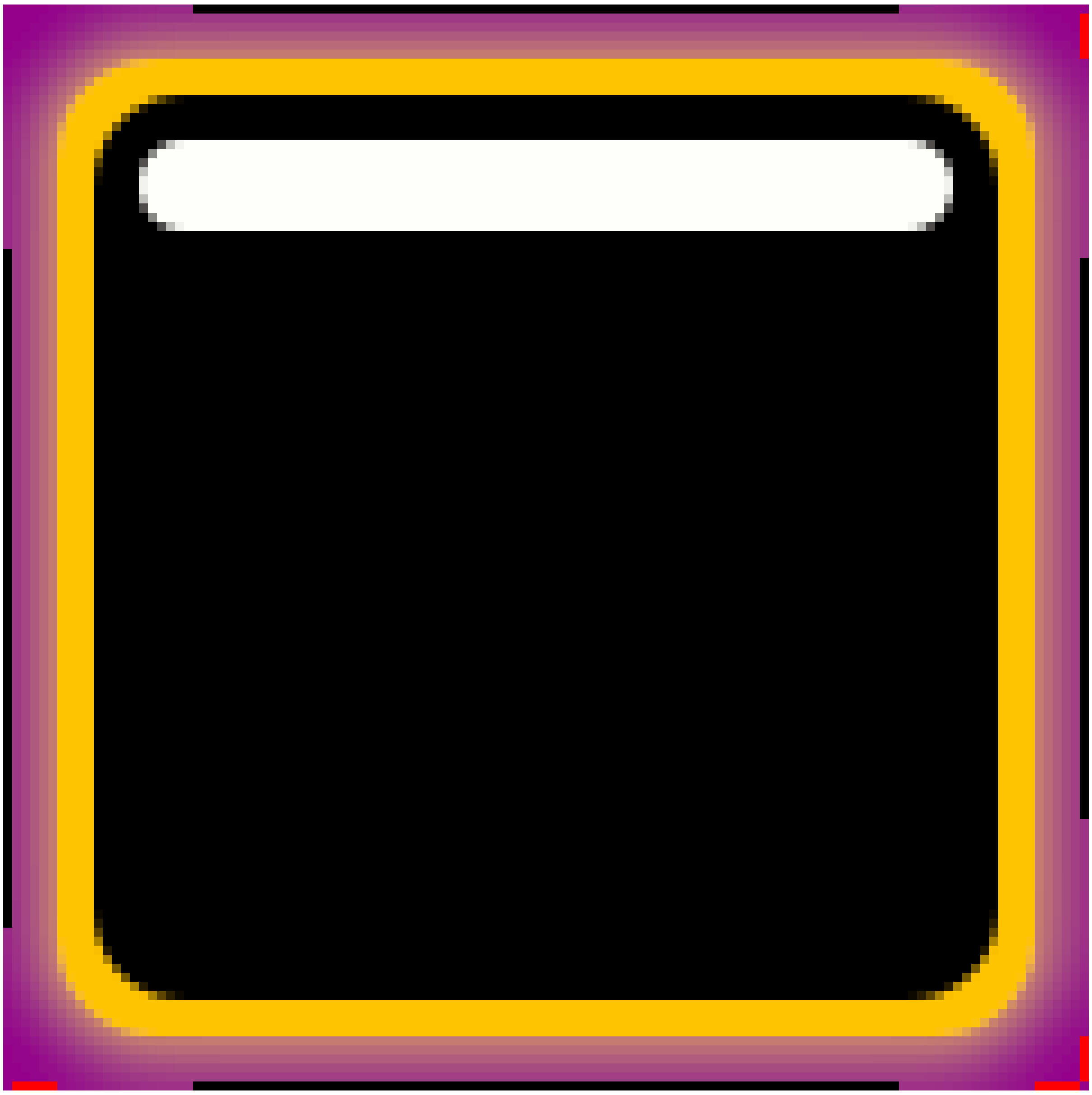


Fig. 12: The `button-background-checked.9.png` asset enlarged.

- **Black** lines along the **right** and **bottom** sides of the asset mark the area used for the control's contents. That means what part of the button is used for text in the example.
- **Red** lines along the **right** and **bottom** sides of the asset mark *inset* areas. These areas are a part of the image, but not considered a part of the control. For the checked image above, this is used for a soft halo extending outside the button.

A demonstration of the usage of an *inset* areas is how the `button-background.9.png` (below) and `button-background-checked.9.png` (above) result in an image that seems to light up, but not move, in the example.

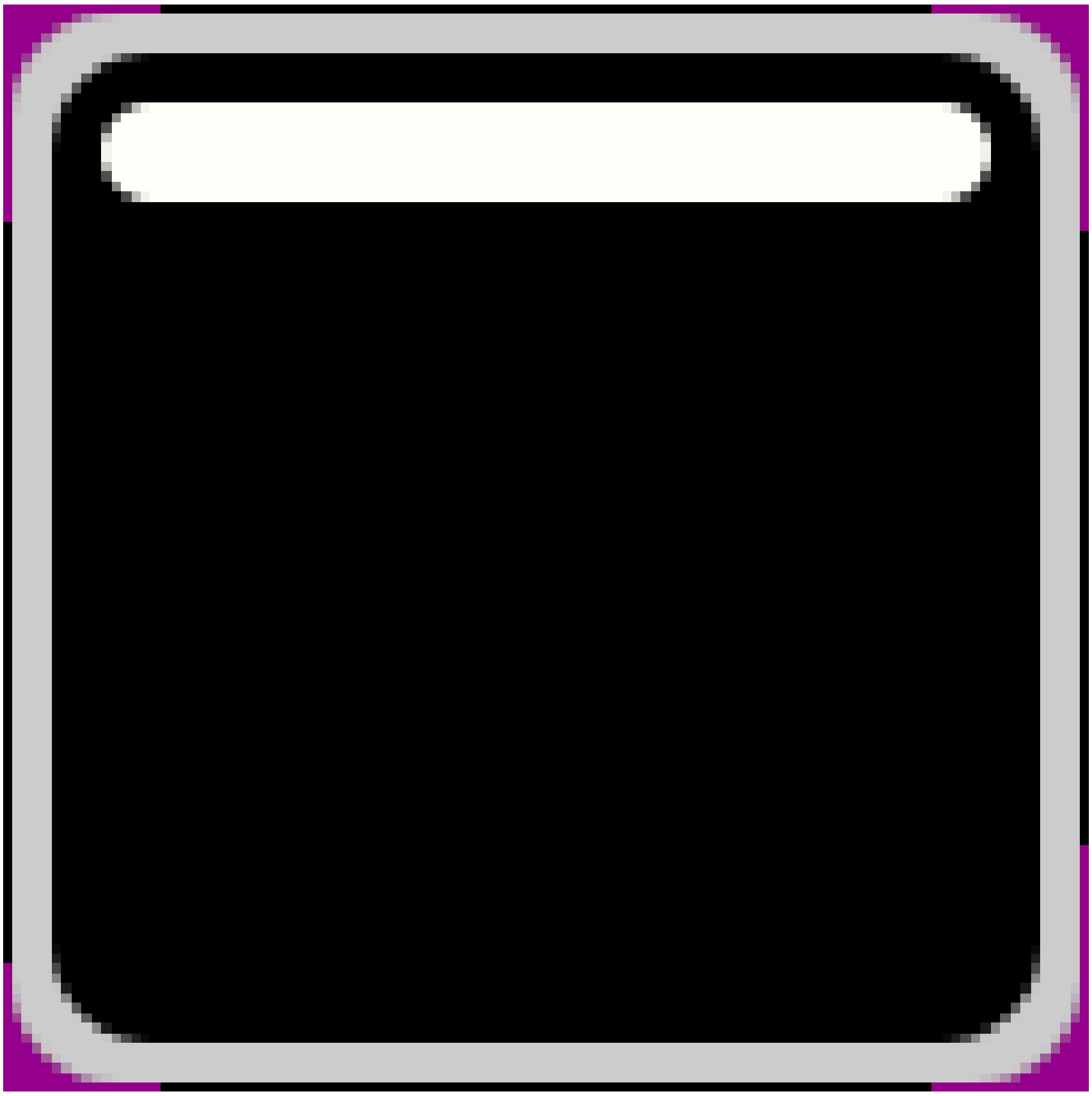


Fig. 13: The `button-background.9.png` asset enlarged.

6.5 Summary

In this chapter we have looked at the Qt Quick Controls 2. They offer set of elements that provide more high level concepts than the basic QML elements. For most scenarios, you will save memory and gain performance by using the Qt Quick Controls 2, as they are based around an optimized C++ logic instead of Javascript and QML.

In the chapter we've demonstrated how different styles can be used, and how a common code base can be developed using file selectors. This way, a single code base can address multiple platforms with user interactions and visual styles.

Finally, we have looked at the Imagine style that allows you to completely customize the look of a QML application through the use of graphical assets. This way an application can be reskinned without any code change what so ever.

CHAPTER

SEVEN

MODEL-VIEW-DELEGATE

Section author: e8johan

Note: Last Build: December 07, 2020 at 10:50 CET

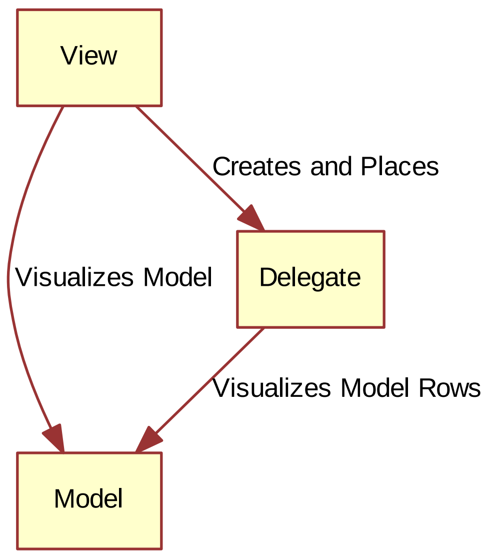
The source code for this chapter can be found in the assets folder.

In Qt Quick, data is separated from the presentation through a model-view separation. For each view, the visualization of each data element is separated into a delegate. Qt Quick comes with a set of predefined models and views. To utilize the system, one must understand these classes and know how to create appropriate delegates to get the right look and feel.

7.1 Concept

One of the most important aspects when developing user interfaces is to keep the representation of the data separate from the visualization. For instance, a phonebook could be arranged as a vertical list of text entries or a grid of pictures of the contacts. In both cases, the data is identical: the phonebook, but the visualization differs. This division is commonly referred to as the model-view pattern. In this pattern, the data is referred to as the model, while the visualization is handled by the view.

In QML, the model and view are joined by the delegate. The responsibilies are divided as follows. The model provides the data. For each data item, there might be multiple values. In the example above, each phonebook entry has a name, a picture, and a number. The data is arranged in a view, in which each item is visualized using a delegate. The task of the view is to arrange the delegates, while each delegate shows the values of each model item to the user.



7.2 Basic Models

The most basic way to separate the data from the presentation is to use the `Repeater` element. It is used to instantiate an array of items and is easy to combine with a positioner to populate a part of the user interface. A repeater uses a model, which can be anything from the number of items to instantiate, to a full-blown model gathering data from the Internet.

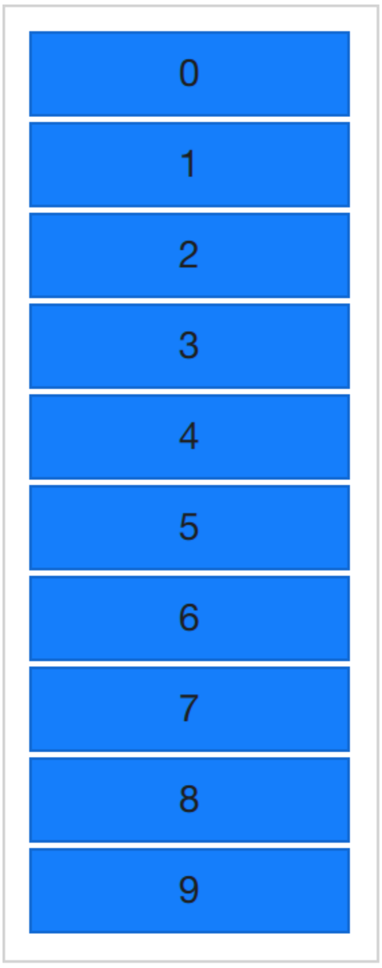
In its simplest form, the repeater can be used to instantiate a specified number of items. Each item will have access to an attached property, the variable `index`, that can be used to tell the items apart. In the example below, a repeater is used to create 10 instances of an item. The number of items is controlled using the `model` property. For each item, the `Rectangle` containing a `Text` element found inside the `Repeater` item, is instantiated. As you can tell, the `text` property is set to the `index` value, thus the items are numbered from zero to nine.

```
import QtQuick 2.5
import "../common"

Column {
    spacing: 2

    Repeater {
        model: 10
        BlueBox {
            width: 120
            height: 32
            text: index
        }
    }
}
```

As nice as lists of numbered items are, it is sometimes interesting to display a more complex data set. By replacing the integer `model` value with a JavaScript array, we can achieve that. The contents of the array can be of any type, be it strings, integers or objects. In the example below, a list of strings is used. We can still access and use the `index` variable, but we also have access to `modelData` containing the data for each element in the array.


0
1
2
3
4
5
6
7
8
9

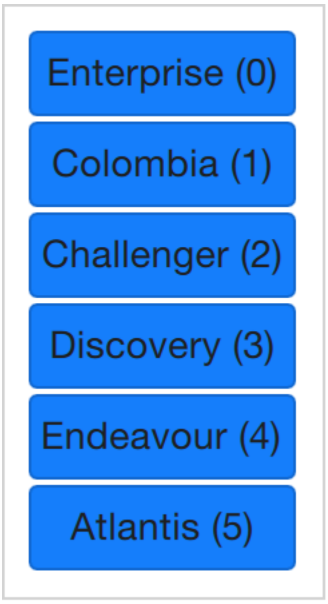
```
import QtQuick 2.5
import "../common"

Column {
    spacing: 2

    Repeater {
        model: ["Enterprise", "Columbia", "Challenger", "Discovery", "Endeavour",
↪"Atlantis"]

        BlueBox {
            width: 100
            height: 32
            radius: 3

            text: modelData + ' (' + index + ')'
        }
    }
}
```



Being able to expose the data of an array, you soon find yourself in a position where you need multiple pieces of data per item in the array. This is where models enter the picture. One of the most trivial models and one of the most commonly used is the `ListModel`. A list model is simply a collection of `ListElement` items. Inside each list element, a number of properties can be bound to values. For instance, in the example below, a name and a color are provided for each element.

The properties bound inside each element are attached to each instantiated item by the repeater. This means that the variables `name` and `surfaceColor` are available from within the scope of each `Rectangle` and `Text` item created by the repeater. This not only makes it easy to access the data, it also makes it easy to read the source code. The `surfaceColor` is the color of the circle to the left of the name, not something obscure as data from column `i` of row `j`.

```
import QtQuick 2.5
import "../common"

Column {
    spacing: 2

    Repeater {
        model: ListModel {
```

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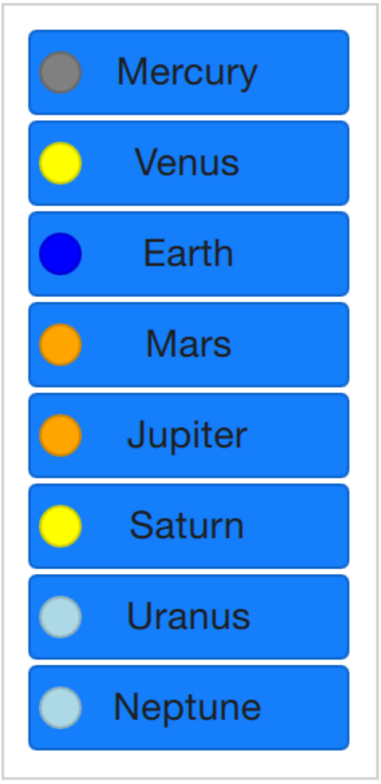
```
            ListElement { name: "Mercury"; surfaceColor: "gray" }
            ListElement { name: "Venus"; surfaceColor: "yellow" }
            ListElement { name: "Earth"; surfaceColor: "blue" }
            ListElement { name: "Mars"; surfaceColor: "orange" }
            ListElement { name: "Jupiter"; surfaceColor: "orange" }
            ListElement { name: "Saturn"; surfaceColor: "yellow" }
            ListElement { name: "Uranus"; surfaceColor: "lightBlue" }
            ListElement { name: "Neptune"; surfaceColor: "lightBlue" }
        }

        BlueBox {
            width: 120
            height: 32

            radius: 3
            text: name

            Box {
                anchors.left: parent.left
                anchors.verticalCenter: parent.verticalCenter
                anchors.leftMargin: 4

                width: 16
                height: 16

                radius: 8

                color: surfaceColor
            }
        }
    }
}
```

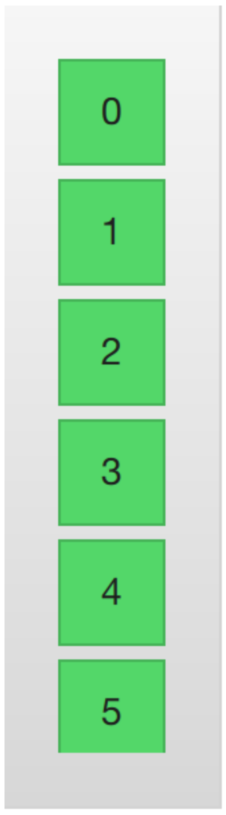


The contents of the repeater that is being instantiated for each item is actually what is bound to the default property, `delegate`. This means that the code of example *Example 01* is synonymous to the code shown below. Notice that the only difference is that the `delegate` property name is spelled out explicitly in the latter.

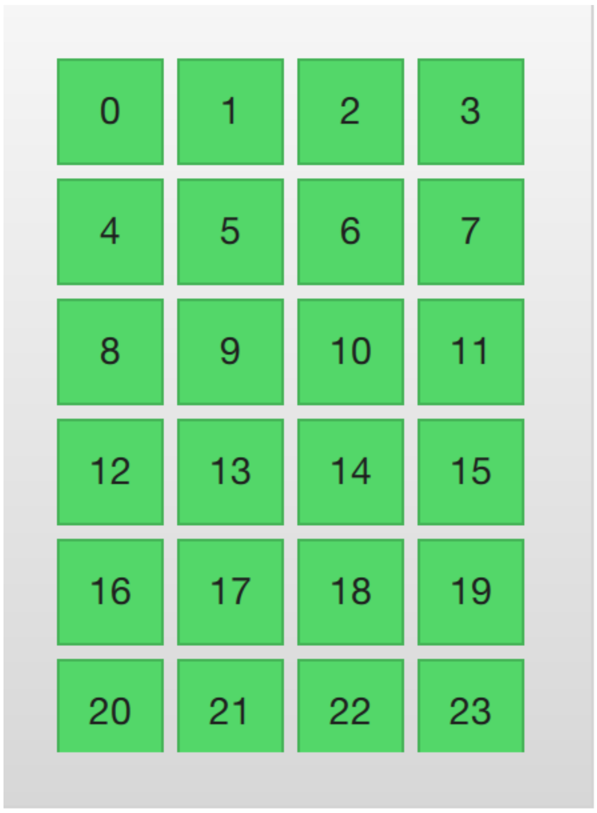
```
import QtQuick 2.5
import "../common"

Column {
    spacing: 2

    Repeater {
        model: 10

        delegate: BlueBox {
            width: 100
            height: 32
            text: index
        }
    }
}
```

7.3 Dynamic Views

Repeaters work well for limited and static sets of data, but in the real world, models are commonly more complex – and larger. Here, a smarter solution is needed. For this, Qt Quick provides the `ListView` and `GridView` elements. These are both based on a `Flickable` area, so the user can move around in a larger dataset. At the same time, they limit the number of concurrently instantiated delegates. For a large model, that means fewer elements in the scene at once.



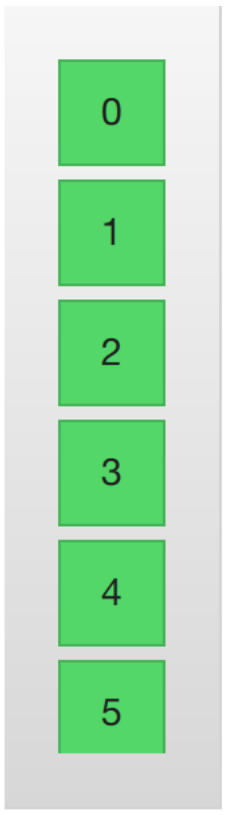
The two elements are similar in their usage. Thus, we will begin with the `ListView` and then describe the `GridView` with the former as the starting point of the comparison. Notice that the `GridView` places a list of items into a two-dimensional grid, left-to-right or top-to-bottom. If you want to show a table of data you need to use the `TableView` which is described in the *Table Models* section.



The `ListView` is similar to the `Repeater` element. It uses a `model`, instantiates a `delegate` and between the delegates, there can be `spacing`. The listing below shows how a simple setup can look.

```
import QtQuick 2.5
import "../common"

Background {
    width: 80
    height: 300

    ListView {
        anchors.fill: parent
        anchors.margins: 20

        clip: true

        model: 100

        delegate: numberDelegate
        spacing: 5
    }

    Component {
        id: numberDelegate

        GreenBox {
            width: 40
            height: 40
            text: index
        }
    }
}
```

If the model contains more data than can fit onto the screen, the `ListView` only shows part of the list. However,



as a consequence of the default behavior of Qt Quick, the list view does not limit the screen area within which the delegates are shown. This means that delegates may be visible outside the list view and that the dynamic creation and destruction of delegates outside the list view is visible to the user. To prevent this, clipping must be activated on the `ListView` element by setting the `clip` property to `true`. The illustration below shows the result of this (left view), compared to when the `clip` property is `false` (right view).

To the user, the `ListView` is a scrollable area. It supports kinetic scrolling, which means that it can be flicked to quickly move through the contents. By default, it also can be stretched beyond the end of contents, and then bounces back, to signal to the user that the end has been reached.

The behavior at the end of the view is controlled using the `boundsBehavior` property. This is an enumerated value and can be configured from the default behavior, `Flickable.DragAndOvershootBounds`, where the view can be both dragged and flicked outside its boundaries, to `Flickable.StopAtBounds`, where the view never will move outside its boundaries. The middle ground, `Flickable.DragOverBounds` lets the user drag the view outside its boundaries, but flicks will stop at the boundary.

It is possible to limit the positions where a view is allowed to stop. This is controlled using the `snapMode` property. The default behavior, `ListView.NoSnap`, lets the view stop at any position. By setting the `snapMode` property to `ListView.SnapToItem`, the view will always align the top of an item with its top. Finally, the `ListView.SnapOneItem`, the view will stop no more than one item from the first visible item when the mouse button or touch was released. The last mode is very handy when flipping through pages.

7.3.1 Orientation

The list view provides a vertically scrolling list by default, but horizontal scrolling can be just as useful. The direction of the list view is controlled through the `orientation` property. It can be set to either the default value, `ListView.Vertical`, or to `ListView.Horizontal`. A horizontal list view is shown below.

```
import QtQuick 2.5
import "../common"

Background {
```

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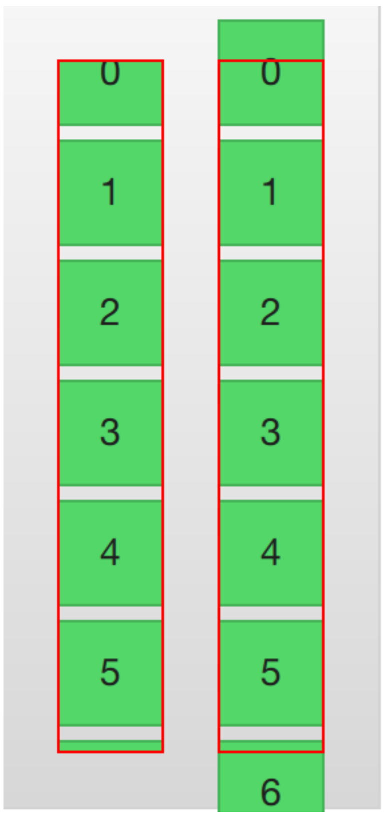

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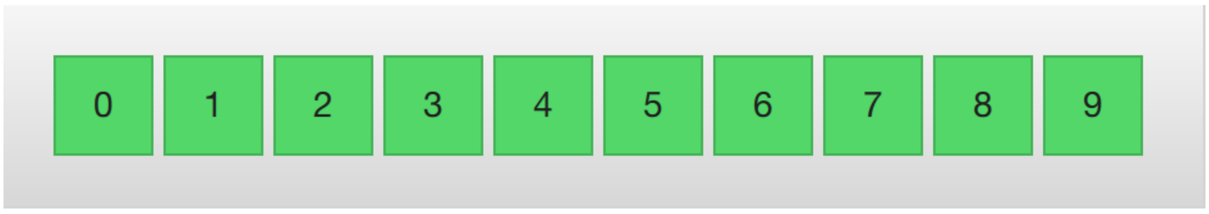
```
    width: 480
    height: 80

    ListView {
        anchors.fill: parent
        anchors.margins: 20
        spacing: 4
        clip: true
        model: 100
        orientation: ListView.Horizontal
        delegate: numberDelegate
    }

    Component {
        id: numberDelegate

        GreenBox {
            width: 40
            height: 40
            text: index
        }
    }
}
```



As you can tell, the direction of the horizontal flows from the left to the right by default. This can be controlled through the `layoutDirection` property, which can be set to either `Qt.LeftToRight` or `Qt.RightToLeft`, depending on the flow direction.

7.3.2 Keyboard Navigation and Highlighting

When using a `ListView` in a touch-based setting, the view itself is enough. In a scenario with a keyboard, or even just arrow keys to select an item, a mechanism to indicate the current item is needed. In QML, this is called highlighting.

Views support a highlight delegate which is shown in the view together with the delegates. It can be considered an additional delegate, only that it is only instantiated once, and is moved into the same position as the current item.

In the example below this is demonstrated. There are two properties involved for this to work. First, the `focus` property is set to true. This gives the `ListView` the keyboard focus. Second, the `highlight` property is set to point out the highlighting delegate to use. The highlight delegate is given the `x`, `y` and `height` of the current item. If the `width` is not specified, the width of the current item is also used.

In the example, the `ListView.view.width` attached property is used for width. The attached properties available to delegates are discussed further in the delegate section of this chapter, but it is good to know that the same properties are available to highlight delegates as well.

```
import QtQuick 2.5
import "../common"

Background {
    width: 240
    height: 300

    ListView {
        id: view
        anchors.fill: parent
        anchors.margins: 20

        clip: true

        model: 100

        delegate: numberDelegate
        spacing: 5

        highlight: highlightComponent
        focus: true
    }

    Component {
        id: highlightComponent

        GreenBox {
            width: ListView.view.width
        }
    }

    Component {
        id: numberDelegate

        Item {
            width: ListView.view.width
            height: 40

            Text {
```

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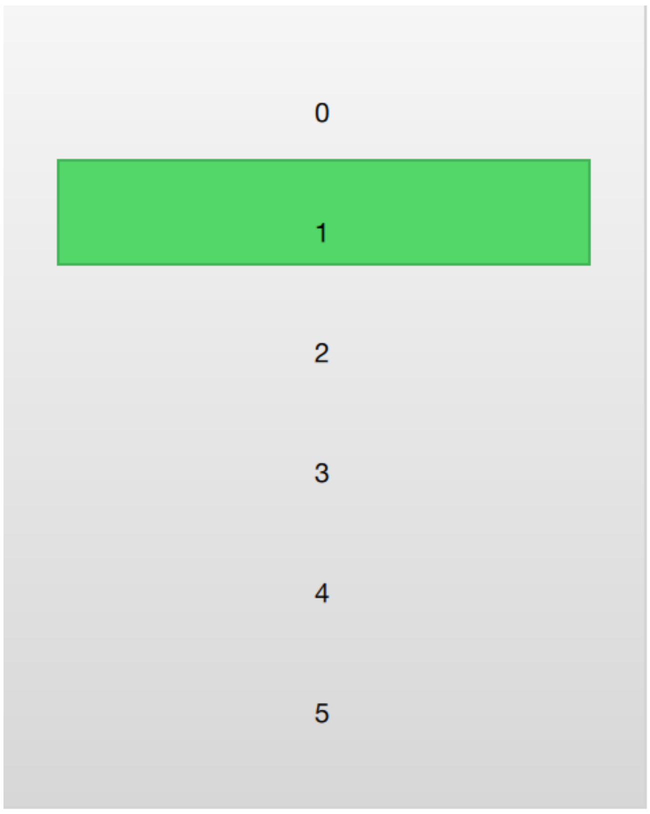
```
                anchors.centerIn: parent

                font.pixelSize: 10

                text: index
            }
        }
    }
}
```



When using a highlight in conjunction with a `ListView`, a number of properties can be used to control its behavior. The `highlightRangeMode` controls how the highlight is affected by what is shown in the view. The default setting, `ListView.NoHighlightRange` means that the highlight and the visible range of items in the view not being related at all.

The value `ListView.StrictlyEnforceRange` ensures that the highlight is always visible. If an action attempts to move the highlight outside the visible part of the view, the current item will change accordingly, so that the highlight remains visible.

The middle ground is the `ListView.ApplyRange` value. It attempts to keep the highlight visible but does not alter the current item to enforce this. Instead, the highlight is allowed to move out of view if necessary.

In the default configuration, the view is responsible for moving the highlight into position. The speed of the movement and resizing can be controlled, either as a velocity or as a duration. The properties involved are `highlightMoveSpeed`, `highlightMoveDuration`, `highlightResizeSpeed` and `highlightResizeDuration`. By default, the speed is set to 400 pixels per second, and the duration is set to -1, indicating that the speed and distance control the duration. If both a speed and a duration is set, the one that results in the quickest animation is chosen.

To control the movement of the highlight more in detail, the `highlightFollowCurrentItem` property can be set to `false`. This means that the view is no longer responsible for the movement of the highlight delegate. Instead, the movement can be controlled through a `Behavior` or an animation.

In the example below, the y property of the highlight delegate is bound to the ListView.view.currentItem.y attached property. This ensures that the highlight follows the current item. However, as we do not let the view move the highlight, we can control how the element is moved. This is done through the Behavior on y. In the example below, the movement is divided into three steps: fading out, moving, before fading in. Notice how SequentialAnimation and PropertyAnimation elements can be used in combination with the NumberAnimation to create a more complex movement.

```
    Component {
        id: highlightComponent

        Item {
            width: ListView.view.width
            height: ListView.view.currentItem.height

            y: ListView.view.currentItem.y

            Behavior on y {
                SequentialAnimation {
                    PropertyAnimation { target: highlightRectangle; property:
↪"opacity"; to: 0; duration: 200 }
                    NumberAnimation { duration: 1 }
                    PropertyAnimation { target: highlightRectangle; property:
↪"opacity"; to: 1; duration: 200 }
                }
            }

            GreenBox {
                id: highlightRectangle
                anchors.fill: parent
            }
        }
    }
```

7.3.3 Header and Footer

At the end of the ListView contents, a header and a footer element can be inserted. These can be considered special delegates placed at the beginning or end of the list. For a horizontal list, these will not appear at the head or foot, but rather at the beginning or end, depending on the layoutDirection used.

The example below illustrates how a header and footer can be used to enhance the perception of the beginning and end of a list. There are other uses for these special list elements. For instance, they can be used to keep buttons to load more contents.

```
import QtQuick 2.5
import "../common"

Background {
    width: 240
    height: 300

    ListView {
        anchors.fill: parent
        anchors.margins: 20

        clip: true

        model: 4

        delegate: numberDelegate
        spacing: 2
```

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```
        header: headerComponent
        footer: footerComponent
    }

    Component {
        id: headerComponent

        YellowBox {
            width: ListView.view.width
            height: 20
            text: 'Header'

        }
    }

    Component {
        id: footerComponent

        YellowBox {
            width: ListView.view.width
            height: 20
            text: 'Footer'
        }
    }

    Component {
        id: numberDelegate

        GreenBox {
            width: ListView.view.width
            height: 40
            text: 'Item #' + index
        }
    }
}
```

Note: Header and footer delegates do not respect the `spacing` property of a `ListView`, instead they are placed directly adjacent to the next item delegate in the list. This means that any spacing must be a part of the header and footer items.

7.3.4 The GridView

Using a `GridView` is very similar to using a `ListView`. The only real difference is that the grid view places the delegates in a two-dimensional grid instead of in a linear list.

Compared to a list view, the grid view does not rely on spacing and the size of its delegates. Instead, it uses the `cellWidth` and `cellHeight` properties to control the dimensions of the contents delegates. Each delegate item is then placed in the top left corner of each such cell.

```
import QtQuick 2.5
import "../common"

Background {
    width: 220
    height: 300

    GridView {
```

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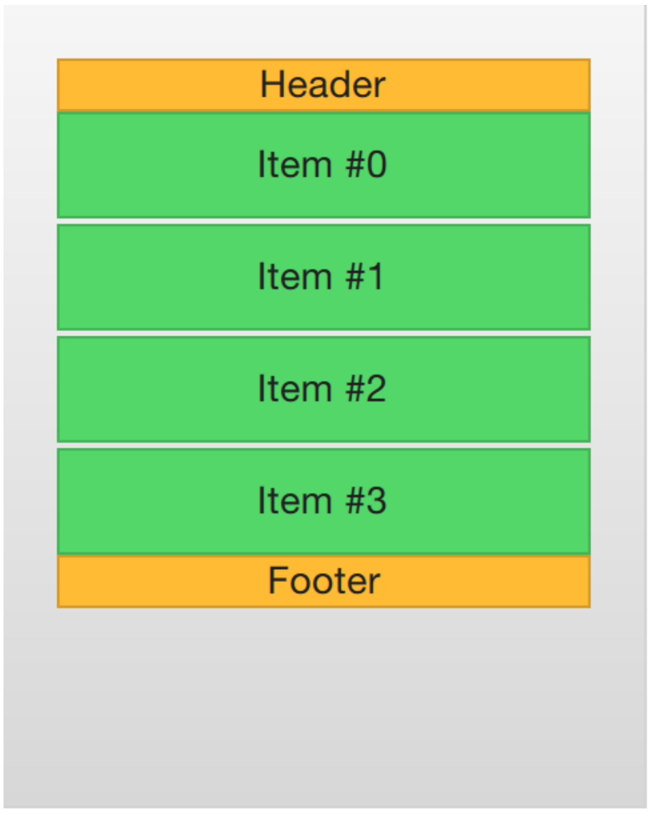
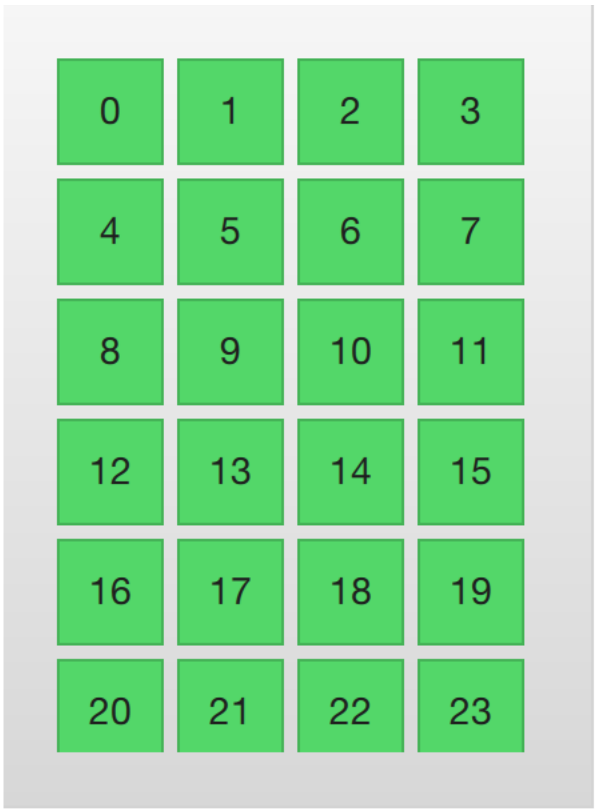

Header
Item #0
Item #1
Item #2
Item #3
Footer


0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23

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```
        id: view
        anchors.fill: parent
        anchors.margins: 20

        clip: true

        model: 100

        cellWidth: 45
        cellHeight: 45

        delegate: numberDelegate
    }

    Component {
        id: numberDelegate

        GreenBox {
            width: 40
            height: 40
            text: index
        }
    }
}
```

A `GridView` contains headers and footers, can use a highlight delegate and supports snap modes as well as various bounds behaviors. It can also be orientated in different directions and orientations.

The orientation is controlled using the `flow` property. It can be set to either `GridView.LeftToRight` or `GridView.TopToBottom`. The former value fills a grid from the left to the right, adding rows from the top to the bottom. The view is scrollable in the vertical direction. The latter value adds items from the top to the bottom, filling the view from left to right. The scrolling direction is horizontal in this case.

In addition to the `flow` property, the `layoutDirection` property can adapt the direction of the grid to left-to-right or right-to-left languages, depending on the value used.

7.4 Delegate

When it comes to using models and views in a custom user interface, the delegate plays a huge role in creating a look. As each item in a model is visualized through a delegate, what is actually visible to the user are the delegates.

Each delegate gets access to a number of attached properties, some from the data model, others from the view. From the model, the properties convey the data for each item to the delegate. From the view, the properties convey state information related to the delegate within the view.

The most commonly used properties attached from the view are `ListView.isCurrentItem` and `ListView.view`. The first is a boolean indicating if the item is the current item, while the latter is a read-only reference to the actual view. Through access to the view, it is possible to create general, reusable delegates that adapt to the size and nature of the view in which they are contained. In the example below, the `width` of each delegate is bound to the `width` of the view, while the background `color` of each delegate depends on the attached `ListView.isCurrentItem` property.

```
import QtQuick 2.5

Rectangle {
    width: 120
    height: 300

    gradient: Gradient {
```

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```
        GradientStop { position: 0.0; color: "#f6f6f6" }
        GradientStop { position: 1.0; color: "#d7d7d7" }
    }

    ListView {
        anchors.fill: parent
        anchors.margins: 20

        clip: true

        model: 100

        delegate: numberDelegate
        spacing: 5

        focus: true
    }

    Component {
        id: numberDelegate

        Rectangle {
            width: ListView.view.width
            height: 40

            color: ListView.isCurrentItem?"#157efb":"#53d769"
            border.color: Qt.lighter(color, 1.1)

            Text {
                anchors.centerIn: parent

                font.pixelSize: 10

                text: index
            }
        }
    }
}
```

If each item in the model is associated with an action, for instance, clicking an item acts upon it, that functionality is a part of each delegate. This divides the event management between the view, which handles the navigation between items in the view, and the delegate which handles actions on a specific item.

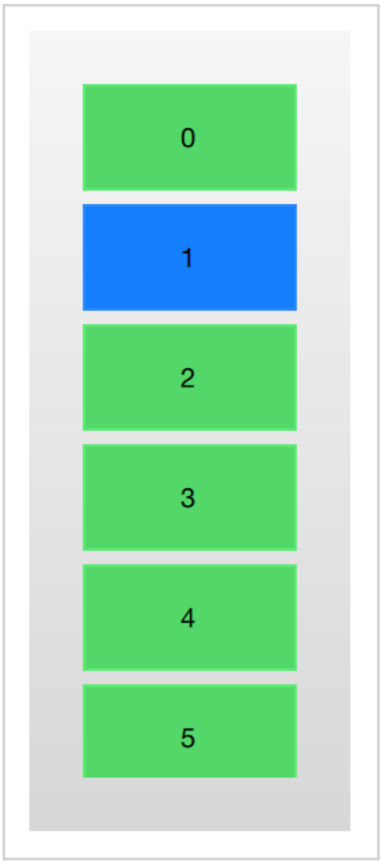
The most basic way to do this is to create a `MouseArea` within each delegate and act on the `onClicked` signal. This is demonstrated in the example in the next section of this chapter.

7.4.1 Animating Added and Removed Items

In some cases, the contents shown in a view changes over time. Items are added and removed as the underlying data model is altered. In these cases, it is often a good idea to employ visual cues to give the user a sense of direction and to help the user understand what data is added or removed.

Conveniently enough, QML views attach two signals, `onAdd` and `onRemove`, to each item delegate. By connecting animations to these, it is easy to create the movement necessary to aid the user in identifying what is taking place.

The example below demonstrates this through the use of a dynamically populated `ListModel`. At the bottom of the screen, a button for adding new items is shown. When it is clicked, a new item is added to the model using the `append` method. This triggers the creation of a new delegate in the view, and the emission of the `GridView.onAdd` signal. The `SequentialAnimation` attached to the signal causes the item to zoom into view by animating the `scale` property of the delegate.



When a delegate in the view is clicked, the item is removed from the model through a call to the `remove` method. This causes the `GridView.onRemove` signal to be emitted, triggering another `SequentialAnimation`. This time, however, the destruction of the delegate must be delayed until the animation has completed. To do this, `PropertyAction` element is used to set the `GridView.delayRemove` property to `true` before the animation, and `false` after. This ensures that the animation is allowed to complete before the delegate item is removed.

```
import QtQuick 2.5

Rectangle {
    width: 480
    height: 300

    gradient: Gradient {
        GradientStop { position: 0.0; color: "#dbddde" }
        GradientStop { position: 1.0; color: "#5fc9f8" }
    }

    ListModel {
        id: theModel

        ListElement { number: 0 }
        ListElement { number: 1 }
        ListElement { number: 2 }
        ListElement { number: 3 }
        ListElement { number: 4 }
        ListElement { number: 5 }
        ListElement { number: 6 }
        ListElement { number: 7 }
        ListElement { number: 8 }
        ListElement { number: 9 }
```

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```
    }

    Rectangle {
        anchors.left: parent.left
        anchors.right: parent.right
        anchors.bottom: parent.bottom
        anchors.margins: 20

        height: 40

        color: "#53d769"
        border.color: Qt.lighter(color, 1.1)

        Text {
            anchors.centerIn: parent

            text: "Add item!"
        }

        MouseArea {
            anchors.fill: parent

            onClicked: {
                theModel.append({"number": ++parent.count});
            }
        }

        property int count: 9
    }

    GridView {
        anchors.fill: parent
        anchors.margins: 20
        anchors.bottomMargin: 80

        clip: true

        model: theModel

        cellWidth: 45
        cellHeight: 45

        delegate: numberDelegate
    }

    Component {
        id: numberDelegate

        Rectangle {
            id: wrapper

            width: 40
            height: 40

            gradient: Gradient {
                GradientStop { position: 0.0; color: "#f8306a" }
                GradientStop { position: 1.0; color: "#fb5b40" }
            }

            Text {
                anchors.centerIn: parent
```

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```
                font.pixelSize: 10

                text: number
            }

            MouseArea {
                anchors.fill: parent

                onClicked: {
                    theModel.remove(index);
                }
            }

            GridView.onRemove: SequentialAnimation {
                PropertyAction { target: wrapper; property: "GridView.delayRemove";
↪ value: true }
                NumberAnimation { target: wrapper; property: "scale"; to: 0;␣
↪duration: 250; easing.type: Easing.InOutQuad }
                PropertyAction { target: wrapper; property: "GridView.delayRemove";
↪ value: false }
            }

            GridView.onAdd: SequentialAnimation {
                NumberAnimation { target: wrapper; property: "scale"; from: 0; to:␣
↪1; duration: 250; easing.type: Easing.InOutQuad }
            }
        }
    }
}
```

7.4.2 Shape-Shifting Delegates

A commonly used mechanism in lists is that the current item is expanded when activated. This can be used to dynamically let the item expand to fill the screen to enter a new part of the user interface, or it can be used to provide slightly more information for the current item in a given list.

In the example below, each item is expanded to the full extent of the `ListView` containing it when clicked. The extra space is then used to add more information. The mechanism used to control this is a state `expanded` that each item delegate can enter, where the item is expanded. In that state, a number of properties are altered.

First of all, the `height` of the `wrapper` is set to the height of the `ListView`. The thumbnail image is then enlarged and moved down to make it move from its small position into its larger position. In addition to this, the two hidden items, the `factsView` and `closeButton` are shown by altering the `opacity` of the elements. Finally, the `ListView` is setup.

Setting up the `ListView` involves setting the `contentsY`, that is the top of the visible part of the view, to the `y` value of the delegate. The other change is to set `interactive` of the view to `false`. This prevents the view from moving. The user can no longer scroll through the list or change the current item.

As the item first is clicked, it enters the `expanded` state, causing the item delegate to fill the `ListView` and the contents to rearrange. When the close button is clicked, the state is cleared, causing the delegate to return to its previous state and re-enabling the `ListView`.

```
import QtQuick 2.5

Item {
    width: 300
    height: 480

```

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```
    Rectangle {
        anchors.fill: parent
        gradient: Gradient {
            GradientStop { position: 0.0; color: "#4a4a4a" }
            GradientStop { position: 1.0; color: "#2b2b2b" }
        }
    }

    ListView {
        id: listView

        anchors.fill: parent

        delegate: detailsDelegate
        model: planets
    }

    ListModel {
        id: planets

        ListElement { name: "Mercury"; imageSource: "images/mercury.jpeg"; facts:
↪"Mercury is the smallest planet in the Solar System. It is the closest planet to␣
↪the sun. It makes one trip around the Sun once every 87.969 days." }
        ListElement { name: "Venus"; imageSource: "images/venus.jpeg"; facts:
↪"Venus is the second planet from the Sun. It is a terrestrial planet because it␣
↪has a solid, rocky surface. The other terrestrial planets are Mercury, Earth and␣
↪Mars. Astronomers have known Venus for thousands of years." }
        ListElement { name: "Earth"; imageSource: "images/earth.jpeg"; facts: "The␣
↪Earth is the third planet from the Sun. It is one of the four terrestrial␣
↪planets in our Solar System. This means most of its mass is solid. The other␣
↪three are Mercury, Venus and Mars. The Earth is also called the Blue Planet,
↪'Planet Earth', and 'Terra'." }
        ListElement { name: "Mars"; imageSource: "images/mars.jpeg"; facts: "Mars␣
↪is the fourth planet from the Sun in the Solar System. Mars is dry, rocky and␣
↪cold. It is home to the largest volcano in the Solar System. Mars is named after␣
↪the mythological Roman god of war because it is a red planet, which signifies␣
↪the colour of blood." }
    }

    Component {
        id: detailsDelegate

        Item {
            id: wrapper

            width: listView.width
            height: 30

            Rectangle {
                anchors.left: parent.left
                anchors.right: parent.right
                anchors.top: parent.top

                height: 30

                color: "#333"
                border.color: Qt.lighter(color, 1.2)
                Text {
                    anchors.left: parent.left
                    anchors.verticalCenter: parent.verticalCenter
                    anchors.leftMargin: 4
```

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```
                    font.pixelSize: parent.height-4
                    color: '#fff'

                    text: name
                }
            }


            Rectangle {
                id: image

                width: 26
                height: 26

                anchors.right: parent.right
                anchors.top: parent.top
                anchors.rightMargin: 2
                anchors.topMargin: 2

                color: "black"


                Image {
                    anchors.fill: parent

                    fillMode: Image.PreserveAspectFit

                    source: imageSource
                }
            }

            MouseArea {
                anchors.fill: parent
                onClicked: parent.state = "expanded"
            }

            Item {
                id: factsView

                anchors.top: image.bottom
                anchors.left: parent.left
                anchors.right: parent.right
                anchors.bottom: parent.bottom

                opacity: 0

                Rectangle {
                    anchors.fill: parent

                    gradient: Gradient {
                        GradientStop { position: 0.0; color: "#fed958" }
                        GradientStop { position: 1.0; color: "#fecc2f" }
                    }
                    border.color: '#000000'
                    border.width: 2

                    Text {
                        anchors.fill: parent
                        anchors.margins: 5
```

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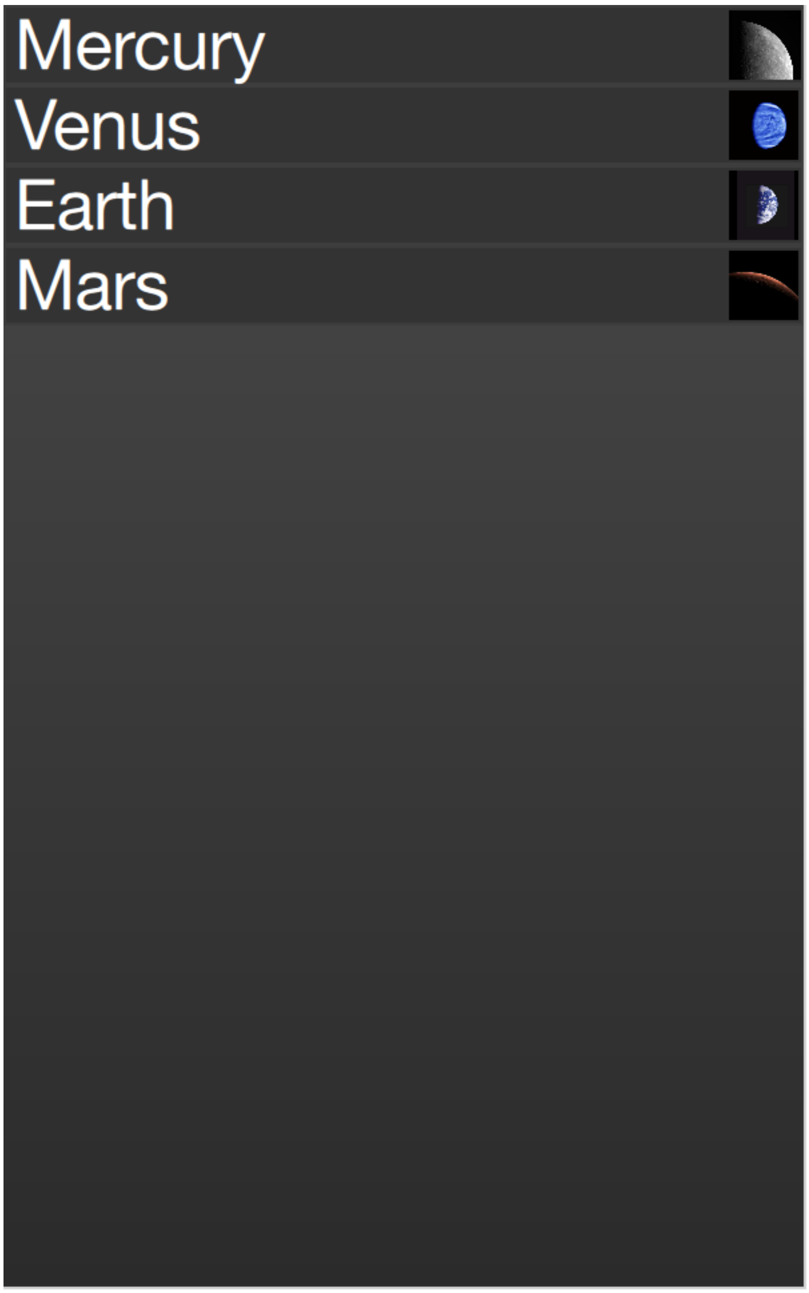
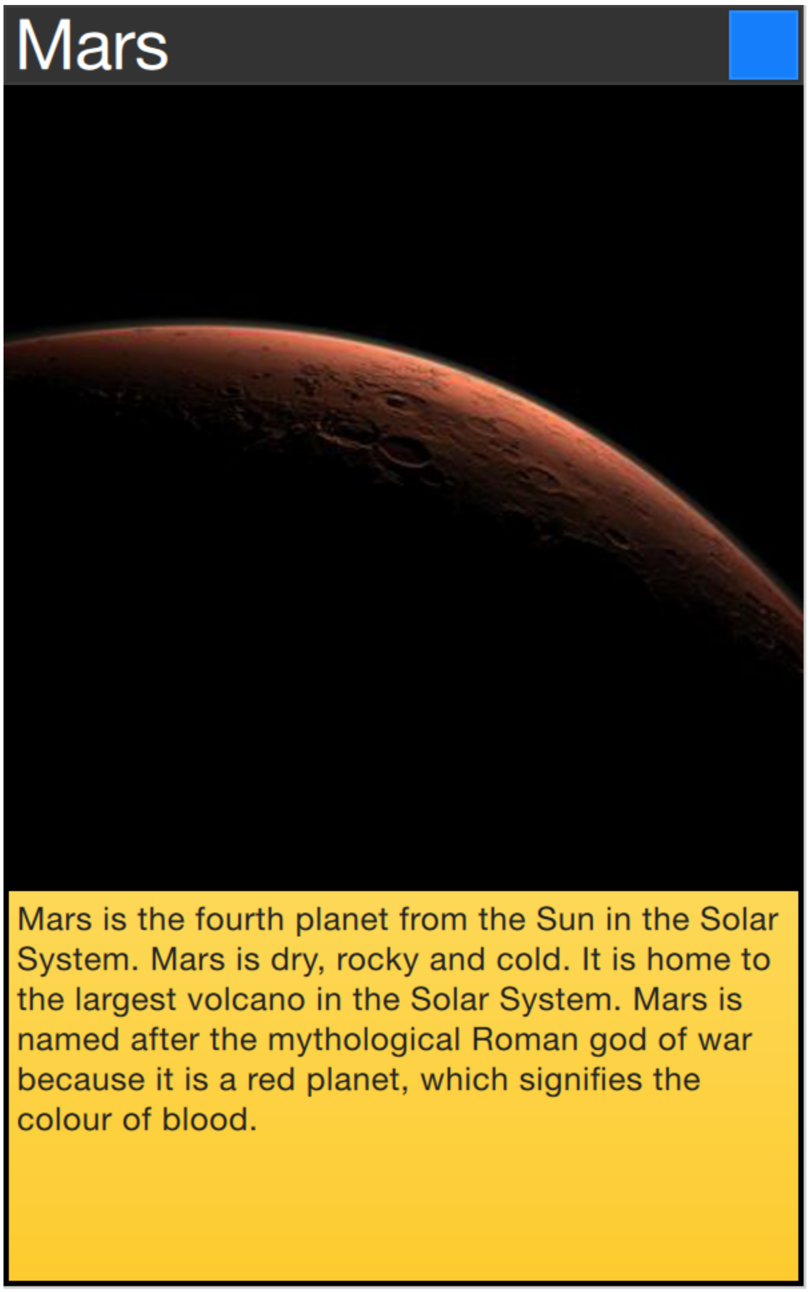
```
                        clip: true
                        wrapMode: Text.WordWrap
                        color: '#1f1f21'

                        font.pixelSize: 12

                        text: facts
                    }
                }
            }

            Rectangle {
                id: closeButton

                anchors.right: parent.right
                anchors.top: parent.top
                anchors.rightMargin: 2
                anchors.topMargin: 2

                width: 26
                height: 26

                color: "#157efb"
                border.color: Qt.lighter(color, 1.1)

                opacity: 0

                MouseArea {
                    anchors.fill: parent
                    onClicked: wrapper.state = ""
                }
            }

            states: [
                State {
                    name: "expanded"

                    PropertyChanges { target: wrapper; height: listView.height }
                    PropertyChanges { target: image; width: listView.width;␣
↪height: listView.width; anchors.rightMargin: 0; anchors.topMargin: 30 }
                    PropertyChanges { target: factsView; opacity: 1 }
                    PropertyChanges { target: closeButton; opacity: 1 }
                    PropertyChanges { target: wrapper.ListView.view; contentY:␣
↪wrapper.y; interactive: false }
                }
            ]

            transitions: [
                Transition {
                    NumberAnimation {
                        duration: 200;
                        properties: "height,width,anchors.rightMargin,anchors.
↪topMargin,opacity,contentY"
                    }
                }
            ]
        }
    }
}
```

The techniques demonstrated here to expand the delegate to fill the entire view can be employed to make an item delegate shift shape in a much smaller way. For instance, when browsing through a list of songs, the current item


Mercury
Venus
Earth
Mars



Mars is the fourth planet from the Sun in the Solar System. Mars is dry, rocky and cold. It is home to the largest volcano in the Solar System. Mars is named after the mythological Roman god of war because it is a red planet, which signifies the colour of blood.

could be made slightly larger, accommodating more information about that particular item.

7.5 Advanced Techniques

7.5.1 The PathView

The `PathView` element is the most powerful, but also the most complex, view provided in Qt Quick. It makes it possible to create a view where the items are laid out along an arbitrary path. Along the same path, attributes such as scale, opacity and more can be controlled in detail.

When using the `PathView`, you have to define a delegate and a path. In addition to this, the `PathView` itself can be customized through a range of properties. The most common being `pathItemCount`, controlling the number of visible items at once, and the highlight range control properties `preferredHighlightBegin`, `preferredHighlightEnd` and `highlightRangeMode`, controlling where along the path the current item is to be shown.

Before looking at the highlight range control properties in depth, we must look at the `path` property. The `path` property expects a `Path` element defining the path that the delegates follow as the `PathView` is being scrolled. The path is defined using the `startX` and `startY` properties in combinations with path elements such as `PathLine`, `PathQuad` and `PathCubic`. These elements are joined together to form a two-dimensional path.

Todo: do we cover the line, quad, and cubic through an illustration, or do we need a paragraph on them?

When the path has been defined, it is possible to further tune it using `PathPercent` and `PathAttribute` elements. These are placed in between path elements and provide more fine-grained control over the path and the delegates on it. The `PathPercent` controls how large a portion of the path that has been covered between each element. This, in turn, controls the distribution of delegates along the path, as they are distributed proportionally to the percentage progressed.

This is where the `preferredHighlightBegin` and `preferredHighlightEnd` properties of the `PathView` enters the picture. They both expect real values in the range between zero and one. The end is also expected to be more or equal to the beginning. Setting both these properties too, for instance, 0.5, the current item will be displayed at the location fifty percent along the path.

In the `Path`, the `PathAttribute` elements are placed between elements, just as `PathPercent` elements. They let you specify property values that are interpolated along the path. These properties are attached to the delegates and can be used to control any conceivable property.

The example below demonstrates how the `PathView` element is used to create a view of cards that the user can flip through. It employs a number of tricks to do this. The path consists of three `PathLine` elements. Using `PathPercent` elements, the central element is properly centered and provided enough space not to be cluttered by other elements. Using `PathAttribute` elements, the rotation, size and `z`-value is controlled.

In addition to the `path`, the `pathItemCount` property of the `PathView` has been set. This controls how densely populated the path will be. The `preferredHighlightBegin` and `preferredHighlightEnd` the `PathView.onPath` is used to control the visibility of the delegates.

```
    PathView {
        anchors.fill: parent

        delegate: flipCardDelegate
        model: 100

        path: Path {
            startX: root.width/2
            startY: 0

```

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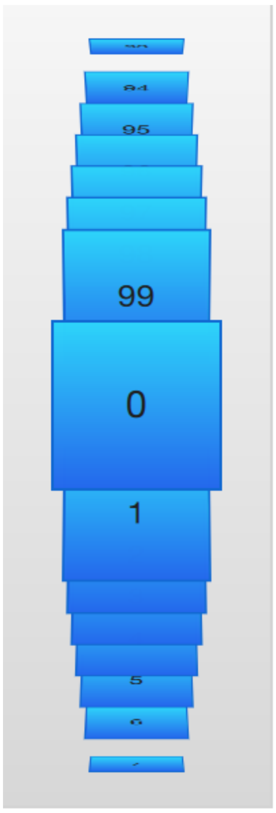

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```
            PathAttribute { name: "itemZ"; value: 0 }
            PathAttribute { name: "itemAngle"; value: -90.0; }
            PathAttribute { name: "itemScale"; value: 0.5; }
            PathLine { x: root.width/2; y: root.height*0.4; }
            PathPercent { value: 0.48; }
            PathLine { x: root.width/2; y: root.height*0.5; }
            PathAttribute { name: "itemAngle"; value: 0.0; }
            PathAttribute { name: "itemScale"; value: 1.0; }
            PathAttribute { name: "itemZ"; value: 100 }
            PathLine { x: root.width/2; y: root.height*0.6; }
            PathPercent { value: 0.52; }
            PathLine { x: root.width/2; y: root.height; }
            PathAttribute { name: "itemAngle"; value: 90.0; }
            PathAttribute { name: "itemScale"; value: 0.5; }
            PathAttribute { name: "itemZ"; value: 0 }
        }

        pathItemCount: 16

        preferredHighlightBegin: 0.5
        preferredHighlightEnd: 0.5
    }
```

The delegate, shown below, utilizes the attached properties `itemZ`, `itemAngle` and `itemScale` from the `PathAttribute` elements. It is worth noticing that the attached properties of the delegate only are available from the `wrapper`. Thus, the `rotX` property is defined to be able to access the value from within the `Rotation` element.

Another detail specific to `PathView` worth noticing is the usage of the attached `PathView.onPath` property. It is common practice to bind the visibility to this, as this allows the `PathView` to keep invisible elements for caching purposes. This can usually not be handled through clipping, as the item delegates of a `PathView` are placed more freely than the item delegates of `ListView` or `GridView` views.

```
    Component {
        id: flipCardDelegate

        BlueBox {
            id: wrapper

            width: 64
            height: 64
            antialiasing: true

            gradient: Gradient {
                GradientStop { position: 0.0; color: "#2ed5fa" }
                GradientStop { position: 1.0; color: "#2467ec" }
            }


            visible: PathView.onPath

            scale: PathView.itemScale
            z: PathView.itemZ

            property variant rotX: PathView.itemAngle
            transform: Rotation {
                axis { x: 1; y: 0; z: 0 }
                angle: wrapper.rotX;
                origin { x: 32; y: 32; }
            }
            text: index
        }
    }
```

When transforming images or other complex elements on in `PathView`, a performance optimization trick that is common to use is to bind the `smooth` property of the `Image` element to the attached property `PathView.view.moving`. This means that the images are less pretty while moving but smoothly transformed when stationary. There is no point spending processing power on smooth scaling when the view is in motion, as the user will not be able to see this anyway.

When using the `PathView` and changing the `currentIndex` programatically you might want to control the direction that the path moves in. You can do this using the `movementDirection` property. It can be set to `PathView.Shortest`, which is the default value. This means that the movement can be either direction, depending on which way is the closest way to move to the target value. The direction can instead be restricted by setting `movementDirection` to `PathView.Negative` or `PathView.Positive`.

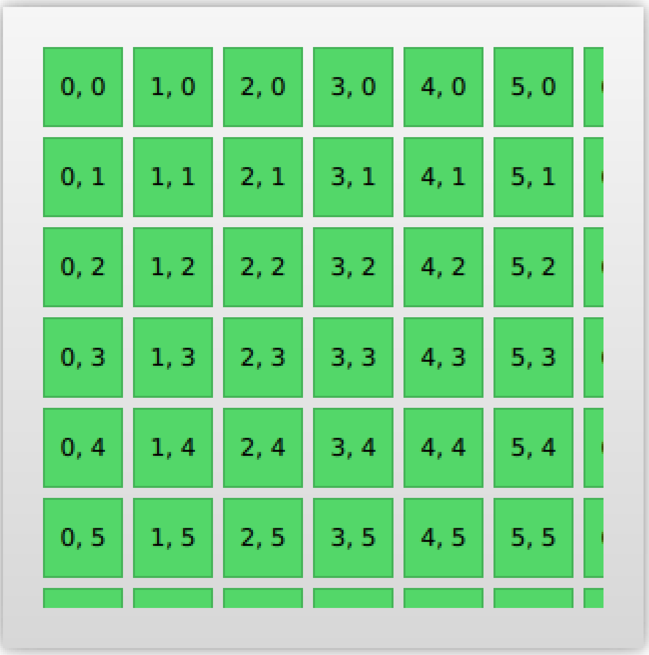
7.5.2 Table Models

All views discussed until now present an array of items one way or another. Even the `GridView` expects the model to provide a one dimensional list of items. For two dimensional tables of data you need to use the `TableView` element.

The `TableView` is similar to other views in that it combines a `model` with a `delegate` to form a grid. If given a list oriented model, it displays a single column, making it very similar to the `ListView` element. However, it can also display two-dimensional models that explicitly define both columns and rows.

In the example below, we set up a simple `TableView` with a custom model exposed from C++. At the moment, it is not possible to create table oriented models directly from QML, but in the 'Qt and C++' chapter the concept is explained. The running example is shown in the figure below.

Before we can use the `TableView` element, we must make sure that the `2.12` version of `QtQuick` is imported. After that, we can set it up. In this example below, we set the `rowSpacing` and `columnSpacing` to control the horizontal and vertical gaps between delegates. The rest of the properties are set up as for any other type of view.



```
import QtQuick 2.12
```

```
TableView {
    id: view
    anchors.fill: parent
    anchors.margins: 20

    rowSpacing: 5
    columnSpacing: 5

    clip: true

    model: tableModel

    delegate: cellDelegate
}
```

The delegate itself can carry an implicit size through the `implicitWidth` and `implicitHeight`. This is what we do in the example below. The actual data contents, i.e. the data returned from the model's `display` role.

```
Component {
    id: cellDelegate

    GreenBox {
        implicitHeight: 40
        implicitWidth: 40

        Text {
            anchors.centerIn: parent
            text: display
        }
    }
}
```

It is possible to provide delegates with different sizes depending on the model contents, e.g.:

```
GreenBox {
    implicitHeight: (1+row)*10
    // ...
}
```

Notice that both the width and the height must be greater than zero.

When providing an implicit size from the delegate, the tallest delegate of each row and the widest delegate of each column controls the size. This can create interesting behaviour if the width of items depend on the row, or if the height depends on the column. This is because not all delegates are instantiated at all times, so the width of a column might change as the user scrolls through the table.

To avoid the issues with specifying column widths and row heights using implicit delegate sizes, you can provide functions that calculate these sizes. This is done using the `columnWidthProvider` and `rowHeightProvider` . These functions return the size of the width and row respectively as shown below:

```
TableView {
    columnWidthProvider: function (column) { return 10*(column+1); }
    // ...
}
```

If you need to dynamically change the column widths or row heights you must notify the view of this by calling the `forceLayout` method. This will make the view re-calculate the size and position of all cells.

7.5.3 A Model from XML

As XML is a ubiquitous data format, QML provides the `XmlListModel` element that exposes XML data as a model. The element can fetch XML data locally or remotely and then processes the data using XPath expressions.

The example below demonstrates fetching images from an RSS flow. The `source` property refers to a remote location over HTTP, and the data is automatically downloaded.

When the data has been downloaded, it is processed into model items and roles. The `query` property is an XPath representing the base query for creating model items. In this example, the path is `/rss/channel/item`, so for every item tag, inside a channel tag, inside an RSS tag, a model item is created.

For every model item, a number of roles are extracted. These are represented by `XmlRole` elements. Each role is given a name, which the delegate can access through an attached property. The actual value of each such property is determined through the XPath query for each role. For instance, the `title` property corresponds to the `title/string()` query, returning the contents between the `<title>` and `</title>` tags.

The `imageSource` property extracts the value of an attribute of a tag instead of the contents of the tag. In this case, the `url` attribute of the `enclosure` tag is extracted as a string. The `@` is used to indicate that an attribute is requested. The `imageSource` property can then be used directly as the `source` for an `Image` element, which loads the image from the given URL.

```
import QtQuick 2.5
import QtQuick.XmlListModel 2.0
import "../common"

Background {
    width: 300
    height: 480

    Component {
        id: imageDelegate

        Box {
            width: listView.width
            height: 220
            color: '#333'
```

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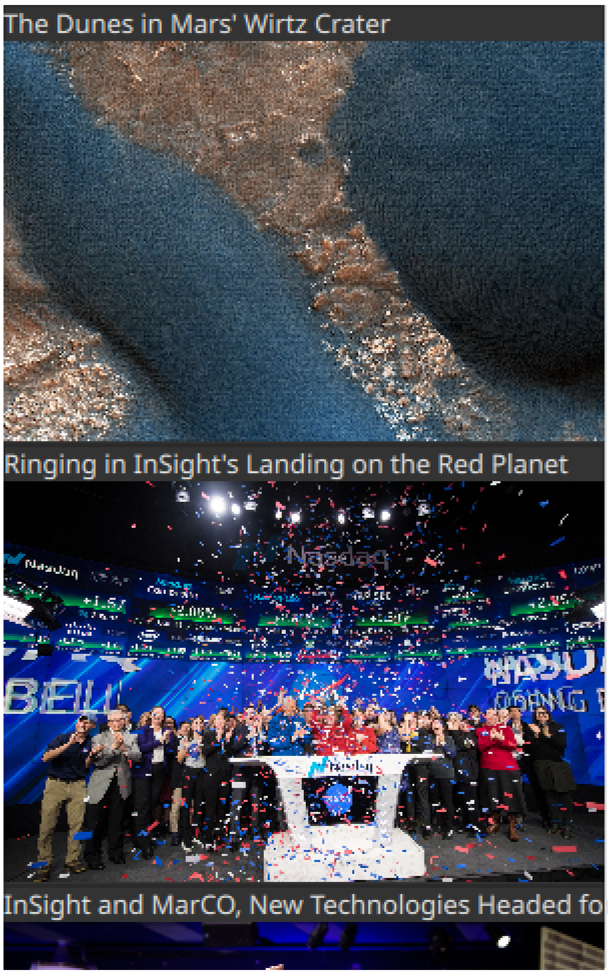

The Dunes in Mars' Wirtz Crater

Ringing in InSight's Landing on the Red Planet

InSight and MarCO, New Technologies Headed fo

(continued from previous page)

```
                Column {
                    Text {
                        text: title
                        color: '#e0e0e0'
                    }
                    Image {
                        width: listView.width
                        height: 200
                        fillMode: Image.PreserveAspectCrop
                        source: imageSource
                    }
                }
            }
        }

        XmlListModel {
            id: imageModel

            source: "https://www.nasa.gov/rss/dyn/image_of_the_day.rss"
            query: "/rss/channel/item"

            XmlRole { name: "title"; query: "title/string()" }
            XmlRole { name: "imageSource"; query: "enclosure/string(@url)" }
        }

        ListView {
            id: listView
            anchors.fill: parent
            model: imageModel
            delegate: imageDelegate
        }
}
```

7.5.4 Lists with Sections

Sometimes, the data in a list can be divided into sections. It can be as simple as dividing a list of contacts into sections under each letter of the alphabet or music tracks under albums. Using a `ListView` it is possible to divide a flat list into categories, providing more depth to the experience.

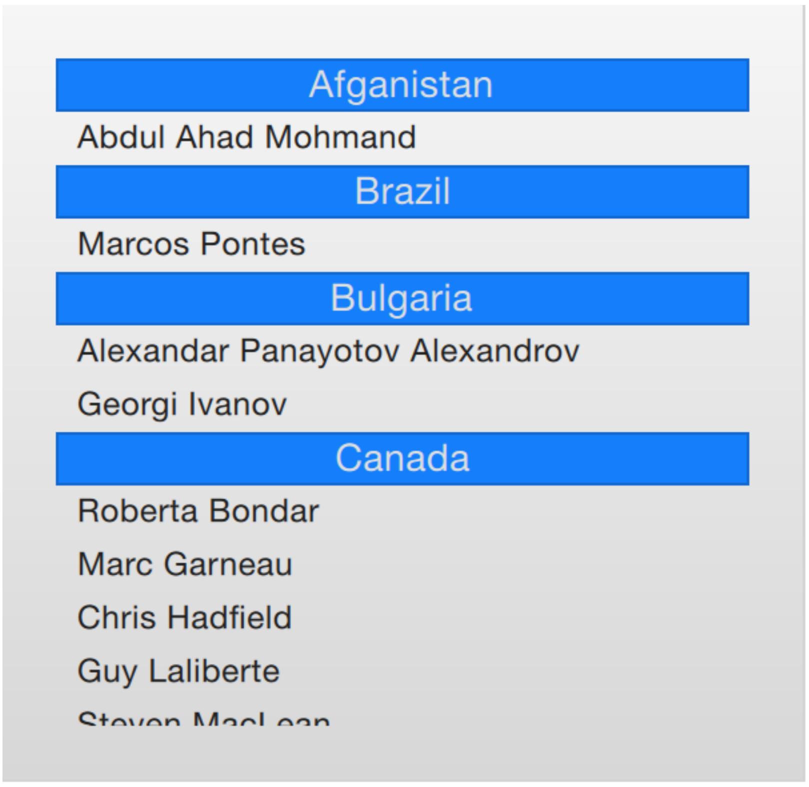
In order to use sections, the `section.property` and `section.criteria` must be set up. The `section.property` defines which property to use to divide the contents into sections. Here, it is important to know that the model must be sorted so that each section consists of continuous elements, otherwise, the same property name might appear in multiple locations.

The `section.criteria` can be set to either `ViewSection.FullString` or `ViewSection.FirstCharacter`. The first is the default value and can be used for models that have clear sections, for example, tracks of music albums. The latter takes the first character of a property and means that any property can be used for this. The most common example being the last name of contacts in a phone book.

When the sections have been defined, they can be accessed from each item using the attached properties `ListView.section`, `ListView.previousSection` and `ListView.nextSection`. Using these properties, it is possible to detect the first and last item of a section and act accordingly.

It is also possible to assign a section delegate component to the `section.delegate` property of a `ListView`. This creates a section header delegate which is inserted before any items of a section. The delegate component can access the name of the current section using the attached property `section`.

The example below demonstrates the section concept by showing a list of spacemen sectioned after their nationality. The `nation` is used as the `section.property`. The `section.delegate` component,



`sectionDelegate`, shows a heading for each nation, displaying the name of the nation. In each section, the names of the spacemen are shown using the `spaceManDelegate` component.

```
import QtQuick 2.5
import "../common"

Background {
    width: 300
    height: 290

    ListView {
        anchors.fill: parent
        anchors.margins: 20

        clip: true

        model: spaceMen

        delegate: spaceManDelegate

        section.property: "nation"
        section.delegate: sectionDelegate
    }

    Component {
        id: spaceManDelegate

        Item {
            width: ListView.view.width
            height: 20
            Text {
                anchors.left: parent.left
                anchors.verticalCenter: parent.verticalCenter
                anchors.leftMargin: 8
```

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```
                font.pixelSize: 12
                text: name
                color: '#1f1f1f'
            }
        }
    }

    Component {
        id: sectionDelegate

        BlueBox {
            width: ListView.view.width
            height: 20
            text: section
            fontColor: '#e0e0e0'
        }
    }


    ListModel {
        id: spaceMen

        ListElement { name: "Abdul Ahad Mohmand"; nation: "Afganistan"; }
        ListElement { name: "Marcos Pontes"; nation: "Brazil"; }
        ListElement { name: "Alexandar Panayotov Alexandrov"; nation: "Bulgaria"; }
        ListElement { name: "Georgi Ivanov"; nation: "Bulgaria"; }
        ListElement { name: "Roberta Bondar"; nation: "Canada"; }
        ListElement { name: "Marc Garneau"; nation: "Canada"; }
        ListElement { name: "Chris Hadfield"; nation: "Canada"; }
        ListElement { name: "Guy Laliberte"; nation: "Canada"; }
        ListElement { name: "Steven MacLean"; nation: "Canada"; }
        ListElement { name: "Julie Payette"; nation: "Canada"; }
        ListElement { name: "Robert Thirsk"; nation: "Canada"; }
        ListElement { name: "Bjarni Tryggvason"; nation: "Canada"; }
        ListElement { name: "Dafydd Williams"; nation: "Canada"; }
    }
}
```

7.5.5 The ObjectModel

In some cases you might want to use a list view for a large set of different items. You can solve this using dynamic QML and `Loader`, but another options is to use an `ObjectModel` from the `QtQml.Models` module. The object model is different from other models as it lets you put the actual visual elements side the model. That way, the view does not need any `delegate`.

In the example below we put three `Rectangle` elements into the `ObjectModel`. However, one rectangle has a `Text` element child while the last one has rounded corners. This would have resulted in a table-style model using something like a `ListModel`. It would also have resulted in empty `Text` elements in the model.

```
import QtQuick 2.0
import QtQml.Models 2.1

Rectangle {
    width: 320
    height: 320

    gradient: Gradient {
        GradientStop { position: 0.0; color: "#f6f6f6" }
        GradientStop { position: 1.0; color: "#d7d7d7" }
```

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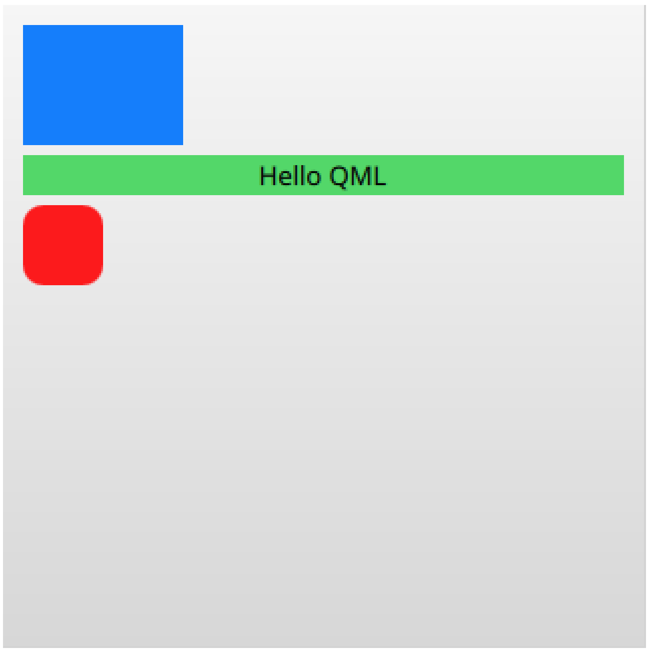

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```
    }

    ObjectModel {
        id: itemModel

        Rectangle { height: 60; width: 80; color: "#157efb" }
        Rectangle { height: 20; width: 300; color: "#53d769"
            Text { anchors.centerIn: parent; color: "black"; text: "Hello QML" }
        }
        Rectangle { height: 40; width: 40; radius: 10; color: "#fc1a1c" }
    }

    ListView {
        anchors.fill: parent
        anchors.margins: 10
        spacing: 5

        model: itemModel
    }
}
```

Another aspect of the `ObjectModel` is that is can be dynamically populated using the `get`, `insert`, `move`, `remove`, and `clear` methods. This way, the contents of the model can be dynamically generated from various sources and still easily shown in a single view.

7.5.6 Models with Actions

Since 5.11, the `ListElement` type supports the binding of Javascript functions to properties. This means that you can put functions into a model. This is very useful when building menus with actions and similar constructs.

The example below demonstrates this by having a model of cities that greet you in different ways. The `actionModel` is a model of four cities, but the `hello` property is bound to functions. Each function takes an argument `value`, but you can have any number arguments.

In the delegate `actionDelegate`, the `MouseArea` calls the function `hello` as an ordinary function and this results a call to the corresponding `hello` property in the model.

```
import QtQuick 2.11

Rectangle {
    width: 120
    height: 300

    gradient: Gradient {
        GradientStop { position: 0.0; color: "#f6f6f6" }
        GradientStop { position: 1.0; color: "#d7d7d7" }
    }

    ListModel {
        id: actionModel

        ListElement {
            name: "Copenhagen"
            hello: function(value) { console.log(value + ": You clicked Copenhagen!
↪"); }
        }
        ListElement {
            name: "Helsinki"
            hello: function(value) { console.log(value + ": Helsinki here!"); }
        }
        ListElement {
            name: "Oslo"
            hello: function(value) { console.log(value + ": Hei Hei fra Oslo!"); }
        }
        ListElement {
            name: "Stockholm"
            hello: function(value) { console.log(value + ": Stockholm calling!"); }
        }
    }

    ListView {
        anchors.fill: parent
        anchors.margins: 20

        clip: true

        model: actionModel

        delegate: actionDelegate
        spacing: 5

        focus: true
    }

    Component {
        id: actionDelegate

        Rectangle {
            width: ListView.view.width
            height: 40

            color: "#157efb"

            Text {
                anchors.centerIn: parent
                font.pixelSize: 10
                text: name
            }
```

(continues on next page)

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```
            MouseArea {
                anchors.fill: parent
                onClicked: hello(index);
            }
        }
    }
}
```

7.5.7 Tuning Performance

The perceived performance of a view of a model depends very much on the time needed to prepare new delegates. For instance, when scrolling downwards through a ListView, delegates are added just outside the view from the bottom and are removed just as they leave sight over the top of the view. This becomes apparent if the `clip` property is set to `false`. If the delegates take too much time to initialize, it will become apparent to the user as soon as the view is scrolled too quickly.

To work around this issue you can tune the margins, in pixels, on the sides of a scrolling view. This is done using the `cacheBuffer` property. In the case described above, vertical scrolling, it will control how many pixels above and below the ListView that will contain prepared delegates. Combining this with asynchronously loading `Image` elements can, for instance, give the images time to load before they are brought into view.

Having more delegates sacrifices memory for a smoother experience and slightly more time to initialize each delegate. This does not solve the problem of complex delegates. Each time a delegate is instantiated, its contents are evaluated and compiled. This takes time, and if it takes too much time, it will lead to a poor scrolling experience. Having many elements in a delegate will also degrade the scrolling performance. It simply costs cycles to move many elements.

To remedy the two latter issues, it is recommended to use `Loader` elements. These can be used to instantiate additional elements when they are needed. For instance, an expanding delegate may use a `Loader` to postpone the instantiation of its detailed view until it is needed. For the same reason, it is good to keep the amount of JavaScript to a minimum in each delegate. It is better to let them call complex pieced of JavaScript that resides outside each delegate. This reduces the time spent compiling JavaScript each time a delegate is created.

Note: Be aware that using a `Loader` to postpone initialization does just that - it postpones a performance issue. This means that the scrolling performance will be improved, but the actual contents will still take time to appear.

7.6 Summary

In this chapter, we have looked at models, views, and delegates. For each data entry in a model, a view instantiates a delegate visualizing the data. This separates the data from the presentation.

A model can be a single integer, where the `index` variable is provided to the delegate. If a JavaScript array is used as a model, the `modelData` variable represents the data of the current index of the array, while `index` holds the index. For more complex cases, where multiple values need to be provided by each data item, a `ListModel` populated with `ListElement` items is a better solution.

For static models, a `Repeater` can be used as the view. It is easy to combine it with a positioner such as `Row`, `Column`, `Grid` or `Flow` to build user interface parts. For dynamic or large data models, a view such as `ListView`, `GridView`, or `TableView` is more appropriate. These create delegate instances on the fly as they are needed, reducing the number of elements live in the scene at once.

The difference between `GridView` and `TableView` is that the table view expects a table type model with multiple columns of data while the grid view shows a list type model in a grid.

The delegates used in the views can be static items with properties bound to data from the model, or they can be dynamic, with states depending on if they are in focus or not. Using the `onAdd` and `onRemove` signals of the view, they can even be animated as they appear and disappear.

CHAPTER

EIGHT

FELGO

Section author: e8johan

Note: Last Build: December 07, 2020 at 10:50 CET

The source code for this chapter can be found in the assets folder.

Felgo is a cross-platform application development solution, based on the Qt framework and greatly extending it. Felgo applications run natively on many platforms, such as Android, iOS, Desktop (all three major OSs), Web (WebAssembly) and Embedded systems.

Felgo offers unique Qt/QML tooling, cloud services, and the Felgo SDK that adds more than 200 APIs extending Qt with capabilities such as:

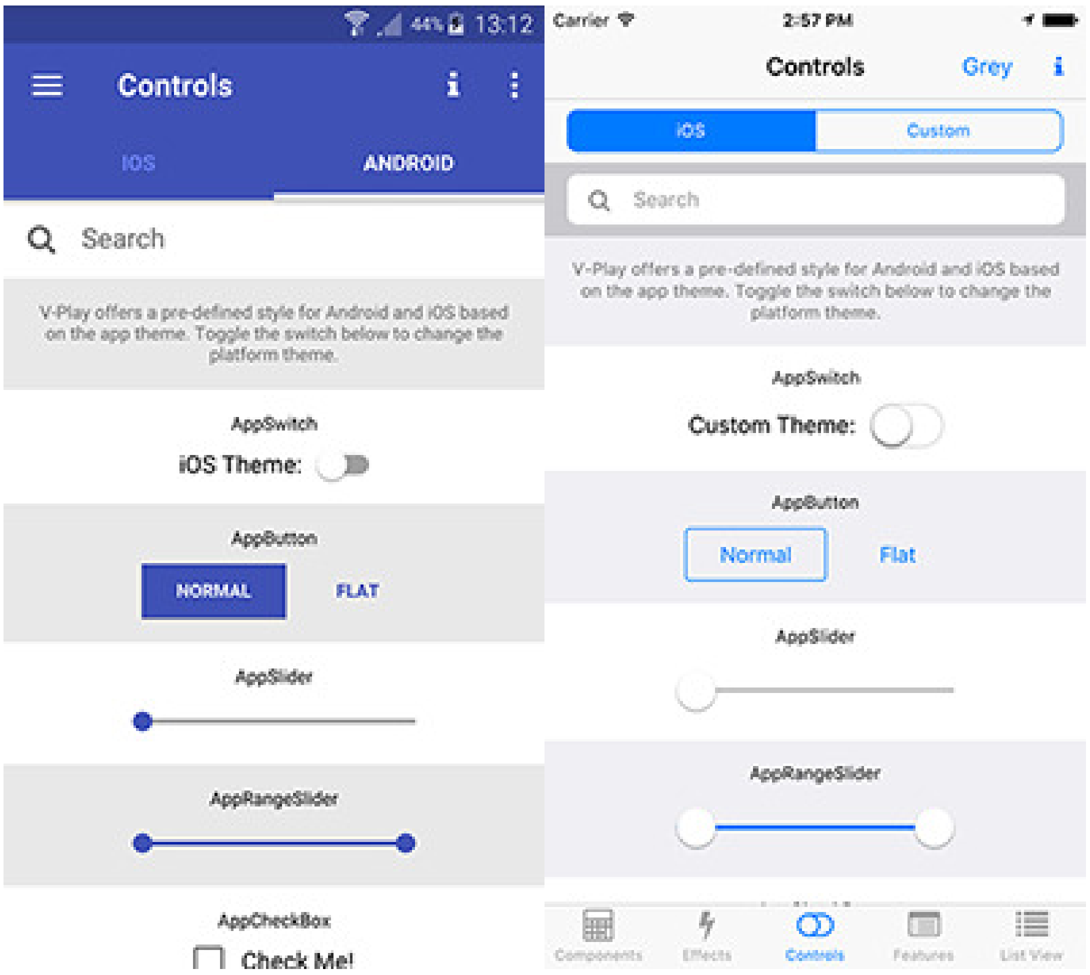
- Advanced controls and native navigation
- Theming and style
- Density independence
- Responsive layout
- File handling (local/remote)
- Data management and model/view
- Multimedia
- REST networking
- Native dialogs and features

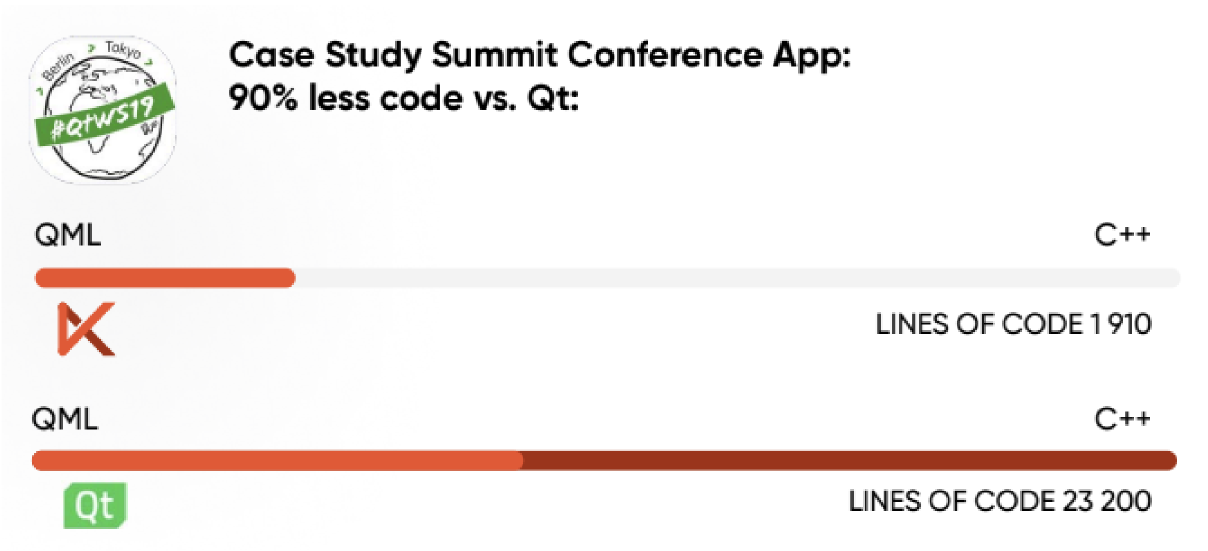
The screenshot below showcases how a single code base can be themed to look native on both Android and iOS.

Felgo is a Qt Technology Partner, and the SDK, which we will use in this chapter, can greatly help you save time and money when developing Qt applications. As the Felgo SDK extends Qt, it is possible to mix Felgo APIs with existing Qt and QML code. This means that you can add Felgo to your existing applications. In addition to the Felgo SDK, Felgo also provides consulting and training.

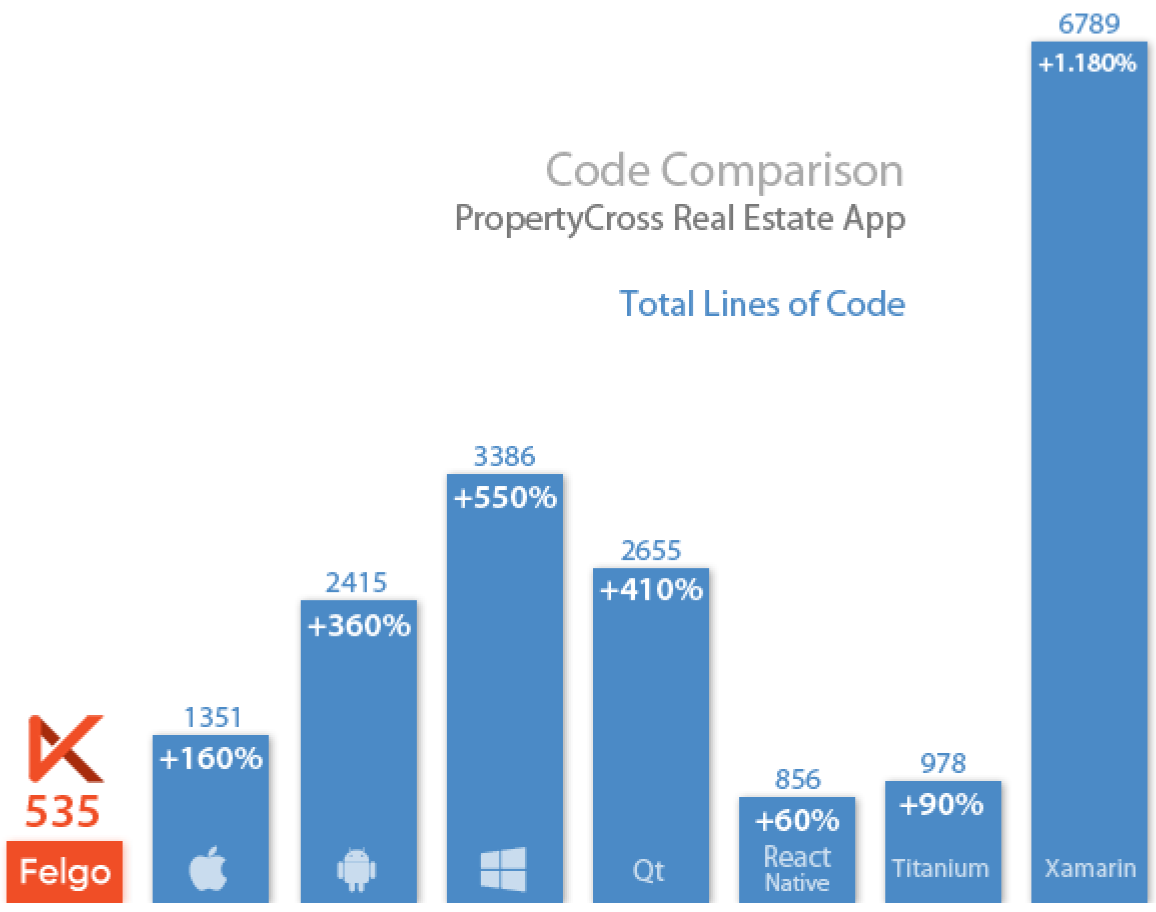
8.1 Why choose Felgo?

Felgo takes the cross platform story one step further. It lets you get more done from QML and reduces the need to write complex C++ code. For instance, the Felgo Qt World Summit Conference App, used at the annual Qt World Summit conference, has saved 90% code compared to the pure Qt/QML implementation.


13:12
Controls
IOS
ANDROID
Search
V-Play offers a pre-defined style for Android and iOS based on the app theme. Toggle the switch below to change the platform theme.
AppSwitch
iOS Theme:
AppButton
NORMAL
FLAT
AppSlider
AppRangeSlider
AppCheckBox
Check Me!
Carrier
2:57 PM
Controls
Grey
iOS
Custom
Search
V-Play offers a pre-defined style for Android and iOS based on the app theme. Toggle the switch below to change the platform theme.
AppSwitch
Custom Theme:
AppButton
Normal
Flat
AppSlider
AppRangeSlider
Components
Effects
Controls
Features
List View


Berlin
Tokyo
#QtWS19
Case Study Summit Conference App:
90% less code vs. Qt:
QML
C++
LINES OF CODE 1 910
QML
C++
Qt
LINES OF CODE 23 200

Code savings are not limited to the Qt world, but Felgo is a lot less verbose also compared to native development and competing cross-platform solutions.



8.2 Installing Felgo

In order to use Felgo you need to perform the following steps:

1. Sign-up to felgo.com. There are different purchasing options including a free tier which grants access to most features. In this text we will only use the free tier features.
2. Depending on your OS of choice, install the requirements: https://felgo.com/doc/felgo-installation/#install-requirements
3. Download Felgo: https://felgo.com/download/
4. Run the installer and proceed to install Felgo.

This installs the Felgo SDK, development tools and several demo applications. Felgo also comes with a specific version of Qt and an own QtCreator that includes useful Felgo plugins. It is possible to install the Felgo SDK in addition to other Qt installations on your system. If you have Qt installed already and only want to add Felgo to your installation take a look here: https://felgo.com/doc/felgo-installation/#add-felgo-to-existing-qt-installation.

8.2.1 Installing the Companion Apps

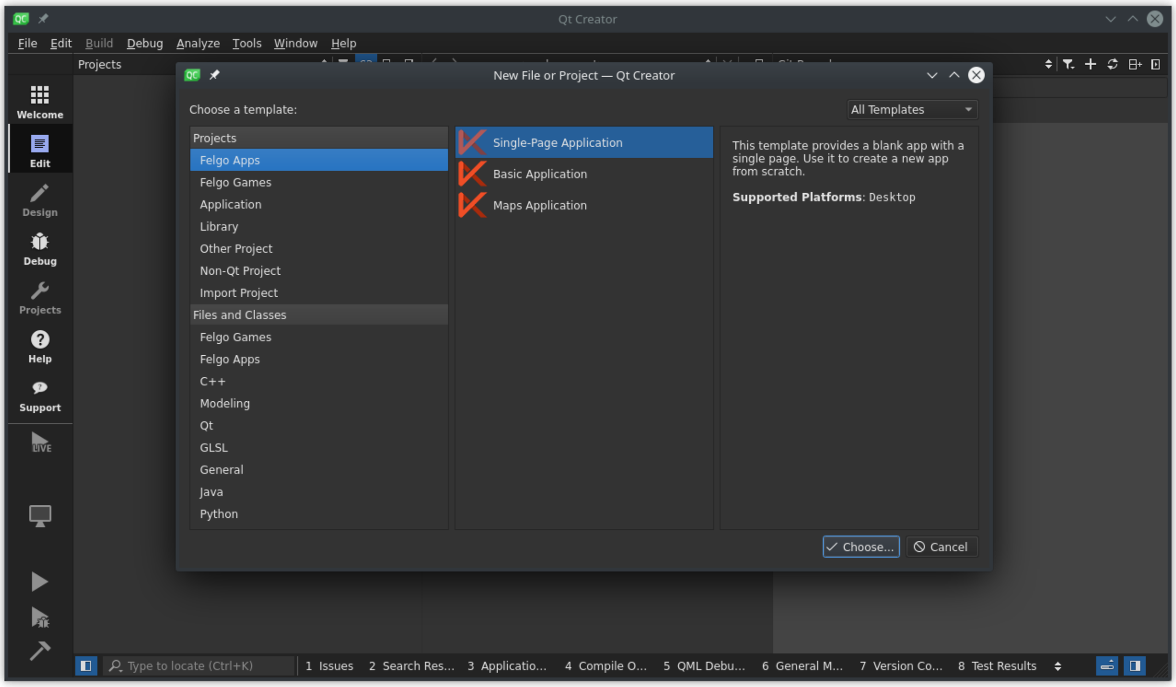
Felgo comes with a companion app that makes it easier to develop mobile apps, the the Felgo Live Client for Android and iOS.

You can connect the client apps to the Felgo Live Server tool that comes with the SDK. This allows you to directly test how your app works on mobile without having to build and deploy an app. With QML Hot Reload, you can see QML and JavaScript code changes applied instantly on all your devices.

8.3 Hello World with Felgo

Now that we have everything in place we can test the setup with our very first Felgo application: the mandatory *Hello World*. To do this, fire up the Felgo SDK Qt Creator and create a new project.

You will be faced by the ordinary project and file creation dialog, but with the *Felgo Apps* and *Felgo Games* categories for both projects and files. In this case, choose the *Single-Page Application* from the Felgo Apps project category.



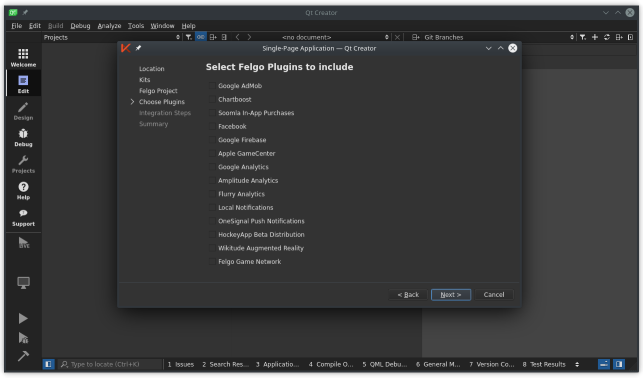
This template provides a blank app with a single page. Use it to create a new app from scratch.

Supported Platforms: Desktop

This will take you through the new project wizard, with some additional Felgo steps. Ensure that you pick the *Felgo Desktop* kit, especially if you have multiple versions of Qt installed. Also do not pick any additional plugins for now.

Felgo Plugins

Felgo comes with a large set of plugins focused at mobile app developers. These include integrations of various frameworks for ads, in-app purchasing as well as analytics. If you activate any of the plugins, the SDK will provide you with a link further outlining how to integrate the service selected.


Qt Creator
File Edit Build Debug Analyze Tools Window Help
Projects
<no document>
Git Branches
Welcome
Edit
Design
Debug
Projects
Help
Support
Type to locate (Ctrl+K)
1 Issues 2 Search Res... 3 Applicatio... 4 Compile O... 5 QML Debu... 6 General M... 7 Version Co... 8 Test Results

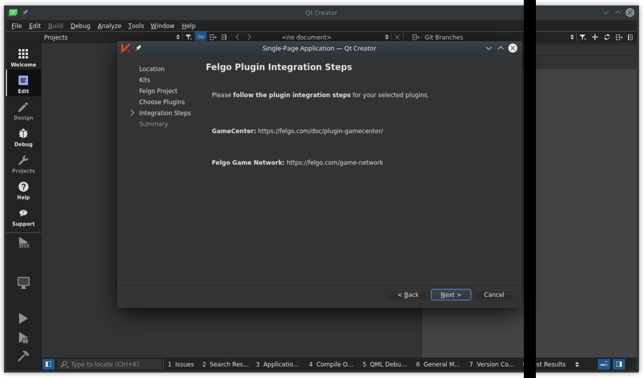
Single-Page Application — Qt Creator

Location
Kits
Felgo Project
Choose Plugins
Integration Steps
Summary

Select Felgo Plugins to include

- Google AdMob
- Chartboost
- Soomla In-App Purchases
- Facebook
- Google Firebase
- Apple GameCenter
- Google Analytics
- Amplitude Analytics
- Flurry Analytics
- Local Notifications
- OneSignal Push Notifications
- HockeyApp Beta Distribution
- Wikitude Augmented Reality
- Felgo Game Network

< Back | Next > | Cancel


Qt Creator
File Edit Build Debug Analyze Tools Window Help
Projects
<no document>
Git Branches
Welcome
Edit
Design
Debug
Projects
Help
Support
Type to locate (Ctrl+K)
1 Issues 2 Search Res... 3 Applicatio... 4 Compile O... 5 QML Debu... 6 General M... 7 Version Co... 8 Test Results

Single-Page Application — Qt Creator

Location
Kits
Felgo Project
Choose Plugins
Integration Steps
Summary

Felgo Plugin Integration Steps

Please **follow the plugin integration steps** for your selected plugins.

GameCenter: https://felgo.com/doc/plugin-gamecenter/

Felgo Game Network: https://felgo.com/game-network

< Back | Next > | Cancel

Once the project has been created, replace the contents of the `Main.qml` with the following Hello World code:

```
import Felgo 3.0
import QtQuick 2.0

App {
  NavigationStack {
    Page {
      title: qsTr("Welcome to Felgo")

      AppText {
        anchors.centerIn: parent
        text: "Hello World"
      }
    }
  }
}
```

You will notice that the live reloader will show a preview of your project looking like the figure below. The Live server and client will start when you load a project into Qt Creator, so if you're quick, you will notice when you changed the source code and saved, the live view was updated. If the Live Server is not running, you can start it via the *Live Run* button. It is placed on top of the *Build and Run* button in the left sidebar. The button starts the Felgo Live Server in addition to the Desktop version of the app.

The code above should look familiar if you've worked through the earlier chapters introducing QML. There is a new import of `Felgo 3.0` which includes every component of the FelgoSDK.

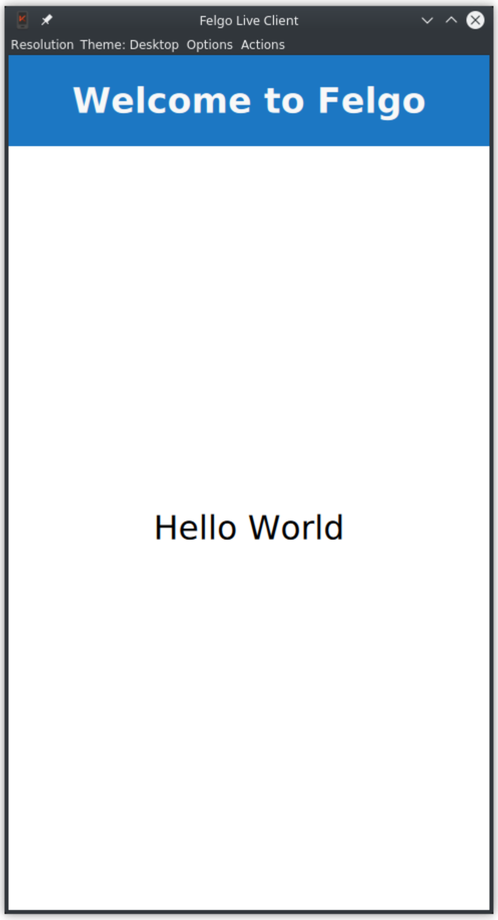
The root element is the App element with a nested NavigationStack. This component takes care of managing all the different Page instances your application is going to present.

Within the Page you can find an AppText element, which inherits from QtQuick.Text, but also manages proper font scaling. It offers a fontSize property that ensures the same physical size on all devices, avoiding the need to manually adapt the font.pixelSize setting of QtQuick.Text to the pixel density of your device.

In the Live Client view, you can you can change simulated resolutions or the application theme from the menu bar. You can test different screen formats and see how the app looks on an Android, iOS or Desktop device.

8.4 A Messaging App

Now that we have familiarized ourselves with the Felgo environment and run the Hello World code, let's transform the Hello World application into a messaging app. It will provide an overview page of all conversations, as well as one page per conversation showing the individual messages.



Welcome to Felgo

Hello World

8.4.1 A Skeleton

We start with defining the skeleton of our application. It initially shows a page with the most recent conversations. Put the following code into the `Main.qml` of a new project (or replace the contents of the Hello World project's `Main.qml`)

```
import Felgo 3.0
import QtQuick 2.0

App {
  Navigation {
    NavigationItem {
          title: qsTr("Recent")
          icon: IconType.clocko

      NavigationStack {
        ListPage {
            title: qsTr("Recent")
            emptyText.text: qsTr("No conversations yet!")
        }
      }
    }
  }
}
```

We can already see two new components: `Navigation`, and `NavigationItem`. The Navigation presents you with a single component for platform-specific navigation patterns. On Android or Desktop it will be displayed as a side menu, while on iOS it will use a bottom tab bar by default.

Now test it on Desktop: in the Live Client, make sure to select the Desktop theme and increase the window size by dragging at the window edges. Over a certain threshold the side-menu automatically gets visible. Felgo implements responsive design by default, meaning that the layout of the application adapts to the screen size and orientation.

The other new component: NavigationItem represents a root entry in the main navigation of your application. You can have multiple `NavigationItem` elements in your `Navigation` element. In the example code we define an icon and a title for the *Recent* page. Felgo comes with comprehensive icon font out of the box.

`NavigationStack` is a component which allows stacking pages on top of each other. At the moment we only have one `Page` that feels a bit empty. Let's include some mock data by creating a new file.

To display lists of items you can rely on the AppListView, or you can take a shortcut and use the ListPage. This last component is a `Page` with a single `AppListView` as a child, with some properties of `AppListView` aliased for convenience such as `model` and `delegate`.

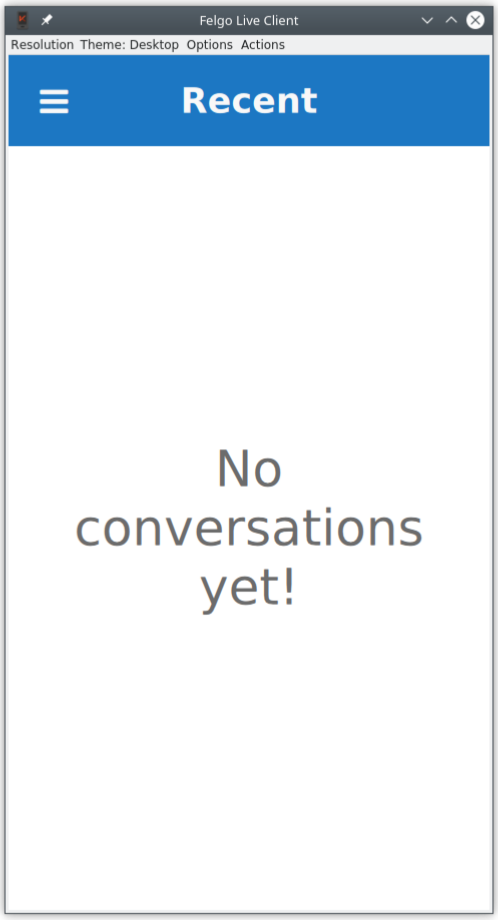
```
// Inside the ListPage
model: [
    { text: "Tom McEloy", detailText: "Sorry for the late reply ...", image: Qt.
↪resolvedUrl("../assets/portrait0.jpg") },
    { text: "Leah Douglas", detailText: "Hahaha :D", image: Qt.resolvedUrl("../
↪assets/portrait1.jpg") }
]
```

The model property is a standard QML ListModel. In this case we are just passing a javascript array. You can use any Qt/QML `ListModel`, or the JsonListModel from Felgo, optimized to handle JSON data in a performant way.

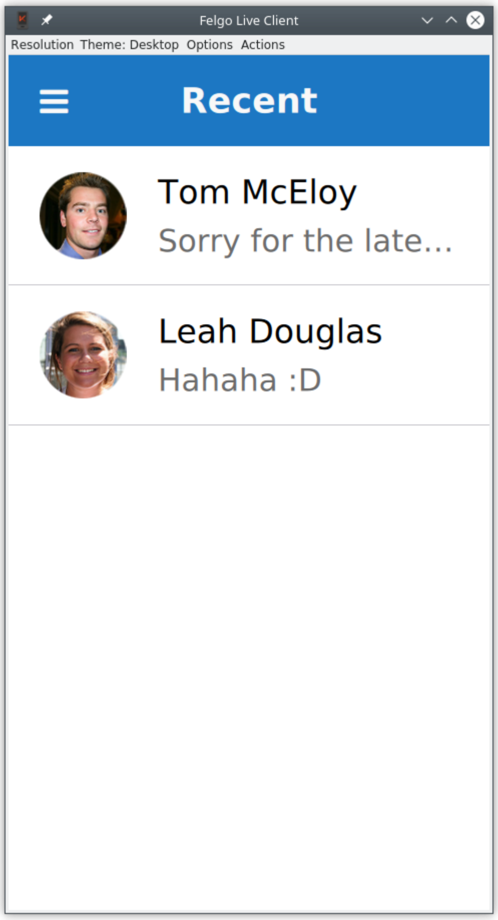
Now let's attach a delegate to show the model contents. The result is shown in the figure below, followed by the source code.

```
// Inside the ListPage
delegate: SimpleRow {
    image.radius: image.height
```

(continues on next page)



No conversations yet!


Felgo Live Client
Resolution Theme: Desktop Options Actions
Recent
Tom McEloy
Sorry for the late...
Leah Douglas
Hahaha :D

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```
    image.fillMode: Image.PreserveAspectCrop
    autoSizeImage: true
    style.showDisclosure: false
    imageMaxSize: dp(48)
    detailTextItem.maximumLineCount: 1
    detailTextItem.elide: Text.ElideRight
}
```

SimpleRow is a flexible Felgo component which represents a single entry in a list. It has many useful properties such as image, primary text and subtext. It also tries to be smart and picks out the corresponding model keys automatically. In the example, the `text`, `detailText`, and `image` are set this way. Check out the element documentation for a complete list of what model properties are picked up automatically by `SimpleRow`.

`SimpleRow` is composed of different QML items that are exposed through properties. You can tweak each item if the default setup is not satisfying. In the example, we are overriding the `radius` property of the `image` item to create a rounded image.

Another interesing detail in the example above is that `imageMaxSize` is defined as `dp(48)`. Felgo uses density independent sizes, meaning that elements have the same size regardless of the device screen. To benefit from this you should always use `dp()` for setting the size of visual items such as buttons, and `sp()` for texts which can also scale along to the preferred base size of a user. For details about how to create apps for multiple screen sizes and densities using Felgo, see: Supporting Multiple Screen Sizes & Screen Densities with Felgo Apps.

8.4.2 Showing Conversations

Now it is time to get interactive. When our user selects a conversation, we want to open a new page for that conversation. Let's start by adding a new `Component` to the bottom of `Main.qml` of our app.

```
// Inside the App
Component {
    id: conversationComponent
    ListPage {
        id: conversationPage
        emptyText.text: qsTr("No messages")
        // ...
```

As you can see from the code above, each conversation is represented by a `ListPage` instance. When the user clicks on a conversation we can now push a new instance of the `conversationComponent` page onto our `navigationStack`. The `title` for each new page is the text of the selected item. This is done from the `onSelected` signal in our `SimpleRow` delegate that we showed earlier. We use the popAllExceptFirstAndPush method to ensure that we only have one conversation at a time open.

```
// Inside the recent list delegate
onSelected: {
    navigationStack.popAllExceptFirstAndPush(conversationComponent, { title: item.
↪text })
}
```

At this stage, you can navigate back and forth between the conversation list and details and see the title changing accordingly. We can fill up the conversation page by adding some mock messages as the model.

```
// Inside the conversationComponent ListPage
model: [
    { text: "There are many variations of passages of Lorem Ipsum available, but␣
↪the majority have suffered alteration.", me: false },
    { text: "Lorem ipsum dolor sit amet, consectetuer adipiscing elit, sed diam␣
↪nonummy nibh euismod tincidunt ut laoreet dolore magna aliquam erat volutpat.",␣
↪me: true },
    { text: "All the Lorem Ipsum generators on the Internet tend to repeat␣
↪predefined chunks as necessary, making this the first true generator on the␣
↪Internet. It uses a dictionary of over 200 Latin words.", me: false },
```

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(continued from previous page)

```
    { text: "There are many variations of passages of Lorem Ipsum available, but␣
↪the majority have suffered alteration.", me: false },
    { text: "Lorem ipsum dolor sit amet, consectetuer adipiscing elit, sed diam␣
↪nonummy nibh euismod tincidunt ut laoreet dolore magna aliquam erat volutpat.",␣
↪me: true },
    { text: "All the Lorem Ipsum generators on the Internet tend to repeat␣
↪predefined chunks as necessary, making this the first true generator on the␣
↪Internet. It uses a dictionary of over 200 Latin words.", me: false }
]
```

Similar to the list of conversations, this model for the messages acts as source for a `ListPage`, but for this page, we want a custom user interface to show the messages. We can do this by creating a custom `delegate` as shown below.

```
// Inside the conversationComponent ListPage
delegate: Item {
    id: bubble

    property real spacing: dp(Theme.contentPadding)

    width: conversationPage.width
    height: bubbleBackground.height + 2 * spacing

    Rectangle {
        id: bubbleBackground
        color: modelData.me ? Theme.tintColor : "#e9e9e9"
        radius: bubble.spacing

        x: modelData.me ? (bubble.width - width - bubble.spacing) : bubble.spacing
        y: bubble.spacing
        width: innerText.width + 2 * bubble.spacing
        height: innerText.implicitHeight + 2 * bubble.spacing

        AppText {
            id: innerText
            x: bubble.spacing
            y: bubble.spacing
            width: Math.min(innerText.implicitWidth, bubble.parent.width * 0.75)
            wrapMode: Text.WordWrap
            text: modelData.text
            color: modelData.me ? "white" : "black"
        }
    }
}
```

This delegate allows us to provide a custom look for our message list, as shown below.

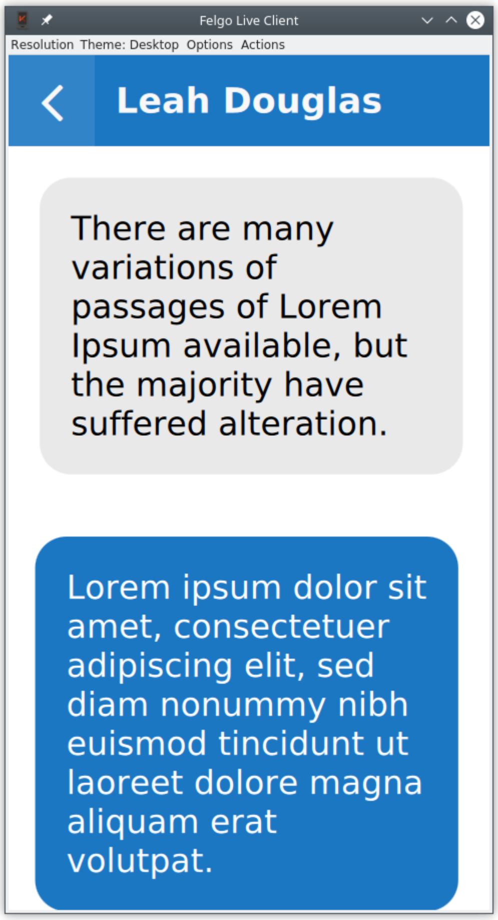
The text is shown using the AppText element, that ensures that the size of the text is device independent. The `AppText` relies on the application's Theme. Each Felgo application has a theme, and inside the `Theme` object, the global styling options for the application are found. In the code above we use `Theme.tintColor` for the primary color and `Theme.contentPadding` for the system dependent padding size. By default, the `Theme` ensures a native look and feel across platforms.

8.4.3 Sending Messages

The last step is to let the user send messages. For this, let's add a AppTextField to the bottom of our conversation page.

```
// Inside the conversationComponent ListPage
listView.anchors.bottomMargin: inputBox.height
```

(continues on next page)



There are many variations of passages of Lorem Ipsum available, but the majority have suffered alteration.

Lorem ipsum dolor sit amet, consectetuer adipiscing elit, sed diam nonummy nibh euismod tincidunt ut laoreet dolore magna aliquam erat volutpat.

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```
// horizontal separator line between input text and
Rectangle {
    height: px(1)
    anchors.bottom: inputBox.top
    anchors.left: parent.left
    anchors.right: parent.right
    color: "#cccccc"
}

AppTextField {
    id: inputBox
    height: dp(48)
    anchors.bottom: parent.bottom
    anchors.left: parent.left
    anchors.right: parent.right
    anchors.leftMargin: Theme.contentPadding
    anchors.rightMargin: Theme.contentPadding
    font.pixelSize: sp(16)
    placeholderText: qsTr("Type a message ...")
    backgroundColor: "white"
    verticalAlignment: Text.AlignVCenter

    onAccepted: {
        // Here we update the model
        var newModel = conversationPage.model
        newModel.push({me: true, text: inputBox.text})
        conversationPage.model = newModel

        inputBox.text = ""
        conversationPage.listView.positionViewAtEnd()
    }
}
```

The `AppTextField` let's the user enter text, and provides the `onAccepted` signal when the text is ready. Each time the user provides a new text, we update the model and clear the text field.

8.4.4 Storing Data

At the moment, the application only uses mock data and does not connect to any backend. This means that all messages the user adds will disappear every time the application is closed. We can fix this by using a data storage API.

QtQuick allows you to use an SQL database, which is a fast option even for large data, but it is rather inconvenient to use for our simple data structure. Instead, we will save our data as JSON data. Something that fits well into QML, as it is based on JavaScript.

With the Storage item, Felgo provides a JSON-optimized component for this. You can access the database as a simple key-value store and there is no need for complex SQL queries. In its simplest form the API looks a bit like: `myStorage.setValue (key, value)` and `value = myStorage.getValue(key)`.

Felgo automatically calls JSON.stringify() when writing composed values, automatically serializing the data. You can also take direct control of the underlying database using SQL queries if needed.

We use the `Storage` class via the `app.settings` property, which is the central application settings store. In the example below, you can see how we populate the model with mock data if the model is empty, or use the stored data otherwise.

```
// Inside the conversationComponent ListPage
Storage {
```

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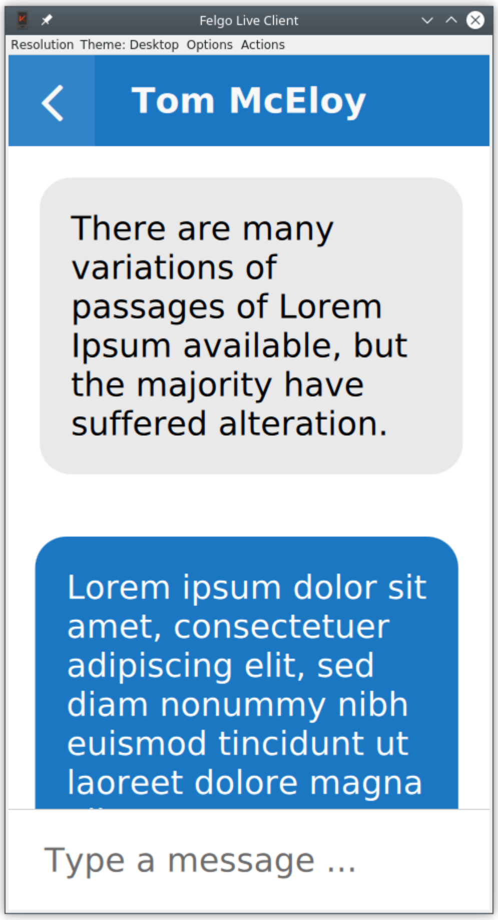


There are many variations of passages of Lorem Ipsum available, but the majority have suffered alteration.

Lorem ipsum dolor sit amet, consectetuer adipiscing elit, sed diam nonummy nibh euismod tincidunt ut laoreet dolore magna

(continued from previous page)

```
    id: storage
}

function loadStorageMessages() {
    var messages = storage.getValue("messages_" + person)
    if (messages === undefined) {
        messages = [
                    { text: "There are many variations of passages of Lorem Ipsum␣
↪available, but the majority have suffered alteration.", me: false },
                    { text: "Lorem ipsum dolor sit amet, consectetuer adipiscing␣
↪elit, sed diam nonummy nibh euismod tincidunt ut laoreet dolore magna aliquam␣
↪erat volutpat.", me: true },
                    { text: "All the Lorem Ipsum generators on the Internet tend␣
↪to repeat predefined chunks as necessary, making this the first true generator␣
↪on the Internet. It uses a dictionary of over 200 Latin words.", me: false },
                    { text: "There are many variations of passages of Lorem Ipsum␣
↪available, but the majority have suffered alteration.", me: false },
                    { text: "Lorem ipsum dolor sit amet, consectetuer adipiscing␣
↪elit, sed diam nonummy nibh euismod tincidunt ut laoreet dolore magna aliquam␣
↪erat volutpat.", me: true },
                    { text: "All the Lorem Ipsum generators on the Internet tend␣
↪to repeat predefined chunks as necessary, making this the first true generator␣
↪on the Internet. It uses a dictionary of over 200 Latin words.", me: false }
                ]
    }
    model = messages
}

Component.onCompleted: loadStorageMessages()

function storeNewMessages() {
    storage.setValue("messages_" + person, model)
}
```

In addition to this snippet, the `conversationPage.storeNewMessages()` has to be called from the `onAccepted` signal in the `AppTextField` so that each new message is stored as it is added.

The screenshot below shows a stored message that has been saved between two executions of the app (you'll have to trust me on that).

If you want to take the messaging application to the next level, you can also use Felgo to directly integrate your QML to Google Firebase or the Felgo Cloud backend, to provide a proper, cloud based storage option. But that is a completely different story.

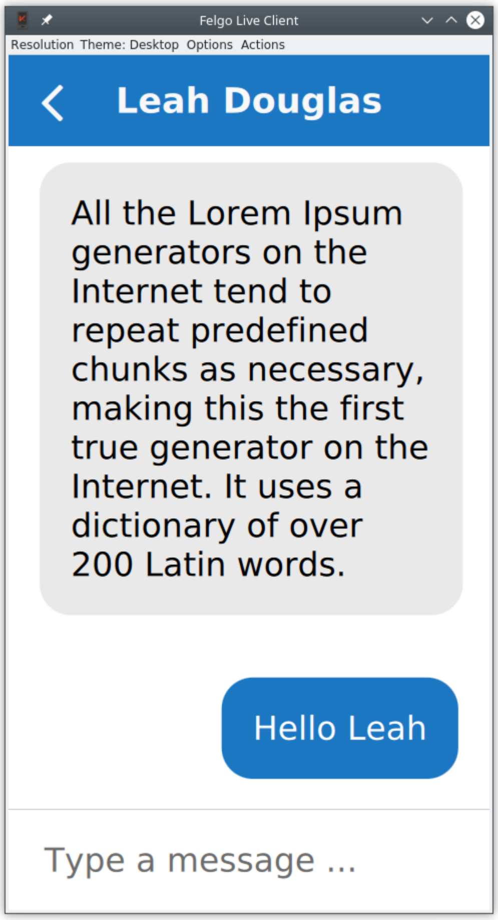
8.4.5 Refactoring

Up until now, we've created the entire messaging app in a single QML file. This works for smaller apps, but we are already way beyond a hundred lines of code in our example. For the interested reader, there is a refactored version of the app available in the chapter example source code tarball where the app has been split into `RecentsPage.qml`, `ConversationPage.qml`, and `Main.qml`. This way, the complexity in each file can be kept down and the various parts of the app can be kept separate from each other.

8.5 Advanced Topics

8.5.1 Theming

Felgo comes with theming capabilities, making it easy to customize the look of your application. The Theme object contains a set of properties that control the appearance of the user interface. It can easily be controlled in



All the Lorem Ipsum generators on the Internet tend to repeat predefined chunks as necessary, making this the first true generator on the Internet. It uses a dictionary of over 200 Latin words.

Hello Leah

the App::onInitTheme signal.

```
App {
  onInitTheme: {
     Theme.colors.textColor = "#000080"
   }
}
```

In the example above we change the tint color. This affects many parts of your UI such as the `ActionBar` color on Android and the highlight color on iOS.

You can also customize the background color, as well as many other details such as the navigation bar color, or the main font. If you feel like it, you can completely change the platform style, as shown below, the Android theme is swapped for the iOS theme and the other way around.

```
App {
  onInitTheme: {
    Theme.na.backgroundColor = "#ff0000"
    Theme.colors.backgroundColor = "#cccccc"
    Theme.colors.secondaryBackgroundColor = "#cccccc"
    Theme.platform = (Theme.platform === "android") ? "ios" : "android"
   }
}
```

You can also lock the `Theme.platform` to a fixed style, and thus offer the same look and experience on all platforms. It all depends on what kind of user experience your are trying to create.

Styling Items

If you want to dig deeper you can customize the look and feel of specific components. Each component has an entry in the theme object. In the example below we customize buttons so they have a red background and a with a border that creates a fake 3D effect.

```
App {
  onInitTheme: {
    Theme.appButton.backgroundColor = "red"
    Theme.appButton.radius = dp(8)

    Theme.appButton.borderColor = Qt.darker("red", 1.2)
    Theme.appButton.flatTextColor = "red"
    Theme.appButton.borderColorPressed = Theme.appButton.borderColor
    Theme.appButton.borderWidth = dp(2)
   }
}
```

While the Desktop and Android versions are going to have a raised style, the default iOS variant will be flat. That is why we also customize the `flatTextColor` to change the appearance. You can switch between platforms in the Felgo Live View to see how your styling appears on all platforms.

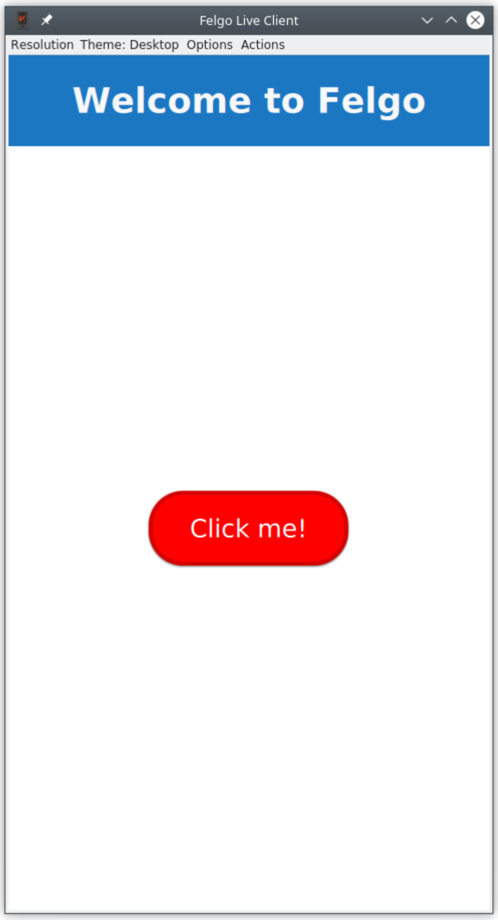
8.5.2 Model Sorting and Filtering

A common use-case in Apps is to sort the contents of a model. Here, Felgo provides a QML version of the SoftFilterProxyModel. Using this element you cannot only sort and filter models from QML, you can provide both sorters and filters directly from QML.

```
import Felgo 3.0
import QtQuick 2.0

 App {
```

(continues on next page)


Felgo Live Client
Resolution Theme: Desktop Options Actions
Welcome to Felgo
Click me!

(continued from previous page)

```
    Page {
      id: page

      //...

      SortFilterProxyModel {
      id: filteredTodoModel
      sourceModel: jsonModel

      // configure sorters
      sorters: [
        StringSorter {
          id: nameSorter
          roleName: "title"
        }]
    }

      AppListView {
        //...
        model: filteredTodoModel
        //...
      }
    }
  }
```

In the example above, a StringSorter is used, but Felgo comes with more sorters, as well as a range of filters.

8.5.3 Native App Features

There are many use cases which require accessing native features on every platform. Using Qt with C++ to bridge between QML, Java (Android) and Objective-C (iOS) can be quite complex. Manually writing this code requires a lot of time and effort, different implementations for each platform. Felgo provides many integrations which you can use out of the box to access native platform features.

The platform native features are exposed through the NativeUtils element, made available under the name `nativeUtils`.

Native Dialogs

Qt allows displaying QML dialogs, but sometimes you need native dialogs that are better integrated with the platform. Felgo provides a number of methods to create them:

- displayAlertDialog
- displayAlertSheet
- displayDatePicker
- displayMessageBox
- displayTextInput

Once one of the methods above are invoked, you can connect to the result in a slot for nativeUtils. Let's see an example in action:

```
import QtQuick 2.0
import Felgo 3.0

App {
  Page {
```

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```
    AppButton {
      text: qsTr("Click me")
      anchors.centerIn: parent
      onClicked: nativeUtils.displayTextInput(null, qsTr("Insert your name"))
    }

    Connections {
      target: nativeUtils
      onTextInputFinished: function (accepted, result) {
      console.log("Here's the result " + result)
    }
  }
}
```

You can also retrieve pictures from your camera or your gallery using `nativeUtils` methods.

- displayImagePicker
- displayCameraPicker

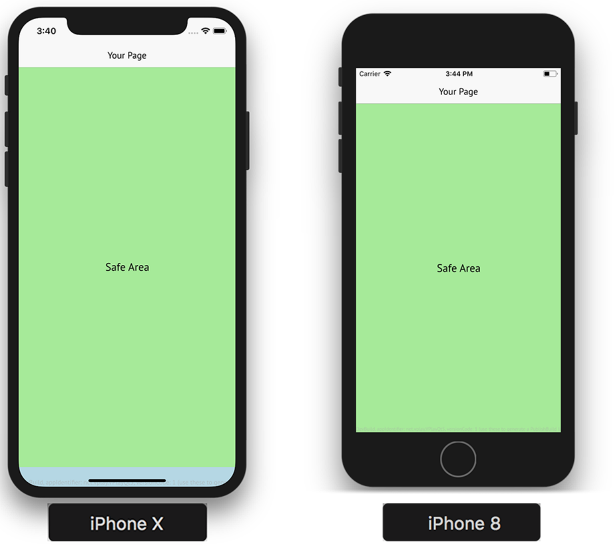
Usage is very similar to working with native dialogs: call the method and wait for a signal on completion.

```
import QtQuick 2.0
import Felgo 3.0

Page {
  Column {
    id: column
    anchors.centerIn: parent

    AppButton {
      text: qsTr("Pick from Gallery")
      onClicked: nativeUtils.displayImagePicker(text)
    }

    AppButton {
      text: qsTr("Pick from Camera")
      onClicked: nativeUtils.displayCameraPicker(text)
    }
  }

  Connections {
    target: nativeUtils
    onImagePickFinished: function (accepted, filePath) {
      console.log("Here's the picked image: " + filePath)
    }
    onCameraPickFinished: function (accepted, filePath) {
      console.log("Here's the camera image:" + filePath)
    }
  }
}
```

The original images will be copied into your application data directory and you'll get the path. This avoids all the complications introduced by the scoped storage policies on mobile devices.

Notch Support

Modern phones sometimes come with the camera placed in a notch inside the screen. Felgo introduces the concept of a `safeArea`. Anything inside this item is guaranteed not to be overlapped with various notch and gesture areas on both on Android and iOS. The safe area is enabled by default, but sometimes, you might feel the need to disable it, as shown below.



```
Page {
   useSafeArea: false // page content can cover whole screen

   // This will be drawn under the cutout or gesture areas
   Rectangle {
     anchors.fill: parent
     color: "red"
   }

   // This is anchored to the safe area so it won't be cut
   Rectangle {
     anchors.fill: parent.safeArea
     color: "lightgreen"
   }
 }
```

This allows full-screen designs, but you need to make sure that important parts of your UI are not affected by notches and gesture areas. To do so, you can rely on `nativeUtils.safeAreaInsets`, which contains the inset sizes in pixel values:

- `nativeUtils.safeAreaInsets.left`
- `nativeUtils.safeAreaInsets.top`
- `nativeUtils.safeAreaInsets.right`
- `nativeUtils.safeAreaInsets.bottom`

Native APIs

Some APIs are less visual than dialogs and notches. For instance, the `nativeUtils.contacts` provides access to the contact information from the device's address book. It is represented by a JavaScript object, and you can display all your contacts in a QML view as shown below.

```
import Felgo 3.0

 App {
   Page {
     AppListView {
       anchors.fill: parent
       model: nativeUtils.contacts
```

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```
      delegate: SimpleRow {
        text: modelData.name
        detailText: modelData.phoneNumbers.join(", ") // Join all numbers into a␣
↪string separated by a comma
      }
    }
  }
}
```

You can also share links and texts using `nativeUtils.share` or interact with files using `fileUtils`. In addition, there are many Felgo Plugins that simplify working with 3rd party Frameworks and libraries that target mobile platforms.

8.5.4 Networking

Felgo comes with a number of utily functions that come in handy. In this section we will show some of them that come in handy when building a modern, connected, application.

HttpRequest

With vanilla Qt/QML it is possible to perform network requests using the JavaScript `XMLHttpRequest` call. Felgo provides the HttpRequest that provides an easier to use interface.

In the example below, a request with a time-out is made, with one function called on success and another one on failure.

```
import Felgo 3.0
 import QtQuick 2.0

 App {
   Component.onCompleted: {
     HttpRequest
       .get("http://httpbin.org/get")
       .timeout(5000)
       .then(function(res) {
         console.log(res.status);
         console.log(JSON.stringify(res.header, null, 4));
         console.log(JSON.stringify(res.body, null, 4));
       })
       .catch(function(err) {
         console.log(err.message)
         console.log(err.response)
       });
   }
 }
```

Compared to `XMLHttpRequest`, the `HttpRequest` approach is more straight forward. All the HTTP CRUD operations are supported (get, post, put, patch, del). There also advanced features like request caching that can be enabled globally in `config`, as shown below.

```
HttpRequest.config({ cache: true });
```

Or for a specific request, as shown here.

```
HttpRequest
    .get("http://httpbin.org/get")
    .cacheSave(true) // cache the result of this request, regardless of global␣
↪cache setting
```

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```
    .cacheLoad(HttpCacheControl.PreferNetwork) // use network if possible,␣
↪otherwise load from cache
    .then(function(res) {
        console.log(JSON.stringify(res.body))
    })
    .catch(function(err) {
        console.log(err.message)
    });
```

Working with JSON data

Very often applications display data coming from remote endpoints. The data is exposed via JSON REST APIs. You can use it as the model for your lists, but a QML ListModel is the preferred and performant way. It allows to track changes and apply view updates on an entry-level, instead of just refreshing the whole list.

Felgo comes with the JsonListModel that provides a model with good performance and Qt integration, while working with JSON data.

In the example below, we populate the `jsonModel` with hardcoded JSON data , but we could just as easily have provided it with data from a remote server.

```
import Felgo 3.0
import QtQuick 2.0

 App {
   Page {
     id: page

     // property with json data
     property var jsonData: [
       {
         "id": 1,
         "title": "Entry 1"
       },
       {
         "id": 2,
         "title": "Entry 2"
       },
       {
         "id": 3,
         "title": "Entry 3"
       }
     ]

     // list model for json data
     JsonListModel {
       id: jsonModel
       source: page.jsonData
       keyField: "id"
     }

     // list view
     AppListView {
       anchors.fill: parent
       model: jsonModel
       delegate: SimpleRow {
         text: model.title
       }
     }
```

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```
    }
}
```

Download Resources, Files and PDFs

A lot of platform and file system specifics play into how you can interact with files on certain systems. The FileUtils element, provided through the global `fileUtils` item that is available as a context property from all QML components encapsulates methods that allow you to read, write and list files.

In the example below, we show how to download a PDF file and then open it with the native PDF viewer application using FileUtils::openFile(). It also uses the `DownloadableResource` type to download the PDF from a web location and store it on the device.

```
import Felgo 3.0
import QtQuick 2.0

App {
  id: app
  // uncomment this to remove the resources on startup, so you can test the␣
↪downloading again
  //Component.onCompleted: pdfResource.remove()
  NavigationStack {
    Page {
      title: "Download PDF"

      Column {
        anchors.centerIn: parent

        AppButton {
          text: "Download / Open"
          onClicked: {
            if(pdfResource.available) openPdf()
            else pdfResource.download()
          }
        }
        AppText {
          text: "Status: " + pdfResource.status
        }
      }
    }
  }
  DownloadableResource {
    id: pdfResource
    source: "http://www.orimi.com/pdf-test.pdf"
    storageLocation: FileUtils.DocumentsLocation
    storageName: "pdf-test.pdf"
    extractAsPackage: false
    // if the download is competed, available will be set to true
    onAvailableChanged: if(available) openPdf()
  }
  function openPdf() {
    // you can also open files with nativeUtils.openUrl() now (for paths starting␣
↪with "file://")
    //nativeUtils.openUrl(pdfResource.storagePath)
    fileUtils.openFile(pdfResource.storagePath)
  }
}
```

8.6 Summary

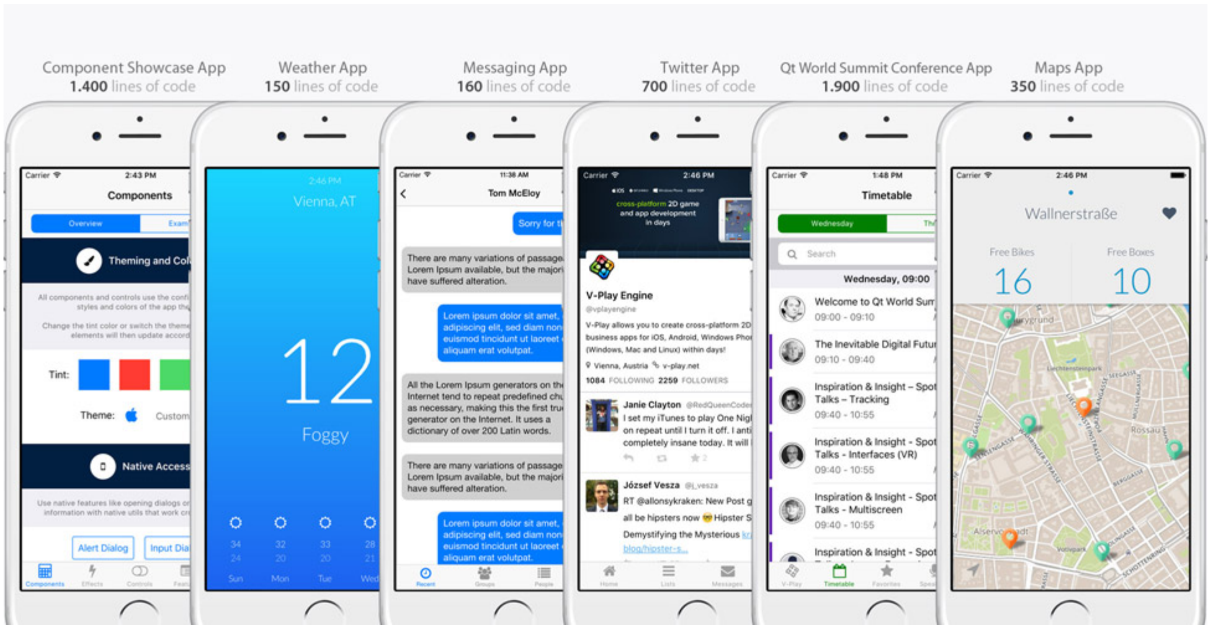
The Felgo SDK brings a lot of benefits to Qt/QML development. It allows you to create cross-platform apps that look native on: Android, iOS, Desktop, Web (WebAssembly) and Embedded systems. Supporting all kinds of devices, regardless of their different screen sizes and densities.

Use the navigation components to build your main menu and implement hierarchies of pages. Compose your page content with Felgo controls, lists and models. Introduce logic for data handling, storage, networking or to access native APIs like the device camera, contacts or dialogs. For all these areas, you can save a lot of time with a big variety of carefully constructed QML components.

Felgo provides you with all important tools for cross-platform app development with QML. Instead of worrying about pitfalls and issues that aren't specific to your project, you can focus on the actual work for your application. The customization options of Felgo leverage the flexibility of QML and are perfect for custom UI and branded apps. You can control the look with app-wide theme settings and freely customize or mix-in your own QML if needed.

This is just scratching the surface of what Felgo offers. You can see the full documentation, which also includes a large selection of Felgo Plugins. If you want to learn more about the Felgo SDK and application development with QML, explore free webinars or join one of the scheduled trainings.

If you enjoyed our messaging app, you can find more sample applications here. Feel free to take a look at their full source-code or use them as starting point to build awesome new applications.



CHAPTER

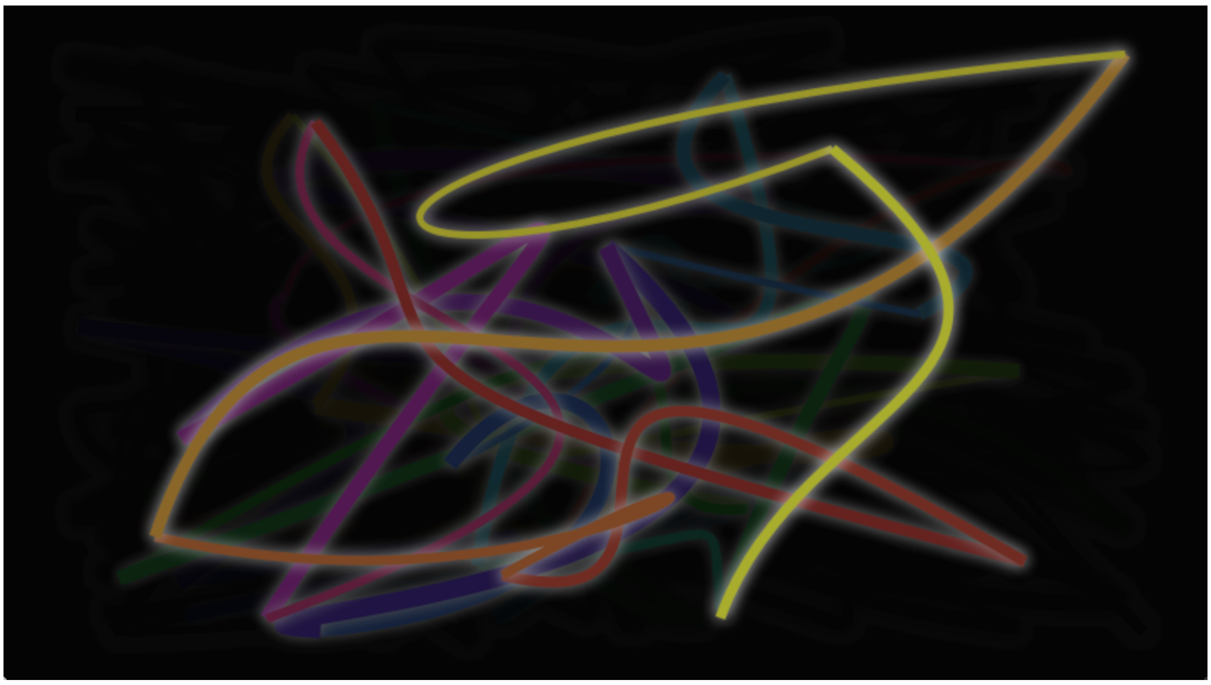
NINE

CANVAS ELEMENT

Section author: jryannel@LinkedIn

Note: Last Build: December 07, 2020 at 10:50 CET

The source code for this chapter can be found in the assets folder.



Early on when QML was introduced in Qt4 there were some discussions about if Qt Quick needs an ellipse. The problem with the ellipse is that others can argue other shapes need also be supported. So there is no ellipse in Qt Quick only rectangular shapes. If you needed one in Qt4 you would need to use an image or write your own C++ ellipse element.

To allow scripted drawings Qt 5 introduces the canvas element. The canvas elements provide a resolution-dependent bitmap canvas, which can be used for graphics, games or to paint other visual images on the fly using JavaScript. The canvas element is based on the HTML5 canvas element.

The fundamental idea of the canvas element is to render paths using a context 2D object. The context 2D object, contains the necessary graphics functions, whereas the canvas acts as the drawing canvas. The 2D context supports strokes, fills gradients, text and a different set of path creation commands.

Let's see an example of a simple path drawing:

```
import QtQuick 2.5

```

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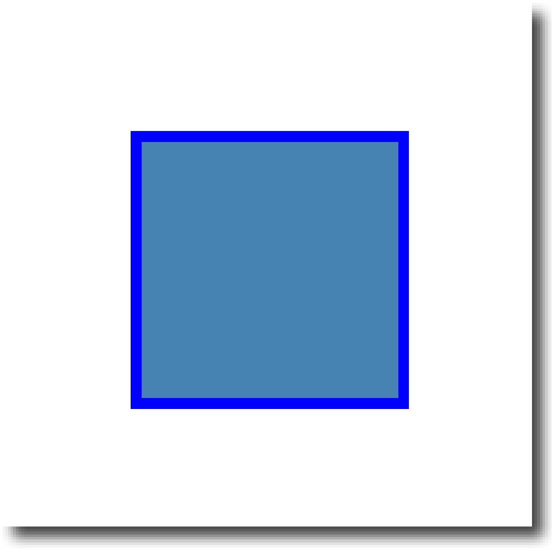
```
Canvas {
    id: root
    // canvas size
    width: 200; height: 200
    // handler to override for drawing
    onPaint: {
        // get context to draw with
        var ctx = getContext("2d")
        // setup the stroke
        ctx.lineWidth = 4
        ctx.strokeStyle = "blue"
        // setup the fill
        ctx.fillStyle = "steelblue"
        // begin a new path to draw
        ctx.beginPath()
        // top-left start point
        ctx.moveTo(50,50)
        // upper line
        ctx.lineTo(150,50)
        // right line
        ctx.lineTo(150,150)
        // bottom line
        ctx.lineTo(50,150)
        // left line through path closing
        ctx.closePath()
        // fill using fill style
        ctx.fill()
        // stroke using line width and stroke style
        ctx.stroke()
    }
}
```

This produces a filled rectangle with a starting point at 50,50 and a size of 100 and a stroke used as a border decoration.



The stroke width is set to 4 and uses a blue color define by `strokeStyle`. The final shape is set up to be filled through the `fillStyle` to a "steel blue" color. Only by calling `stroke` or `fill` the actual path will be drawn and they can be used independently from each other. A call to `stroke` or `fill` will draw the current path. It's not possible to store a path for later reuse only a drawing state can be stored and restored.

In QML the `Canvas` element acts as a container for the drawing. The 2D context object provides the actual drawing operation. The actual drawing needs to be done inside the `onPaint` event handler.

```
Canvas {
    width: 200; height: 200
    onPaint: {
        var ctx = getContext("2d")
        // setup your path
        // fill or/and stroke
    }
}
```

The canvas itself provides a typical two-dimensional Cartesian coordinate system, where the top-left is the (0,0) point. A higher y-value goes down and a hight x-value goes to the right.

A typical order of commands for this path based API is the following:

1. Setup stroke and/or fill
2. Create path
3. Stroke and/or fill

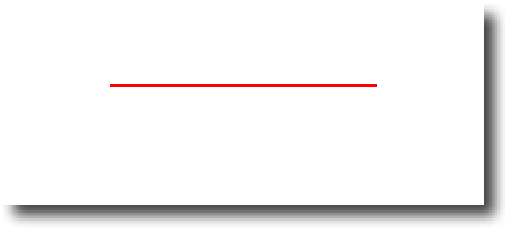
```
    onPaint: {
        var ctx = getContext("2d")

        // setup the stroke
        ctx.strokeStyle = "red"

        // create a path
        ctx.beginPath()
        ctx.moveTo(50,50)
        ctx.lineTo(150,50)

        // stroke path
        ctx.stroke()
    }
```

This produces a horizontal stroked line from point `P1(50,50)` to point `P2(150,50)`.



Note: Typically you always want to set a start point when you reset your path, so the first operation after `beginPath` is often `moveTo`.

9.1 Convenient API

For operations on rectangles, a convenience API is provided which draws directly and does need a stroke or fill call.

```
// convenient.qml

import QtQuick 2.5

Canvas {
```

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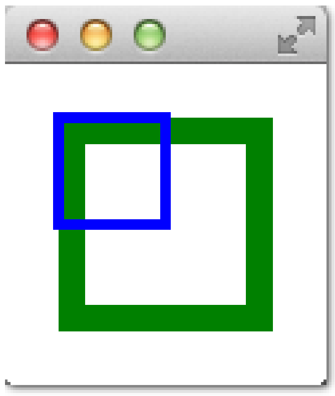
```
    id: root
    width: 120; height: 120
    onPaint: {
        var ctx = getContext("2d")
        ctx.fillStyle = 'green'
        ctx.strokeStyle = "blue"
        ctx.lineWidth = 4

        // draw a filles rectangle
        ctx.fillRect(20, 20, 80, 80)
        // cut our an inner rectangle
        ctx.clearRect(30,30, 60, 60)
        // stroke a border from top-left to
        // inner center of the larger rectangle
        ctx.strokeRect(20,20, 40, 40)
    }
}
```



Note: The stroke area extends half of the line width on both sides of the path. A 4 px lineWidth will draw 2 px outside the path and 2 px inside.

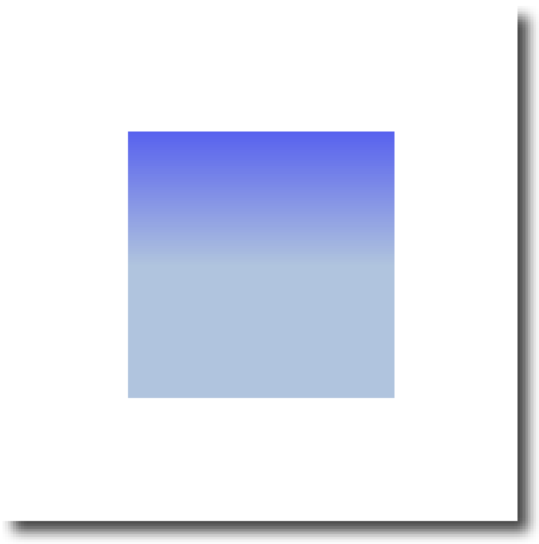
9.2 Gradients

Canvas can fill shapes with color but also with gradients or images.

```
    onPaint: {
        var ctx = getContext("2d")

        var gradient = ctx.createLinearGradient(100,0,100,200)
        gradient.addColorStop(0, "blue")
        gradient.addColorStop(0.5, "lightsteelblue")
        ctx.fillStyle = gradient
        ctx.fillRect(50,50,100,100)
    }
```

The gradient in this example is defined along the starting point (100,0) to the end point (100,200), which gives a vertical line in the middle of our canvas. The gradient-stops can be defined as a color from 0.0 (gradient start point) to 1.0 (gradient endpoint). Here we use a “blue” color at 0.0 (100,0) and a “lightsteelblue” color at the 0.5 (100,200) position. The gradient is defined as much larger than the rectangle we want to draw, so the rectangle clips gradient to it’s defined the geometry.

Note: The gradient is defined in canvas coordinates not in coordinates relative to the path to be painted. A canvas



does not have the concept of relative coordinates, as we are used to by now from QML.

9.3 Shadows

A path can be visually enhanced using shadows with the 2D context object. A shadow is an area around the path with an offset, color and specified blurring. For this you can specify a `shadowColor`, `shadowOffsetX`, `shadowOffsetY` and a `shadowBlur`. All of this needs to be defined using the 2D context. The 2D context is your only API to the drawing operations.

A shadow can also be used to create a glow effect around a path. In the next example, we create a text "Canvas" with a white glow around. All this on a dark background for better visibility.

First, we draw the dark background:

```
        // setup a dark background
        ctx.strokeStyle = "#333"
        ctx.fillRect(0,0,canvas.width,canvas.height);
```

then we define our shadow configuration, which will be used for the next path:

```
        // setup a blue shadow
        ctx.shadowColor = "#2ed5fa";
        ctx.shadowOffsetX = 2;
        ctx.shadowOffsetY = 2;
        ctx.shadowBlur = 10;
```

Finally, we draw our "Canvas" text using a large bold 80px font from the *Ubuntu* font family.

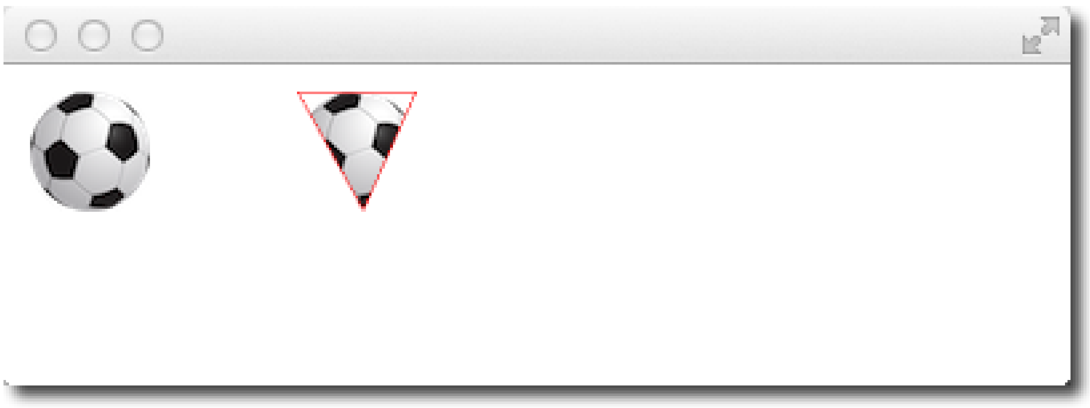
```
        // render green text
        ctx.font = 'bold 80px Ubuntu';
        ctx.fillStyle = "#24d12e";
        ctx.fillText("Canvas!",30,180);
```

9.4 Images

The QML canvas supports image drawing from several sources. To use an image inside the canvas the image needs to be loaded first. We will use the `Component.onCompleted` handler to load the image in our example.

```
    onPaint: {
        var ctx = getContext("2d")


        // draw an image
        ctx.drawImage('assets/ball.png', 10, 10)

        // store current context setup
        ctx.save()
        ctx.strokeStyle = '#ff2a68'
        // create a triangle as clip region
        ctx.beginPath()
        ctx.moveTo(110,10)
        ctx.lineTo(155,10)
        ctx.lineTo(135,55)
        ctx.closePath()
        // translate coordinate system
        ctx.clip()  // create clip from the path
        // draw image with clip applied
        ctx.drawImage('assets/ball.png', 100, 10)
        // draw stroke around path
        ctx.stroke()
        // restore previous context
        ctx.restore()

    }

    Component.onCompleted: {
        loadImage("assets/ball.png")
    }
```

The left shows our ball image painted at the top-left position of 10x10. The right image shows the ball with a clipping path applied. Images and any other path can be clipped using another path. The clipping is applied by defining a path and calling the `clip()` function. All following drawing operations will now be clipped by this path. The clipping is disabled again by restoring the previous state or by setting the clip region to the whole canvas.



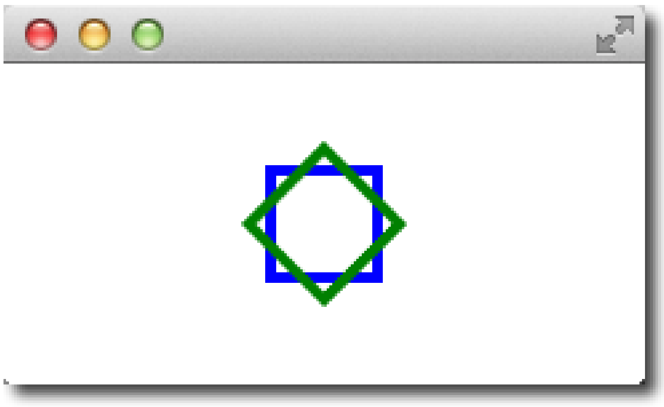
9.5 Transformation

The canvas allows you to transform the coordinate system in several ways. This is very similar to the transformation offered by QML items. You have the possibility to `scale`, `rotate`, `translate` the coordinate system. Indifference to QML the transform origin is always the canvas origin. For example to scale a path around its center you would need to translate the canvas origin to the center of the path. It is also possible to apply a more complex transformation using the transform method.

```
// transform.qml

import QtQuick 2.5

Canvas {
    id: root
    width: 240; height: 120
    onPaint: {
        var ctx = getContext("2d")
            var ctx = getContext("2d");
            ctx.lineWidth = 4;
            ctx.strokeStyle = "blue";

            // translate x/y coordinate system
            ctx.translate(root.width/2, root.height/2);

            // draw path
            ctx.beginPath();
            ctx.rect(-20, -20, 40, 40);
            ctx.stroke();

            // rotate coordinate system
            ctx.rotate(Math.PI/4);
            ctx.strokeStyle = "green";

            // draw path
            ctx.beginPath();
            ctx.rect(-20, -20, 40, 40);
            ctx.stroke();
    }
}
```

Besides translate the canvas allows also to scale using `scale(x,y)` around x and y-axis, to rotate using `rotate(angle)`, where the angle is given in radius (*360 degree = 2*Math.PI*) and to use a matrix transformation using the `setTransform(m11, m12, m21, m22, dx, dy)`.

Note: To reset any transformation you can call the `resetTransform()` function to set the transformation



matrix back to the identity matrix:

```
ctx.resetTransform()
```

9.6 Composition Modes

Composition allows you to draw a shape and blend it with the existing pixels. The canvas supports several composition modes using the `globalCompositeOperation(mode)` operation.

- `source-over`
- `source-in`
- `source-out`
- `source-atop`

```
    onPaint: {
        var ctx = getContext("2d")
        ctx.globalCompositeOperation = "xor"
        ctx.fillStyle = "#33a9ff"

        for(var i=0; i<40; i++) {
            ctx.beginPath()
            ctx.arc(Math.random()*400, Math.random()*200, 20, 0, 2*Math.PI)
            ctx.closePath()
            ctx.fill()
        }
    }
```

This little examples iterates over a list of composite modes and generates a rectangle with a circle.

```
    property var operation : [
        'source-over', 'source-in', 'source-over',
        'source-atop', 'destination-over', 'destination-in',
        'destination-out', 'destination-atop', 'lighter',
        'copy', 'xor', 'qt-clear', 'qt-destination',
        'qt-multiply', 'qt-screen', 'qt-overlay', 'qt-darken',
        'qt-lighten', 'qt-color-dodge', 'qt-color-burn',
        'qt-hard-light', 'qt-soft-light', 'qt-difference',
        'qt-exclusion'
        ]

    onPaint: {
```

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```
        var ctx = getContext('2d')

        for(var i=0; i<operation.length; i++) {
            var dx = Math.floor(i%6)*100
            var dy = Math.floor(i/6)*100
            ctx.save()
            ctx.fillStyle = '#33a9ff'
            ctx.fillRect(10+dx,10+dy,60,60)
            // TODO: does not work yet
            ctx.globalCompositeOperation = root.operation[i]
            ctx.fillStyle = '#ff33a9'
            ctx.globalAlpha = 0.75
            ctx.beginPath()
            ctx.arc(60+dx, 60+dy, 30, 0, 2*Math.PI)
            ctx.closePath()
            ctx.fill()
            ctx.restore()
        }
    }
```

9.7 Pixel Buffers

When working with the canvas you are able to retrieve pixel data from the canvas to read or manipulate the pixels of your canvas. To read the image data use `createImageData(sw,sh)` or `getImageData(sx,sy,sw, sh)`. Both functions return an `ImageData` object with a `width`, `height` and a `data` variable. The data variable contains a one-dimensional array of the pixel data retrieved in the *RGBA* format, where each value varies in the range of 0 to 255. To set pixels on the canvas you can use the `putImageData(imagedata, dx, dy)` function.

Another way to retrieve the content of the canvas is to store the data into an image. This can be achieved with the `Canvas` functions `save(path)` or `toDataURL(mimeType)`, where the later function returns an image URL, which can be used to be loaded by an `Image` element.

```
import QtQuick 2.5

Rectangle {
    width: 240; height: 120
    Canvas {
        id: canvas
        x: 10; y: 10
        width: 100; height: 100
        property real hue: 0.0
        onPaint: {
            var ctx = getContext("2d")
            var x = 10 + Math.random(80)*80
            var y = 10 + Math.random(80)*80
            hue += Math.random()*0.1
            if(hue > 1.0) { hue -= 1 }
            ctx.globalAlpha = 0.7
            ctx.fillStyle = Qt.hsla(hue, 0.5, 0.5, 1.0)
            ctx.beginPath()
            ctx.moveTo(x+5,y)
            ctx.arc(x,y, x/10, 0, 360)
            ctx.closePath()
            ctx.fill()
        }
        MouseArea {
            anchors.fill: parent
```

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```
                onClicked: {
                    var url = canvas.toDataURL('image/png')
                    print('image url=', url)
                    image.source = url
                }
            }
        }

        Image {
            id: image
            x: 130; y: 10
            width: 100; height: 100
        }

        Timer {
            interval: 1000
            running: true
            triggeredOnStart: true
            repeat: true
            onTriggered: canvas.requestPaint()
        }
}
```

In our little example, we paint every second a small circle on the left canvas. When the user clicks on the mouse area the canvas content is stored and an image URL is retrieved. On the right side of our example, the image is then displayed.

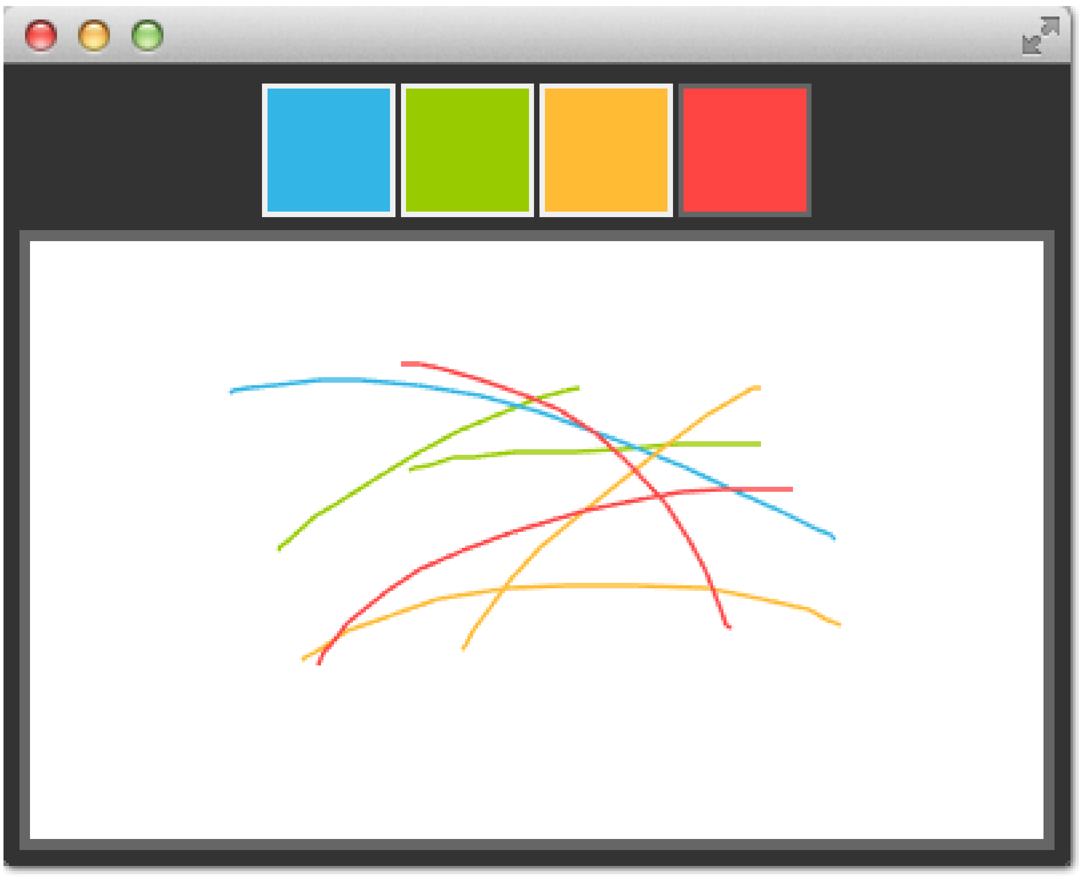
Note: Retrieving image data seems not to work currently in the Qt 5 Alpha SDK.

9.8 Canvas Paint

In this example, we would like to create a small paint application using the `Canvas` element.

For this, we arrange four color squares on the top of our scene using a row positioner. A color square is a simple rectangle filled with a mouse area to detect clicks.

```
    Row {
        id: colorTools
        anchors {
            horizontalCenter: parent.horizontalCenter
            top: parent.top
            topMargin: 8
        }
        property variant activeSquare: red
        property color paintColor: "#33B5E5"
        spacing: 4
        Repeater {
            model: ["#33B5E5", "#99CC00", "#FFBB33", "#FF4444"]
            ColorSquare {
                id: red
                color: modelData
                active: parent.paintColor == color
                onClicked: {
                    parent.paintColor = color
                }
            }
        }
    }
```



The colors are stored in an array and the paint color. When one the user clicks in one of the squares the color of the square is assigned to the paintColor property of the row named *colorTools*.

To enable tracking of the mouse events on the canvas we have a MouseArea covering the canvas element and hooked up the pressed and position changed handlers.

```
    Canvas {
        id: canvas
        anchors {
            left: parent.left
            right: parent.right
            top: colorTools.bottom
            bottom: parent.bottom
            margins: 8
        }
        property real lastX
        property real lastY
        property color color: colorTools.paintColor

        onPaint: {
            var ctx = getContext('2d')
            ctx.lineWidth = 1.5
            ctx.strokeStyle = canvas.color
            ctx.beginPath()
            ctx.moveTo(lastX, lastY)
            lastX = area.mouseX
            lastY = area.mouseY
            ctx.lineTo(lastX, lastY)
            ctx.stroke()
        }
        MouseArea {
```

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```
            id: area
            anchors.fill: parent
            onPressed: {
                canvas.lastX = mouseX
                canvas.lastY = mouseY
            }
            onPositionChanged: {
                canvas.requestPaint()
            }
        }
    }
```

A mouse press stores the initial mouse position into the *lastX* and *lastY* properties. Every change on the mouse position triggers a paint request on the canvas, which will result in calling the *onPaint* handler.

To finally draw the users stroke, in the *onPaint* handler we begin a new path and move to the last position. Then we gather the new position from the mouse area and draw a line with the selected color to the new position. The mouse position is stored as the new *last* position.

9.9 Porting from HTML5 Canvas

- https://developer.mozilla.org/en-US/docs/Web/API/Canvas_API/Tutorial/Transformations
- http://en.wikipedia.org/wiki/Spirograph

It is fairly easy to port an HTML5 canvas graphics over to use the QML canvas. From the thousands of examples, we picked one and tried it yourself.

Spiro Graph

We use a spirograph example from the Mozilla project as our foundation. The original HTML5 was posted as part of the canvas tutorial.

There were a few lines we needed to change:

- Qt Quick requires you to declare a variable, so we needed to add some *var* declarations

```
for (var i=0;i<3;i++) {
    ...
}
```

- Adapted the draw method to receive the Context2D object

```
function draw(ctx) {
    ...
}
```

- we needed to adapt the translation for each spiro due to different sizes

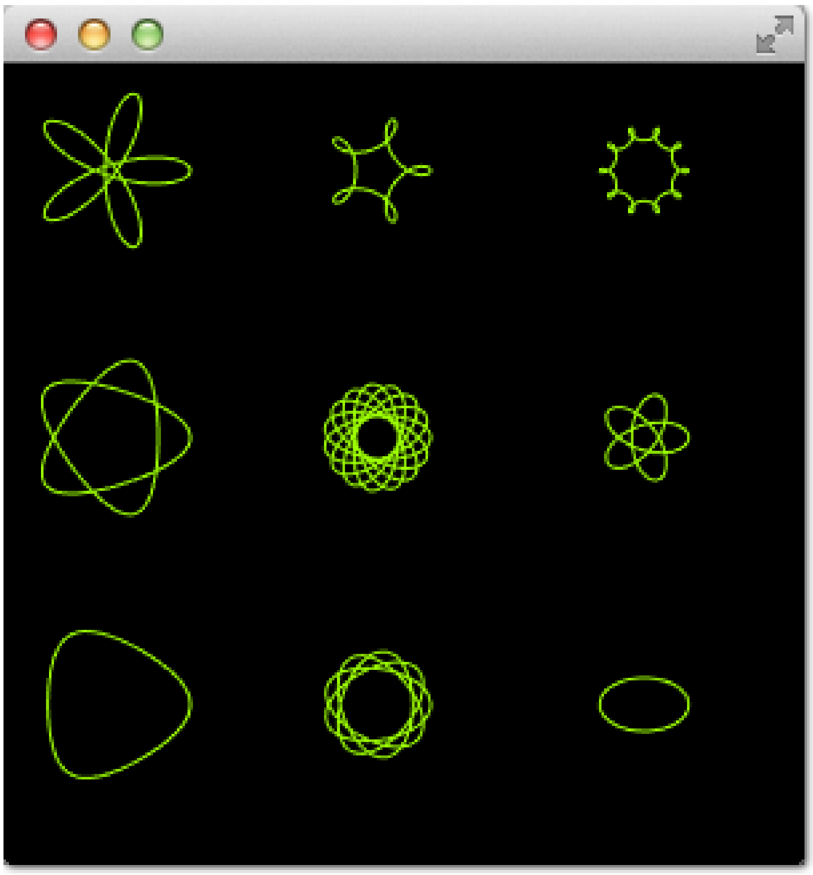
```
ctx.translate(20+j*50,20+i*50);
```

Finally, we completed our `onPaint` handler. Inside we acquire a context and call our draw function.

```
    onPaint: {
        var ctx = getContext("2d");
        draw(ctx);
    }
```

The result is a ported spiro graph graphics running using the QML canvas

That's all.



Glowing Lines

Here is another more complicated port from the W3C organization. The original pretty glowing lines has some pretty nice aspects, which makes the porting more challenging.

```
<!DOCTYPE HTML>
<html lang="en">
<head>
    <title>Pretty Glowing Lines</title>
</head>
<body>

<canvas width="800" height="450"></canvas>
<script>
var context = document.getElementsByTagName('canvas')[0].getContext('2d');

// initial start position
var lastX = context.canvas.width * Math.random();
var lastY = context.canvas.height * Math.random();
var hue = 0;

// closure function to draw
// a random bezier curve with random color with a glow effect
function line() {

    context.save();

    // scale with factor 0.9 around the center of canvas
    context.translate(context.canvas.width/2, context.canvas.height/2);
    context.scale(0.9, 0.9);
    context.translate(-context.canvas.width/2, -context.canvas.height/2);
```

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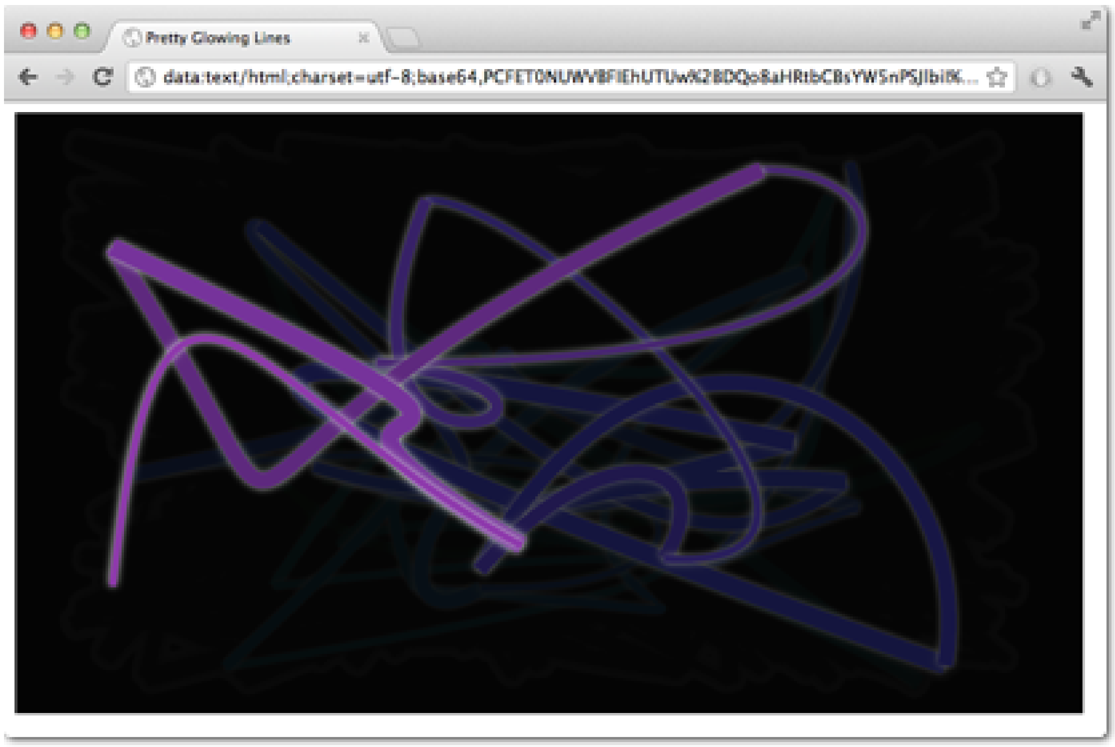
Pretty Glowing Lines
data:text/html;charset=utf-8;base64,PCFETONUWVBFIEhUTUw%2BDQo8aHRtbCBsYW5nPSJlbiI%...

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```
    context.beginPath();
    context.lineWidth = 5 + Math.random() * 10;

    // our start position
    context.moveTo(lastX, lastY);

    // our new end position
    lastX = context.canvas.width * Math.random();
    lastY = context.canvas.height * Math.random();

    // random bezier curve, which ends on lastX, lastY
    context.bezierCurveTo(context.canvas.width * Math.random(),
    context.canvas.height * Math.random(),
    context.canvas.width * Math.random(),
    context.canvas.height * Math.random(),
    lastX, lastY);

    // glow effect
    hue = hue + 10 * Math.random();
    context.strokeStyle = 'hsl(' + hue + ', 50%, 50%)';
    context.shadowColor = 'white';
    context.shadowBlur = 10;
    // stroke the curve
    context.stroke();
    context.restore();
}

// call line function every 50msecs
setInterval(line, 50);

function blank() {
    // makes the background 10% darker on each call
    context.fillStyle = 'rgba(0,0,0,0.1)';
```

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```
    context.fillRect(0, 0, context.canvas.width, context.canvas.height);
}

// call blank function every 50msecs
setInterval(blank, 40);

</script>
</body>
</html>
```

In HTML5 the Context2D object can paint at any time on the canvas. In QML it can only point inside the `onPaint` handler. The timer in usage with `setInterval` triggers in HTML5 the stroke of the line or to blank the screen. Due to the different handling in QML, it's not possible to just call these functions, because we need to go through the `onPaint` handler. Also, the color presentations need to be adapted. Let's go through the changes on by one.

Everything starts with the canvas element. For simplicity, we just use the `Canvas` element as the root element of our QML file.

```
import QtQuick 2.5

Canvas {
   id: canvas
   width: 800; height: 450

   ...
}
```

To untangle the direct call of the functions through the `setInterval`, we replace the `setInterval` calls with two timers which will request a repaint. A `Timer` is triggered after a short interval and allows us to execute some code. As we can't tell the paint function which operation we would like to trigger we define for each operation a bool flag request an operation and trigger then a repaint request.

Here is the code for the line operation. The blank operation is similar.

```
...
property bool requestLine: false

Timer {
    id: lineTimer
    interval: 40
    repeat: true
    triggeredOnStart: true
    onTriggered: {
        canvas.requestLine = true
        canvas.requestPaint()
    }
}

Component.onCompleted: {
    lineTimer.start()
}
...
```

Now we have an indication which (line or blank or even both) operation we need to perform during the `onPaint` operation. As we enter the `onPaint` handler for each paint request we need to extract the initialization of the variable into the canvas element.

```
Canvas {
    ...
    property real hue: 0
```

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```
    property real lastX: width * Math.random();
    property real lastY: height * Math.random();
    ...
}
```

Now our paint function should look like this:

```
onPaint: {
    var context = getContext('2d')
    if(requestLine) {
        line(context)
        requestLine = false
    }
    if(requestBlank) {
        blank(context)
        requestBlank = false
    }
}
```

The *line* function was extracted for a canvas as an argument.

```
function line(context) {
    context.save();
    context.translate(canvas.width/2, canvas.height/2);
    context.scale(0.9, 0.9);
    context.translate(-canvas.width/2, -canvas.height/2);
    context.beginPath();
    context.lineWidth = 5 + Math.random() * 10;
    context.moveTo(lastX, lastY);
    lastX = canvas.width * Math.random();
    lastY = canvas.height * Math.random();
    context.bezierCurveTo(canvas.width * Math.random(),
        canvas.height * Math.random(),
        canvas.width * Math.random(),
        canvas.height * Math.random(),
        lastX, lastY);

    hue += Math.random()*0.1
    if(hue > 1.0) {
        hue -= 1
    }
    context.strokeStyle = Qt.hsla(hue, 0.5, 0.5, 1.0);
    // context.shadowColor = 'white';
    // context.shadowBlur = 10;
    context.stroke();
    context.restore();
}
```

The biggest change was the use of the QML `Qt.rgba()` and `Qt.hsla()` functions, which required to adopt the values to the used 0.0 … 1.0 range in QML.

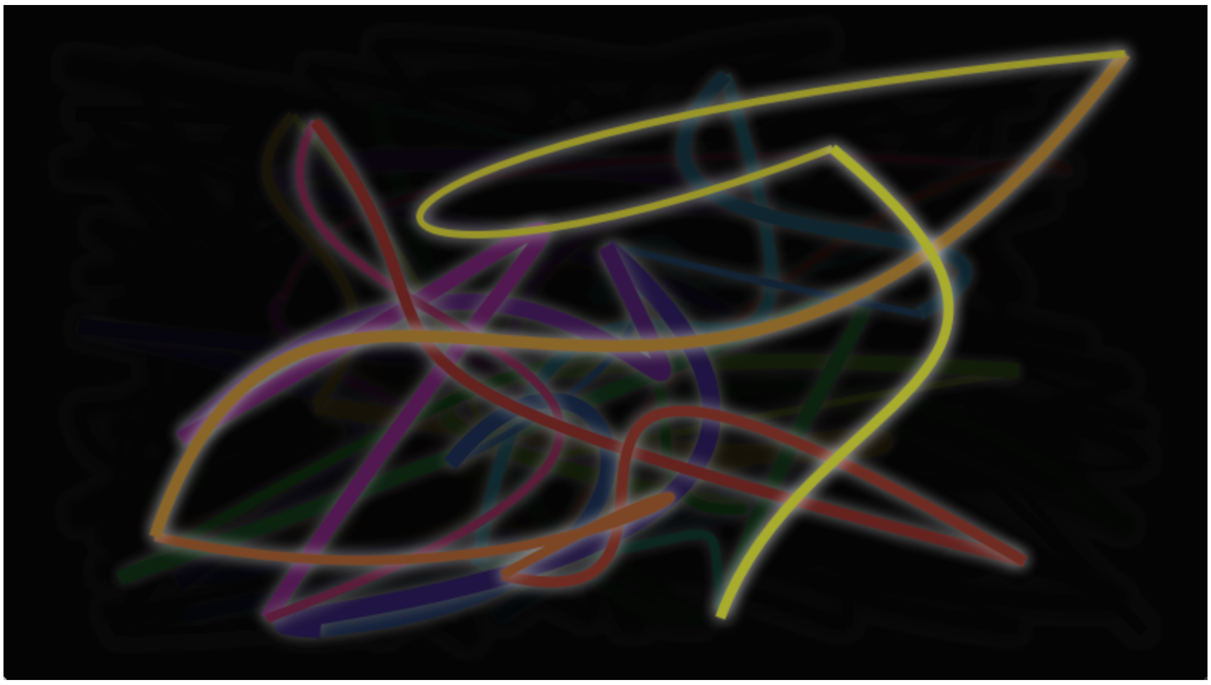
Same applies to the *blank* function.

```
function blank(context) {
    context.fillStyle = Qt.rgba(0,0,0,0.1)
    context.fillRect(0, 0, canvas.width, canvas.height);
}
```

The final result will look similar to this.

See also:

- W3C HTML Canvas 2D Context Specification



- Mozilla Canvas Documentation
- HTML5 Canvas Tutorial

CHAPTER

TEN

PARTICLE SIMULATIONS

Section author: jryannel@LinkedIn

Note: Last Build: December 07, 2020 at 10:50 CET

The source code for this chapter can be found in the assets folder.

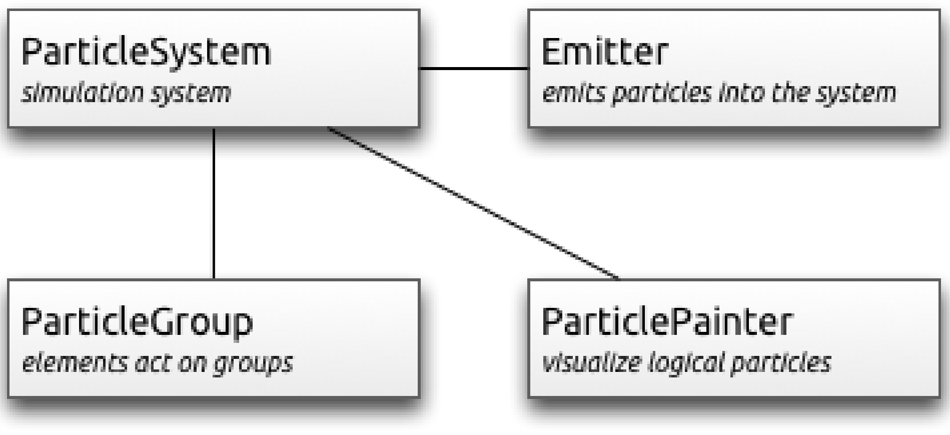
Particles are a computer graphics techniques to visualize certain graphics effects. Typical effects could be falling leaves, fire, explosions, meteors, clouds, etc.

It differs from other graphics rendering as particles rendering is based on fuzzy aspects. The outcome is not exactly predictable on pixel-base. Parameters to the particle system describe the boundaries for the stochastic simulation. The phenomena rendered with particles is often difficult to visualize with traditional rendering techniques. The good thing is you can let QML elements interact with the particles systems. Also as parameters are expressed as properties they can be animated using the traditional animation techniques.

10.1 Concept

In the heart of the particle simulation is the `ParticleSystem` which controls the shared timeline. A scene can have several particles systems, each of them with an independent time-line. A particle is emitted using an `Emitter` element and visualized with a `ParticlePainter`, which can be an image, QML item or a shader item. An emitter provides also the direction for particle using a vector space. Particle ones emitted can't be manipulated by the emitter anymore. The particle module provides the `Affector`, which allows manipulating parameters of the particle after it has been emitted.

Particles in a system can share timed transitions using the `ParticleGroup` element. By default, every particle is on the empty ('') group.



- `ParticleSystem` - manages shared time-line between emitters
- `Emitter` - emits logical particles into the system
- `ParticlePainter` - particles are visualized by a particle painter
- `Direction` - vector space for emitted particles
- `ParticleGroup` - every particle is a member of a group
- `Affector` - manipulates particles after they have been emitted

10.2 Simple Simulation

Let us have a look at a very simple simulation to get started. Qt Quick makes it actually very simple to get started with particle rendering. For this we need:

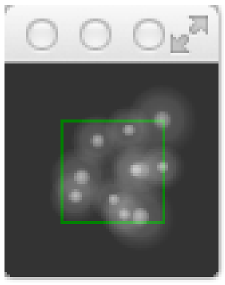
- A `ParticleSystem` which binds all elements to a simulation
- An `Emitter` which emits particles into the system
- A `ParticlePainter` derived element, which visualizes the particles

```
import QtQuick 2.5
import QtQuick.Particles 2.0

Rectangle {
    id: root
    width: 480; height: 160
    color: "#1f1f1f"

    ParticleSystem {
        id: particleSystem
    }

    Emitter {
        id: emitter
        anchors.centerIn: parent
        width: 160; height: 80
        system: particleSystem
        emitRate: 10
        lifeSpan: 1000
        lifeSpanVariation: 500
        size: 16
        endSize: 32
        Tracer { color: 'green' }
    }

    ImageParticle {
        source: "assets/particle.png"
        system: particleSystem
    }
}
```

The outcome of the example will look like this:

We start with an 80x80 pixel dark rectangle as our root element and background. Therein we declare a `ParticleSystem`. This is always the first step as the system binds all other elements together. Typically the next element is the `Emitter`, which defines the emitting area based on it's bounding box and basic parameters for them to be emitted particles. The emitter is bound to the system using the `system` property.

The emitter in this example emits 10 particles per second (`emitRate: 10`) over the area of the emitter with each a lifespan of 1000msec (`lifeSpan : 1000`) and a lifespan variation between emitted particles of 500



msec (`lifeSpanVariation: 500`). A particle shall start with a size of 16px (`size: 16`) and at the end of its life shall be 32px (`endSize: 32`).

The green bordered rectangle is a tracer element to show the geometry of the emitter. This visualizes that also while the particles are emitted inside the emitters bounding box the rendering is not limited to the emitters bounding box. The rendering position depends upon life-span and direction of the particle. This will get more clear when we look into how to change the direction particles.

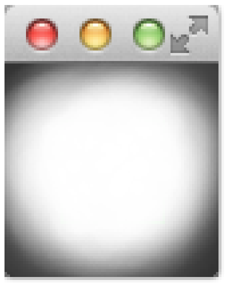
The emitter emits logical particles. A logical particle is visualized using a `ParticlePainter` in this example we use an `ImageParticle`, which takes an image URL as the source property. The image particle has also several other properties, which control the appearance of the average particle.

- `emitRate`: particles emitted per second (defaults to 10 per second)
- `lifeSpan`: milliseconds the particle should last for (defaults to 1000 msec)
- `size`, `endSize`: size of the particles at the beginning and end of their life (defaults to 16 px)

Changing these properties can influence the result in a drastically way

```
    Emitter {
        id: emitter
        anchors.centerIn: parent
        width: 20; height: 20
        system: particleSystem
        emitRate: 40
        lifeSpan: 2000
        lifeSpanVariation: 500
        size: 64
        sizeVariation: 32
        Tracer { color: 'green' }
    }
```

Besides increasing the emit rate to 40 and the lifespan to 2 seconds the size now starts at 64 pixels and decreases 32 pixels at the end of a particle lifespan.



Increasing the `endSize` even more would lead to a more or less white background. Please note also when the particles are only emitted in the area defined by the emitter the rendering is not constrained to it.

10.3 Particle Parameters

We saw already how to change the behavior of the emitter to change our simulation. The particle painter used allows us how the particle image is visualized for each particle.

Coming back to our example we update our `ImageParticle`. First, we change our particle image to a small sparking star image:

```
ImageParticle {
    ...
    source: 'assets/star.png'
}
```

The particle shall be colorized in an gold color which varies from particle to particle by +/- 20%:

```
color: '#FFD700'
colorVariation: 0.2
```

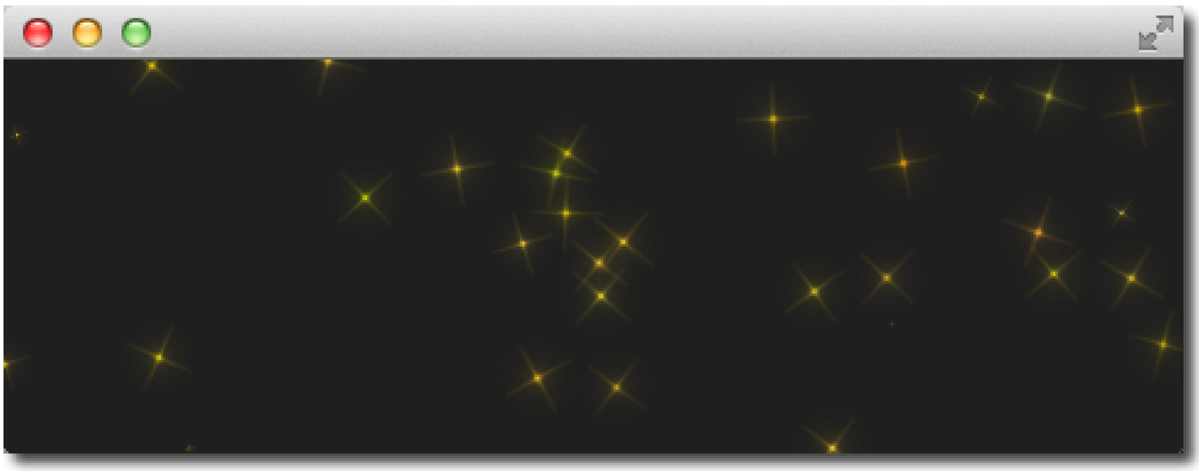
To make the scene more alive we would like to rotate the particles. Each particle should start by 15 degrees clockwise and varies between particles by +/-5 degrees. Additional the particle should continuously rotate with the velocity of 45 degrees per second. The velocity shall also vary from particle to particle by +/- 15 degrees per second:

```
rotation: 15
rotationVariation: 5
rotationVelocity: 45
rotationVelocityVariation: 15
```

Last but not least, we change the entry effect for the particle. This is the effect used when a particle comes to life. In this case, we want to use the scale effect:

```
entryEffect: ImageParticle.Scale
```

So now we have rotating golden stars appearing all over the place.



Here is the code we changed for the image-particle in one block.

```
    ImageParticle {
        source: "assets/star.png"
        system: particleSystem
        color: '#FFD700'
        colorVariation: 0.2
        rotation: 0
        rotationVariation: 45
```

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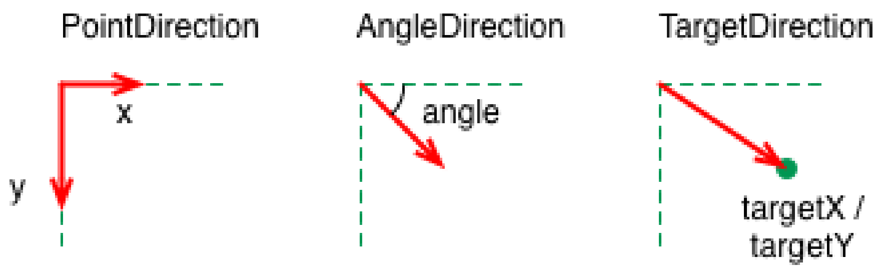
```
        rotationVelocity: 15
        rotationVelocityVariation: 15
        entryEffect: ImageParticle.Scale
    }
```

10.4 Directed Particles

We have seen particles can rotate. But particles can also have a trajectory. The trajectory is specified as the velocity or acceleration of particles defined by a stochastic direction also named a vector space.

There are different vector spaces available to define the velocity or acceleration of a particle:

- `AngleDirection` - a direction that varies in angle
- `PointDirection` - a direction that varies in x and y components
- `TargetDirection` - a direction towards the target point



Let's try to move the particles over from the left to the right side of our scene by using the velocity directions.

We first try the `AngleDirection`. For this we need to specify the `AngleDirection` as an element of the velocity property of our emitter:

```
velocity: AngleDirection { }
```

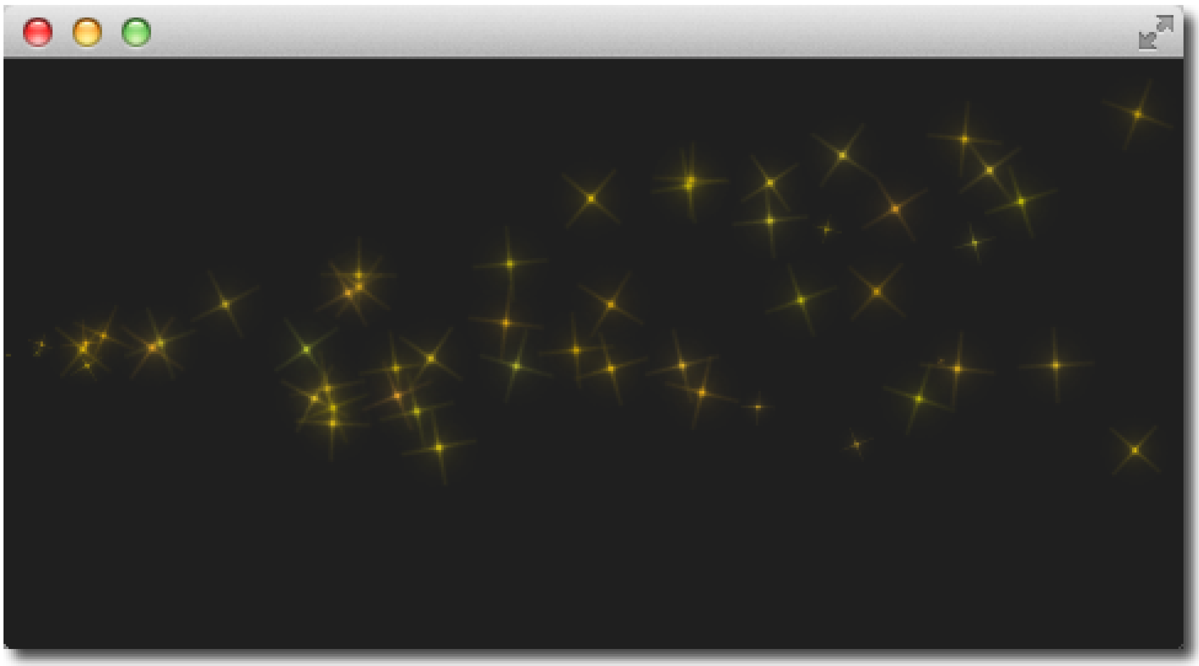
The angle where the particles are emitted is specified using the angle property. The angle is provided as a value between 0..360 degree and 0 points to the right. For our example, we would like the particles to move to the right so 0 is already the right direction. The particles shall spread by +/- 5 degrees:

```
velocity: AngleDirection {
    angle: 0
    angleVariation: 15
}
```

Now we have set our direction, the next thing is to specify the velocity of the particle. This is defined by a magnitude. The magnitude is defined in pixels per seconds. As we have ca. 640px to travel 100 seems to be a good number. This would mean by an average lifetime of 6.4 secs a particle would cross the open space. To make the traveling of the particles more interesting we vary the magnitude using the `magnitudeVariation` and set this to the half of the magnitude:

```
velocity: AngleDirection {
    ...
    magnitude: 100
    magnitudeVariation: 50
}
```

Here is the full source code, with an average lifetime set to 6.4 seconds. We set the emitter width and height to 1px. This means all particles are emitted at the same location and from thereon travel based on our given trajectory.



```
    Emitter {
        id: emitter
        anchors.left: parent.left
        anchors.verticalCenter: parent.verticalCenter
        width: 1; height: 1
        system: particleSystem
        lifeSpan: 6400
        lifeSpanVariation: 400
        size: 32
        velocity: AngleDirection {
            angle: 0
            angleVariation: 15
            magnitude: 100
            magnitudeVariation: 50
        }
    }
```

So what is then the acceleration doing? The acceleration adds an acceleration vector to each particle, which changes the velocity vector over time. For example, let's make a trajectory like an arc of stars. For this we change our velocity direction to -45 degree and remove the variations, to better visualize a coherent arc:

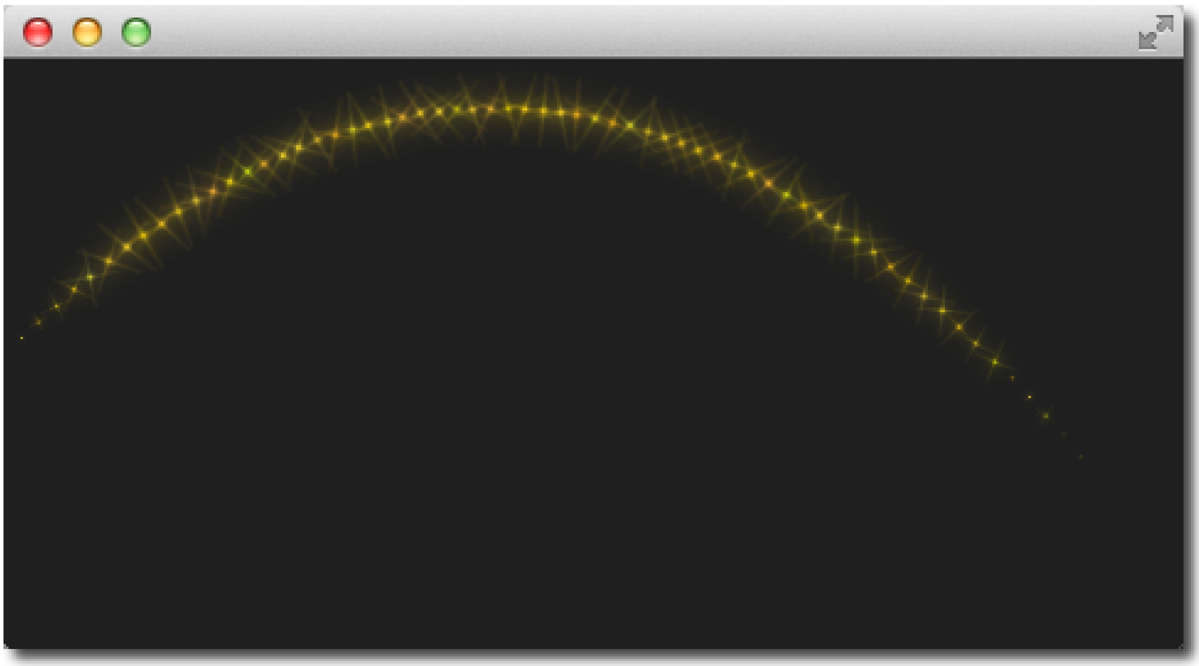
```
velocity: AngleDirection {
    angle: -45
    magnitude: 100
}
```

The acceleration direction shall be 90 degrees (down direction) and we choose one-fourth of the velocity magnitude for this:

```
acceleration: AngleDirection {
    angle: 90
    magnitude: 25
}
```

The result is an arc going from the center-left to the bottom right.

The values are discovered by try-and-error.



Here is the full code of our emitter.

```
    Emitter {
        id: emitter
        anchors.left: parent.left
        anchors.verticalCenter: parent.verticalCenter
        width: 1; height: 1
        system: particleSystem
        emitRate: 10
        lifeSpan: 6400
        lifeSpanVariation: 400
        size: 32
        velocity: AngleDirection {
            angle: -45
            angleVariation: 0
            magnitude: 100
        }
        acceleration: AngleDirection {
            angle: 90
            magnitude: 25
        }
    }
```

In the next example we would like that the particles again travel from left to right but this time we use the `PointDirection` vector space.

A `PointDirection` derived its vector space from an x and y component. For example, if you want the particles to travel in a 45-degree vector, you need to specify the same value for x and y.

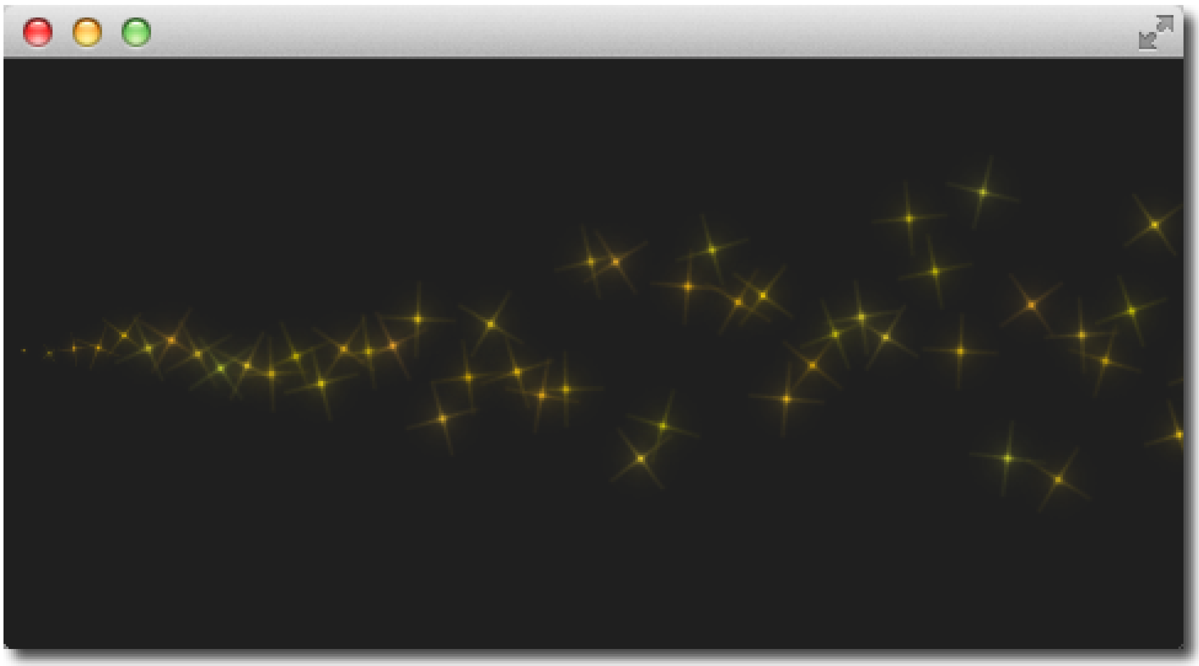
In our case we want the particles to travel from left-to-right building a 15-degree cone. For this we specify a `PointDirection` as our velocity vector space:

```
velocity: PointDirection { }
```

To achieve a traveling velocity of 100 px per seconds we set our x component to 100. For the 15 degrees (which is 1/6th of 90 degrees) we specify an y variation of 100/6:

```
velocity: PointDirection {
    x: 100
    y: 0
    xVariation: 0
    yVariation: 100/6
}
```

The result should be particles traveling in a 15-degree cone from right to left.



Now coming to our last contender, the `TargetDirection`. The target direction allows us to specify a target point as an x and y coordinate relative to the emitter or an item. When an item has specified the center of the item will become the target point. You can achieve the 15-degree cone by specifying a target variation of 1/6 th of the x target:

```
velocity: TargetDirection {
    targetX: 100
    targetY: 0
    targetVariation: 100/6
    magnitude: 100
}
```

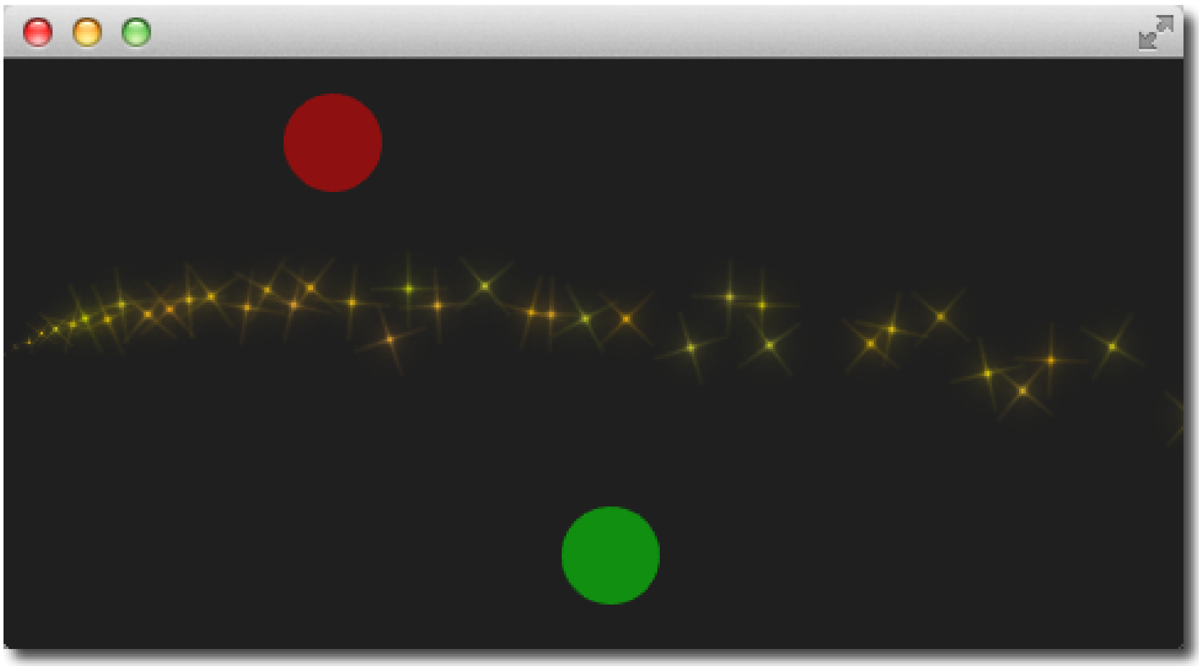
Note: Target direction are great to use when you have a specific x/y coordinate you want the stream of particles emitted towards.

I spare you the image as it looks the same as the previous one, instead, I have a quest for you.

In the following image, the red and the green circle specify each a target item for the target direction of the velocity respective the acceleration property. Each target direction has the same parameters. Here the question: Who is responsible for velocity and who is for acceleration?

10.5 Particle Painters

Till now we have only used the image based particle painter to visualize particles. Qt comes also with other particle painters:



- `ItemParticle`: delegate based particle painter
- `CustomParticle`: shader based particle painter

The ItemParticle can be used to emit QML items as particles. For this, you need to specify your own delegate to the particle.

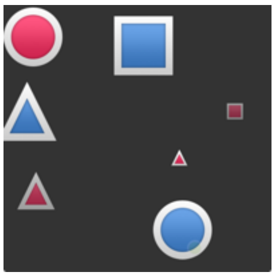
```
    ItemParticle {
        id: particle
        system: particleSystem
        delegate: itemDelegate
    }
```

Our delegate, in this case, is a random image (using *Math.random()*), visualized with a white border and a random size.

```
    Component {
        id: itemDelegate
        Item {
            id: container
            width: 32*Math.ceil(Math.random()*3); height: width
            Image {
                anchors.fill: parent
                anchors.margins: 4
                source: 'assets/'+images[Math.floor(Math.random()*9)]
            }
        }
    }
```

We emit 4 images per second with a lifespan of 4 seconds each. The particles fade automatically in and out.

For more dynamic cases it is also possible to create an item on your own and let the particle take control of it with `take(item, priority)`. By this, the particle simulation takes control of your particle and handles the item like an ordinary particle. You can get back control of the item by using `give(item)`. You can influence item particles even more by halt their life progression using `freeze(item)` and resume their life using `unfreeze(item)`.



10.6 Affecting Particles

Particles are emitted by the emitter. After a particle was emitted it can't be changed any more by the emitter. The affectors allows you to influence particles after they have been emitted.

Each type of affector affects particles in a different way:

- `Age` - alter where the particle is in its life-cycle
- `Attractor` - attract particles towards a specific point
- `Friction` - slows down movement proportional to the particle's current velocity
- `Gravity` - set's an acceleration in an angle
- `Turbulence` - fluid like forces based on a noise image
- `Wander` - randomly vary the trajectory
- `GroupGoal` - change the state of a group of a particle
- `SpriteGoal` - change the state of a sprite particle

Age

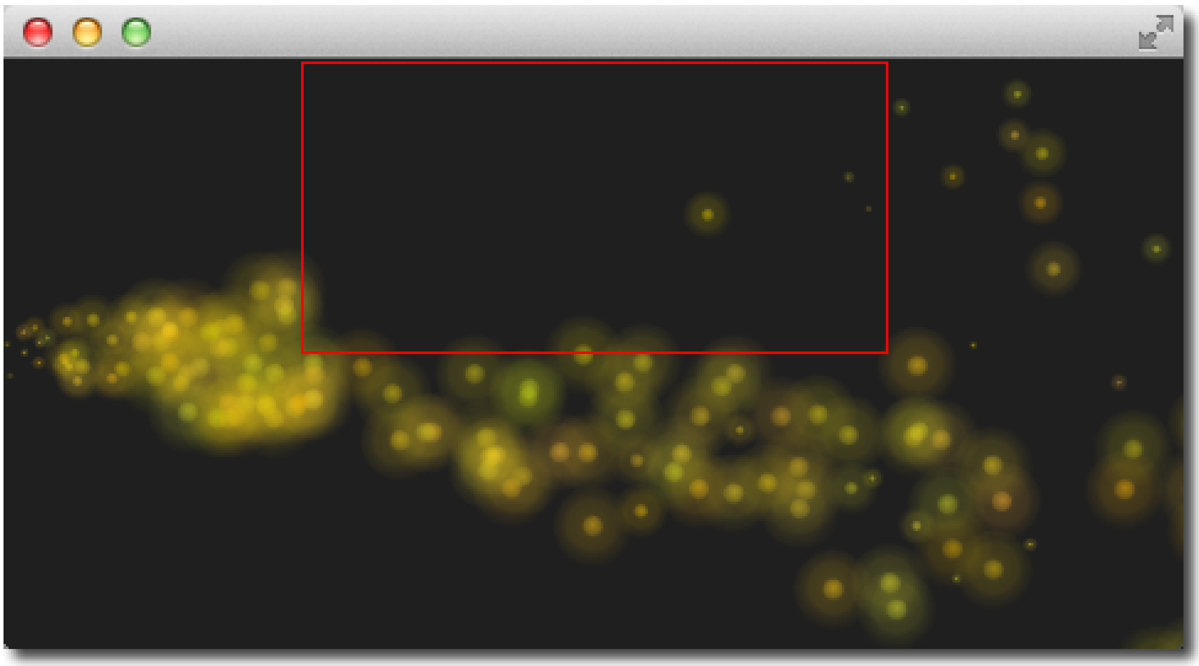
Allows particle to age faster. the *lifeLeft* property specified how much life a particle should have left.

```
    Age {
        anchors.horizontalCenter: parent.horizontalCenter
        width: 240; height: 120
        system: particleSystem
        advancePosition: true
        lifeLeft: 1200
        once: true
        Tracer {}
    }
```

In the example, we shorten the life of the upper particles once when they reach the age of affector to 1200 msec. As we have set the *advancePosition* to true, we see the particle appearing again on a position when the particle has 1200 msecs left to live.

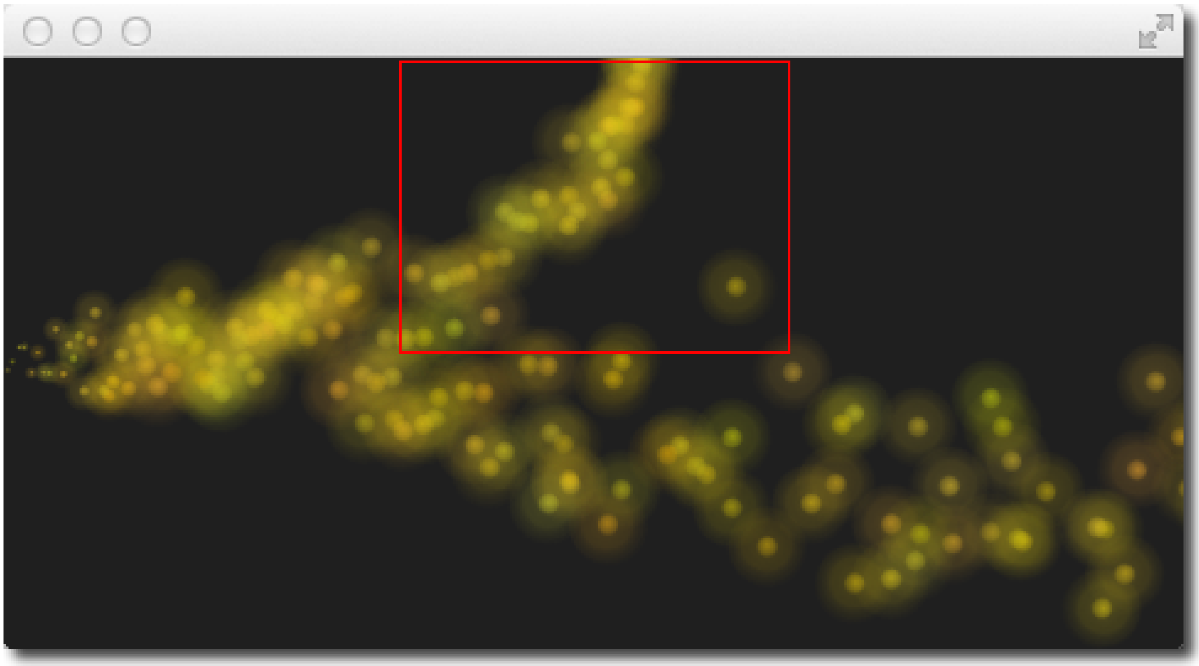
Attractor

The attractor attracts particles towards a specific point. The point is specified using `pointX` and `pointY`, which is relative to the attractor geometry. The strength specifies the force of attraction. In our example we let particles travel from left to right. The attractor is placed on the top and half of the particles travel through the attractor. Affector only affect particles while they are in their bounding box. This split allows us to see the normal stream and the affected stream simultaneous.



```
    Attractor {
        anchors.horizontalCenter: parent.horizontalCenter
        width: 160; height: 120
        system: particleSystem
        pointX: 0
        pointY: 0
        strength: 1.0
        Tracer {}
    }
```

It's easy to see that the upper half of the particles are affected by the attracted to the top. The attraction point is set to top-left (0/0 point) of the attractor with a force of 1.0.

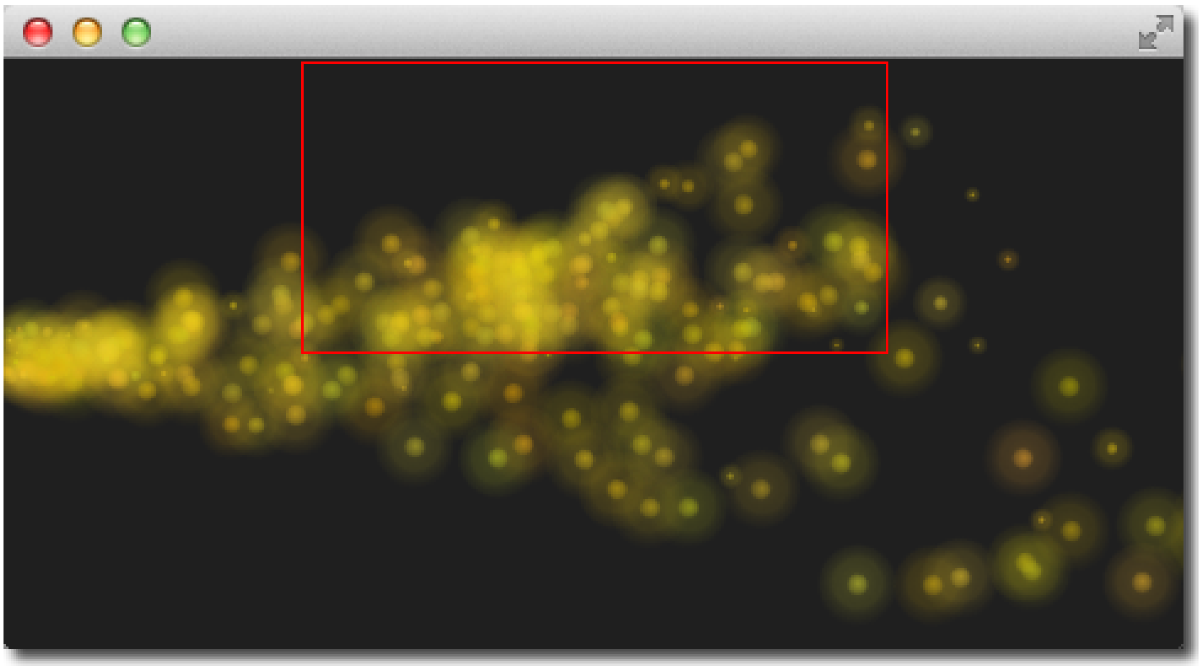


Friction

The friction affector slows down particles by a factor until a certain threshold is reached.

```
    Friction {
        anchors.horizontalCenter: parent.horizontalCenter
        width: 240; height: 120
        system: particleSystem
        factor : 0.8
        threshold: 25
        Tracer {}
    }
```

In the upper friction area, the particles are slowed down by a factor of 0.8 until the particle reaches 25 pixels per seconds velocity. The threshold act's like a filter. Particles traveling above the threshold velocity are slowed down by the given factor.

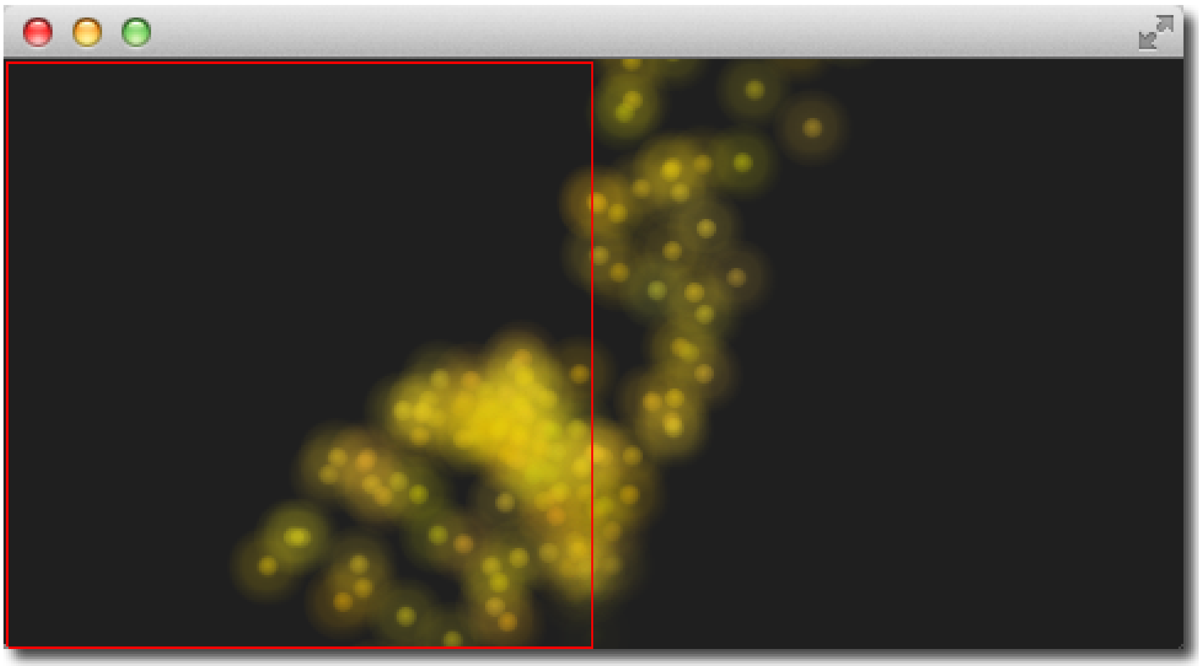


Gravity

The gravity affector applies an acceleration In the example we stream the particles from the bottom to the top using an angle direction. The right side is unaffected, where on the left a gravity effect is applied. The gravity is angled to 90 degrees (bottom-direction) with a magnitude of 50.

```
    Gravity {
        width: 240; height: 240
        system: particleSystem
        magnitude: 50
        angle: 90
        Tracer {}
    }
```

Particles on the left side try to climb up, but the steady applied acceleration towards the bottom drags them into the direction of the gravity.



Turbulence

The turbulence affector applies a *chaos* map of force vectors to the particles. The chaos map is defined by a noise image, which can be defined with the *noiseSource* property. The strength defines how strong the vector will be applied to the particle movements.

```
    Turbulence {
        anchors.horizontalCenter: parent.horizontalCenter
        width: 240; height: 120
        system: particleSystem
        strength: 100
        Tracer {}
    }
```

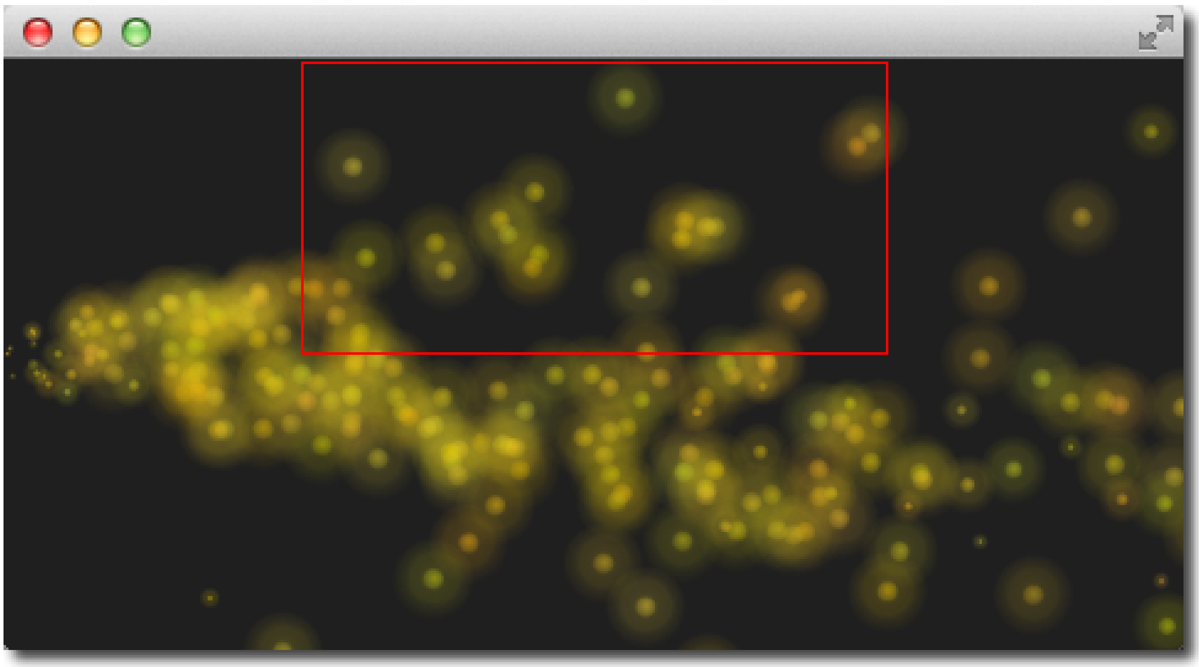
In the upper area of the example, particles are influenced by the turbulence. Their movement is more erratic. The amount of erratic deviation from the original path is defined by the strength.

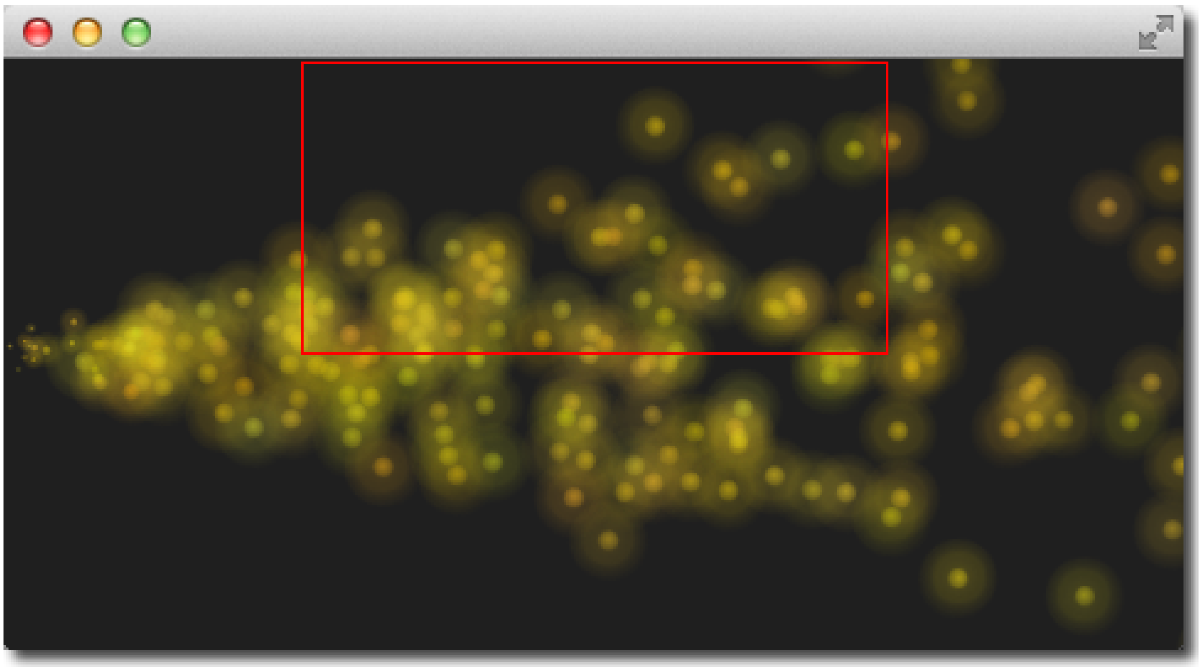
Wander

The wander manipulates the trajectory. With the property *affectedParameter* can be specified which parameter (velocity, position or acceleration) is affector by the wander. The *pace* property specifies the maximum of attribute changes per second. The yVariance and yVariance specify the influence on x and y component of the particle trajectory.

```
    Wander {
        anchors.horizontalCenter: parent.horizontalCenter
        width: 240; height: 120
        system: particleSystem
        affectedParameter: Wander.Position
        pace: 200
        yVariance: 240
        Tracer {}
    }
```

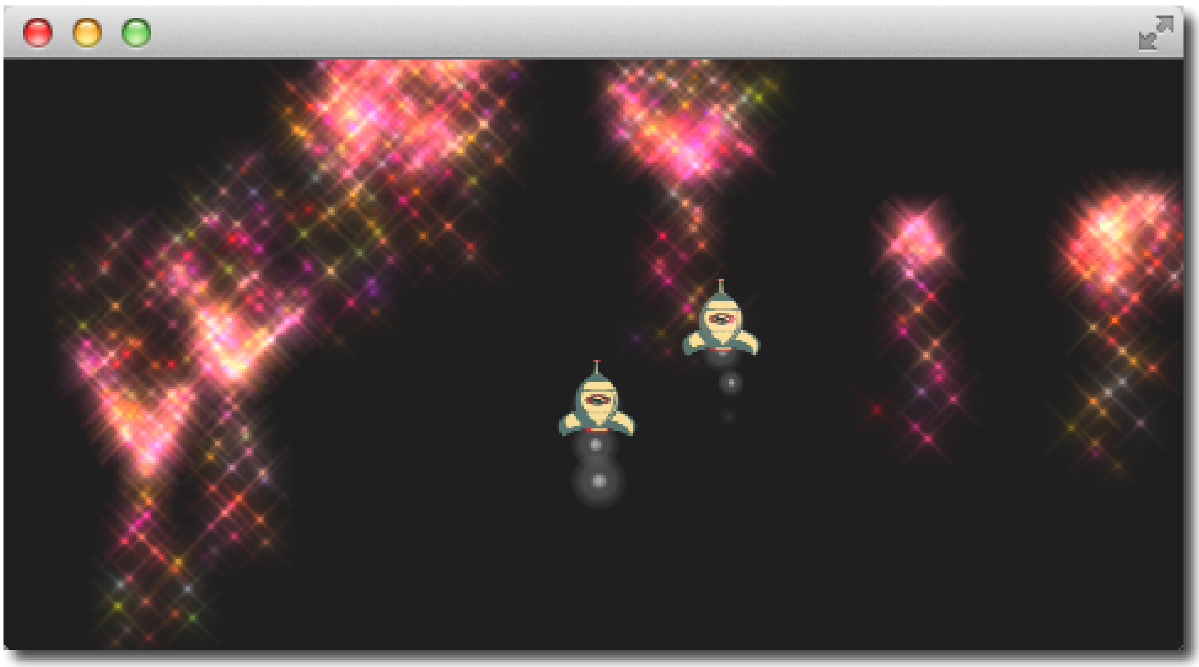
In the top wander affector particles are shuffled around by random trajectory changes. In this case, the position is changed 200 times per second in the y-direction.





10.7 Particle Groups

At the beginning of this chapter, we stated particles are in groups, which is by default the empty group (‘’). Using the `GroupGoal` affector is it possible to let the particle change groups. To visualize this we would like to create a small firework, where rockets start into space and explode in the air into a spectacular firework.



The example is divided into 2 parts. The 1st part called “Launch Time” is concerned to set up the scene and introduce particle groups and the 2nd part called “Let there be fireworks” focuses on the group changes.

Let’s get started!

Launch Time

To get it going we create a typical dark scene:

```
import QtQuick 2.5
import QtQuick.Particles 2.0

Rectangle {
    id: root
    width: 480; height: 240
    color: "#1F1F1F"
    property bool tracer: false
}
```

The tracer property will be used to switch the tracer scene wide on and off. The next thing is to declare our particle system:

```
ParticleSystem {
    id: particleSystem
}
```

And our two image particles (one for the rocket and one for the exhaust smoke):

```
ImageParticle {
    id: smokePainter
```

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```
    system: particleSystem
    groups: ['smoke']
    source: "assets/particle.png"
    alpha: 0.3
    entryEffect: ImageParticle.None
}

ImageParticle {
    id: rocketPainter
    system: particleSystem
    groups: ['rocket']
    source: "assets/rocket.png"
    entryEffect: ImageParticle.None
}
```

You can see in on the images, they use the *groups* property to declare to which group the particle belongs. It is enough to just declare a name and an implicit group will be created by Qt Quick.

Now it's time to emit some rockets into the air. For this, we create an emitter on the bottom of our scene and set the velocity in an upward direction. To simulate some gravity we set an acceleration downwards:

```
Emitter {
    id: rocketEmitter
    anchors.bottom: parent.bottom
    width: parent.width; height: 40
    system: particleSystem
    group: 'rocket'
    emitRate: 2
    maximumEmitted: 4
    lifeSpan: 4800
    lifeSpanVariation: 400
    size: 32
    velocity: AngleDirection { angle: 270; magnitude: 150; magnitudeVariation: 10 }
    acceleration: AngleDirection { angle: 90; magnitude: 50 }
    Tracer { color: 'red'; visible: root.tracer }
}
```

The emitter is in the group *'rocket'*, the same as our rocket particle painter. Through the group name, they are bound together. The emitter emits particles into the group 'rocket' and the rocket particle painter will pain them.

For the exhaust, we use a trail emitter, which follows our rocket. It declares an own group called 'smoke' and follows the particles from the 'rocket' group:

```
TrailEmitter {
    id: smokeEmitter
    system: particleSystem
    emitHeight: 1
    emitWidth: 4
    group: 'smoke'
    follow: 'rocket'
    emitRatePerParticle: 96
    velocity: AngleDirection { angle: 90; magnitude: 100; angleVariation: 5 }
    lifeSpan: 200
    size: 16
    sizeVariation: 4
    endSize: 0
}
```

The smoke is directed downwards to simulate the force the smoke comes out of the rocket. The *emitHeight* and *emitWidth* specify the are around the particle followed from where the smoke particles shall be emitted. If this is not specified then they are of the particle followed is taken but for this example, we want to increase the effect that the particles stem from a central point near the end of the rocket.

If you start the example now you will see the rockets fly up and some are even flying out of the scene. As this is not really wanted we need to slow them down before they leave the screen. A friction affector can be used here to slow the particles down to a minimum threshold:

```
Friction {
    groups: ['rocket']
    anchors.top: parent.top
    width: parent.width; height: 80
    system: particleSystem
    threshold: 5
    factor: 0.9
}
```

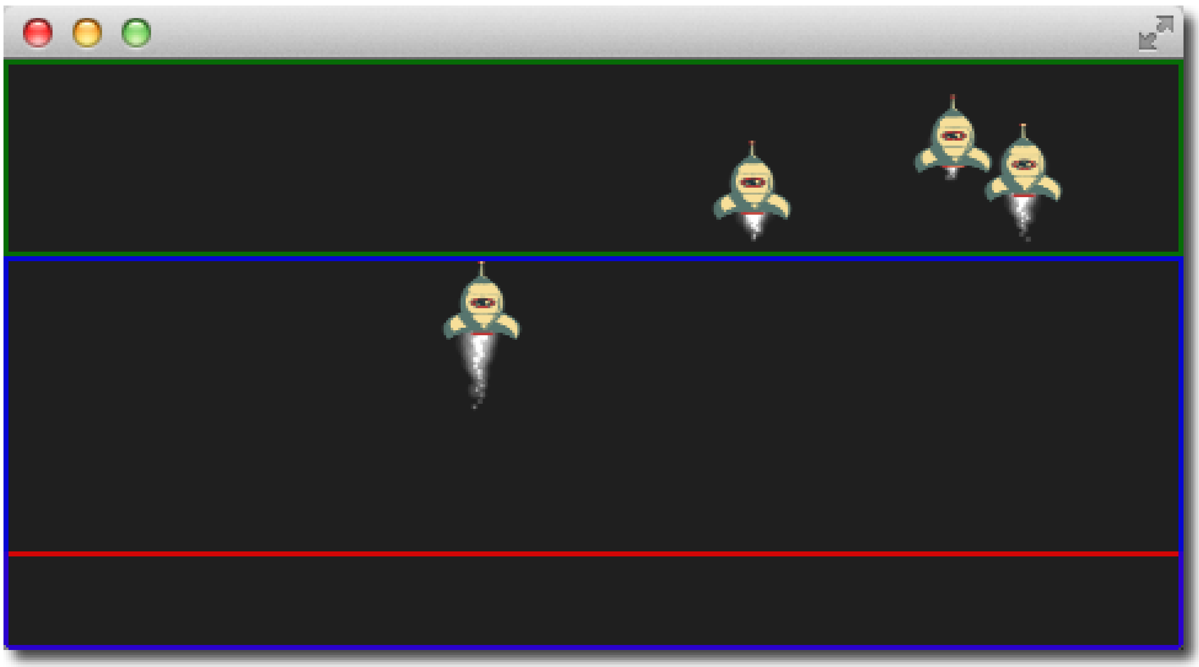
In the friction affector, you also need to declare which groups of particles it shall affect. The friction will slow all rockets, which are 80 pixels downwards from the top of the screen down by a factor of 0.9 (try 100 and you will see they almost stop immediately) until they reach a velocity of 5 pixels per second. As the particles have still an acceleration downwards applied the rockets will start sinking toward the ground after they reach the end of their life-span.

As climbing up in the air is hard work and a very unstable situation we want to simulate some turbulences while the ship is climbing:

```
Turbulence {
    groups: ['rocket']
    anchors.bottom: parent.bottom
    width: parent.width; height: 160
    system: particleSystem
    strength: 25
    Tracer { color: 'green'; visible: root.tracer }
}
```

Also, the turbulence needs to declare which groups it shall affect. The turbulence itself reaches from the bottom 160 pixels upwards (until it reaches the border of the friction). They also could overlap.

When you start the example now you will see the rockets are climbing up and then will be slowed down by the friction and fall back to the ground by the still applied downwards acceleration. The next thing would be to start the firework.



Note: The image shows the scene with the tracers enabled to show the different areas. Rocket particles are emitted in the red area and then affected by the turbulence in the blue area. Finally, they are slowed down by the friction affector in the green area and start falling again, because of the steady applied downwards acceleration.

Let there be fireworks

To be able to change the rocket into a beautiful firework we need add a `ParticleGroup` to encapsulate the changes:

```
ParticleGroup {
    name: 'explosion'
    system: particleSystem
}
```

We change to the particle group using a `GroupGoal` affector. The group goal affector is placed near the vertical center of the screen and it will affect the group 'rocket'. With the *groupGoal* property we set the target group for the change to 'explosion', our earlier defined particle group:

```
GroupGoal {
    id: rocketChanger
    anchors.top: parent.top
    width: parent.width; height: 80
    system: particleSystem
    groups: ['rocket']
    goalState: 'explosion'
    jump: true
    Tracer { color: 'blue'; visible: root.tracer }
}
```

The *jump* property states the change in groups shall be immediately and not after a certain duration.

Note: In the Qt 5 alpha release we could the *duration* for the group change not get working. Any ideas?

As the group of the rocket now changes to our 'explosion' particle group when the rocket particle enters the group goal area we need to add the firework inside the particle group:

```
// inside particle group
TrailEmitter {
    id: explosionEmitter
    anchors.fill: parent
    group: 'sparkle'
    follow: 'rocket'
    lifeSpan: 750
    emitRatePerParticle: 200
    size: 32
    velocity: AngleDirection { angle: -90; angleVariation: 180; magnitude: 50 }
}
```

The explosion emits particles into the 'sparkle' group. We will define soon a particle painter for this group. The trail emitter used follows the rocket particle and emits per rocket 200 particles. The particles are directed upwards and vary by 180 degrees.

As the particles are emitted into the 'sparkle' group, we also need to define a particle painter for the particles:

```
ImageParticle {
    id: sparklePainter
    system: particleSystem
```

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```
    groups: ['sparkle']
    color: 'red'
    colorVariation: 0.6
    source: "assets/star.png"
    alpha: 0.3
}
```

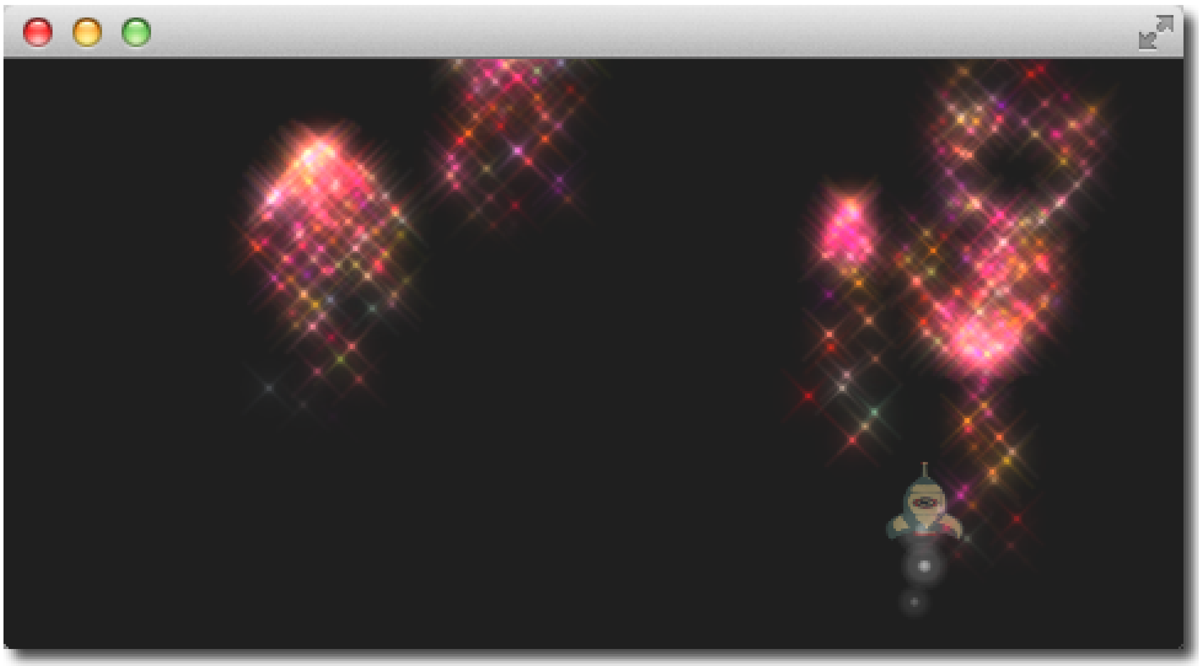
The sparkles of our firework shall be little red stars with an almost transparent color to allow some shine effects.

To make the firework more spectacular we also add a second trail emitter to our particle group, which will emit particles in a narrow cone downwards:

```
// inside particle group
TrailEmitter {
    id: explosion2Emitter
    anchors.fill: parent
    group: 'sparkle'
    follow: 'rocket'
    lifeSpan: 250
    emitRatePerParticle: 100
    size: 32
    velocity: AngleDirection { angle: 90; angleVariation: 15; magnitude: 400 }
}
```

Otherwise, the setup is similar to the other explosion trail emitter. That's it.

Here is the final result.



Here is the full source code of the rocket firework.

```
import QtQuick 2.5
import QtQuick.Particles 2.0

Rectangle {
    id: root
    width: 480; height: 240
    color: "#1F1F1F"
    property bool tracer: false
```

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```
    ParticleSystem {
        id: particleSystem
    }

    ImageParticle {
        id: smokePainter
        system: particleSystem
        groups: ['smoke']
        source: "assets/particle.png"
        alpha: 0.3
    }

    ImageParticle {
        id: rocketPainter
        system: particleSystem
        groups: ['rocket']
        source: "assets/rocket.png"
        entryEffect: ImageParticle.Fade
    }

    Emitter {
        id: rocketEmitter
        anchors.bottom: parent.bottom
        width: parent.width; height: 40
        system: particleSystem
        group: 'rocket'
        emitRate: 2
        maximumEmitted: 8
        lifeSpan: 4800
        lifeSpanVariation: 400
        size: 128
        velocity: AngleDirection { angle: 270; magnitude: 150; magnitudeVariation:␣
↪10 }
        acceleration: AngleDirection { angle: 90; magnitude: 50 }
        Tracer { color: 'red'; visible: root.tracer }
    }

    TrailEmitter {
        id: smokeEmitter
        system: particleSystem
        group: 'smoke'
        follow: 'rocket'
        size: 16
        sizeVariation: 8
        emitRatePerParticle: 16
        velocity: AngleDirection { angle: 90; magnitude: 100; angleVariation: 15 }
        lifeSpan: 200
        Tracer { color: 'blue'; visible: root.tracer }
    }

    Friction {
        groups: ['rocket']
        anchors.top: parent.top
        width: parent.width; height: 80
        system: particleSystem
        threshold: 5
        factor: 0.9

    }
```

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```
    Turbulence {
        groups: ['rocket']
        anchors.bottom: parent.bottom
        width: parent.width; height: 160
        system: particleSystem
        strength:25
        Tracer { color: 'green'; visible: root.tracer }
    }


    ImageParticle {
        id: sparklePainter
        system: particleSystem
        groups: ['sparkle']
        color: 'red'
        colorVariation: 0.6
        source: "assets/star.png"
        alpha: 0.3
    }

    GroupGoal {
        id: rocketChanger
        anchors.top: parent.top
        width: parent.width; height: 80
        system: particleSystem
        groups: ['rocket']
        goalState: 'explosion'
        jump: true
        Tracer { color: 'blue'; visible: root.tracer }
    }

    ParticleGroup {
        name: 'explosion'
        system: particleSystem

        TrailEmitter {
            id: explosionEmitter
            anchors.fill: parent
            group: 'sparkle'
            follow: 'rocket'
            lifeSpan: 750
            emitRatePerParticle: 200
            size: 32
            velocity: AngleDirection { angle: -90; angleVariation: 180; magnitude:␣
↪50 }
        }

        TrailEmitter {
            id: explosion2Emitter
            anchors.fill: parent
            group: 'sparkle'
            follow: 'rocket'
            lifeSpan: 250
            emitRatePerParticle: 100
            size: 32
            velocity: AngleDirection { angle: 90; angleVariation: 15; magnitude:␣
↪400 }
        }
    }
}
```

10.8 Summary

Particles are a very powerful and fun way to express graphical phenomena like smoke. firework, random visual elements. The extended API in Qt 5 is very powerful and we have just scratched the surface. There are several elements we haven't yet played with like sprites, size tables or color tables. Also when the particles look very playful they have a great potential when used wisely to create some eye catcher in any user interface. Using too many particle effects inside a user interface will definitely lead to the impression towards a game. Creating games is also the real strength of the particles.

CHAPTER

ELEVEN

SHADER EFFECTS

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Note: Last Build: December 07, 2020 at 10:50 CET

The source code for this chapter can be found in the assets folder.

Objective

- http://doc.qt.io/qt-5/qml-qtquick-shadereffect.html
- http://www.opengl.org/registry/doc/GLSLangSpec.4.20.6.clean.pdf
- http://www.khronos.org/registry/gles/specs/2.0/GLSL_ES_Specification_1.0.17.pdf
- http://www.lighthouse3d.com/opengl/glsl/
- http://wiki.delphigl.com/index.php/Tutorial_glsl
- Qt5Doc qtquick-shaders

Give a short introduction to shader effects and then present the shader effects and their use.

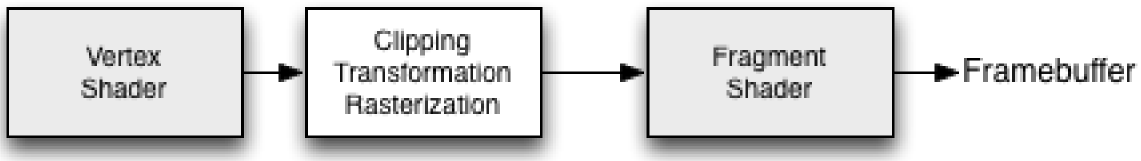
Shaders allow us to create awesome rendering effects on top of the SceneGraph API leveraging directly the power of OpenGL running on the GPU. Shaders are implemented using the ShaderEffect and ShaderEffectSource elements. The shader algorithm itself is implemented using the OpenGL Shading Language.

Practically it means you mix QML code with shader code. On execution will the shader code be sent over to the GPU and compiled and executed on the GPU. The shader QML elements allow you to interact through properties with the OpenGL shader implementation.

Let’s first have a look what OpenGL shaders are.

11.1 OpenGL Shaders

OpenGL uses a rendering pipeline split into stages. A simplified OpenGL pipeline would contain a vertex and fragment shader.



The vertex shader receives vertex data and must assign it to the *gl_Position* at the end of the routine. In the next stage, the vertexes are clipped, transformed and rasterized for pixel output. From there the fragments (pixels) arrive in the fragment shader and can further be manipulated and the resulting color needs to be assigned to *gl_FragColor*. The vertex shader is called for each corner point of your polygon (vertex = point in 3D) and is responsible for any 3D manipulation of these points. The fragment (fragment = pixel) shader is called for each pixel and determines the color of that pixel.

11.2 Shader Elements

For programming shaders, Qt Quick provides two elements. The ShaderEffectSource and the ShaderEffect. The shader effect applies custom shaders and the shader effect source renders a QML item into a texture and renders it. As shader effect can apply custom shaders to its rectangular shape and can use sources for the shader operation. A source can be an image, which is used as a texture or a shader effect source.

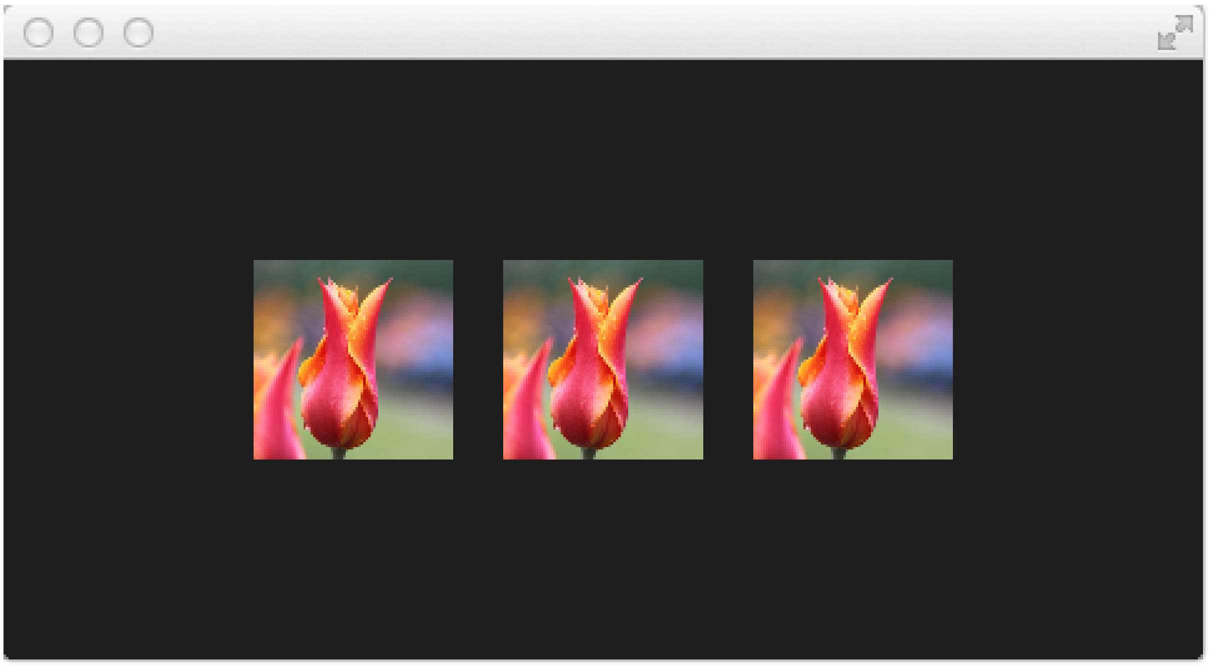
The default shader uses the source and renders it unmodified.

```
import QtQuick 2.5

Rectangle {
    width: 480; height: 240
    color: '#1e1e1e'

    Row {
        anchors.centerIn: parent
        spacing: 20
        Image {
            id: sourceImage
            width: 80; height: width
            source: 'assets/tulips.jpg'
        }
        ShaderEffect {
            id: effect
            width: 80; height: width
            property variant source: sourceImage
        }
        ShaderEffect {
            id: effect2
            width: 80; height: width
            // the source where the effect shall be applied to
            property variant source: sourceImage
            // default vertex shader code
            vertexShader: "
                uniform highp mat4 qt_Matrix;
                attribute highp vec4 qt_Vertex;
                attribute highp vec2 qt_MultiTexCoord0;
                varying highp vec2 qt_TexCoord0;
                void main() {
                    qt_TexCoord0 = qt_MultiTexCoord0;
                    gl_Position = qt_Matrix * qt_Vertex;
                }"
            // default fragment shader code
            fragmentShader: "
                varying highp vec2 qt_TexCoord0;
                uniform sampler2D source;
                uniform lowp float qt_Opacity;
                void main() {
                    gl_FragColor = texture2D(source, qt_TexCoord0) * qt_Opacity;
                }"
        }
    }
}
```

In the above example, we have a row of 3 images. The first is the real image. The second is rendered using the



default shader and the third is rendered using the default shader code for the fragment and vertex extracted from the Qt 5 source code.

Note: If you don't want to see the source image and only the effected image you can set the *Image* to invisible (`` visible: false``). The shader effects will still use the image data just the *Image* element will not be rendered.

Let's have a closer look at the shader code.

```
vertexShader: "
    uniform highp mat4 qt_Matrix;
    attribute highp vec4 qt_Vertex;
    attribute highp vec2 qt_MultiTexCoord0;
    varying highp vec2 qt_TexCoord0;
    void main() {
        qt_TexCoord0 = qt_MultiTexCoord0;
        gl_Position = qt_Matrix * qt_Vertex;
    }"
```

Both shaders are from the Qt side a string bound to the *vertexShader* and *fragmentShader* property. Every shader code has to have a *main() { ... }* function, which is executed by the GPU. Variable starting with *qt_* are provided by default by Qt already.

Here a short rundown on the variables:

uniform	value does not change during processing
attribute	linkage to external data
varying	shared value between shaders
highp	high precision value
lowp	low precision value
mat4	4x4 float matrix
vec2	2=dim float vector
sampler2D	2D texture
float	floating scalar

A better reference is the OpenGL ES 2.0 API Quick Reference Card

Now we might be better able to understand what the variable is:

- qt_Matrix: model-view-projection matrix
- qt_Vertex: current vertex position
- qt_MultiTexCoord0: texture coordinate
- qt_TexCoord0: shared texture coordinate

So we have available the projection matrix, the current vertex and the texture coordinate. The texture coordinate relates to the texture given as the source. In the *main()* function we store the texture coordinate for later use in the fragment shader. Every vertex shader needs to assign the *gl_Position* this is done using here by multiplying the project matrix with the vertex, our point in 3D.

The fragment shader receives our texture coordinate from the vertex shader and also the texture from our QML source property. It shall be noted how easy it is to pass a variable between the shader code and QML. Beautiful. Additional we have the opacity of the shader effect available as *qt_Opacity*. Every fragment shader needs to assign the *gl_FragColor* variable, this is done in the default shader code by picking the pixel from the source texture and multiplying it with the opacity.

```
fragmentShader: "
    varying highp vec2 qt_TexCoord0;
    uniform sampler2D source;
    uniform lowp float qt_Opacity;
    void main() {
        gl_FragColor = texture2D(source, qt_TexCoord0) * qt_Opacity;
    }"
```

During the next examples, we will be playing around with some simple shader mechanics. First, we concentrate on the fragment shader and then we will come back to the vertex shader.

Note: In the example above, the shader code is written inline in a string inside the QML code. This is supported for OpenGL, but for other platforms a pre-compiled bytecode version of the shader is expected. To import such a shader, simply replace the shader code with a filename refering the the pre-compiled bytecode.

11.3 Fragment Shaders

The fragment shader is called for every pixel to be rendered. We will develop a small red lens, which will increase the red color channel value of the image.

Setting up the scene

First, we set up our scene, with a grid centered in the field and our source image be displayed.

```
import QtQuick 2.5

Rectangle {
    width: 480; height: 240
    color: '#1e1e1e'

    Grid {
        anchors.centerIn: parent
        spacing: 20
        rows: 2; columns: 4
        Image {
            id: sourceImage
            width: 80; height: width
```

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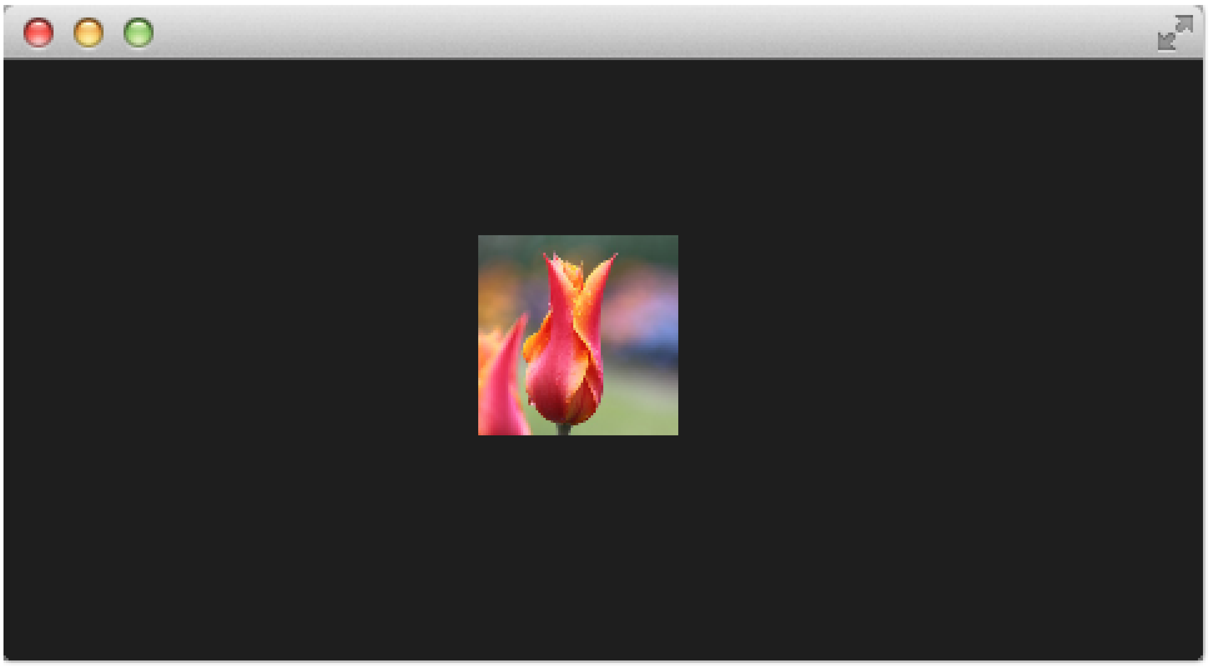
```
            source: 'assets/tulips.jpg'
        }
    }
}
```



A red shader

Next, we will add a shader, which displays a red rectangle by providing for each fragment a red color value.

```
            fragmentShader: "
                uniform lowp float qt_Opacity;
                void main() {
                    gl_FragColor = vec4(1.0, 0.0, 0.0, 1.0) * qt_Opacity;
                }"
```

In the fragment shader we simply assign a *vec4(1.0, 0.0, 0.0, 1.0)* which represents a red color with full opacity (alpha=1.0) to the *gl_FragColor* for each fragment.

A red shader with texture

Now we want to apply the red color to each texture pixel. For this, we need the texture back in the vertex shader. As we don't do anything else in the vertex shader the default vertex shader is enough for us.

```
        ShaderEffect {
            id: effect2
            width: 80; height: width
            property variant source: sourceImage
            visible: root.step>1
            fragmentShader: "
                varying highp vec2 qt_TexCoord0;
                uniform sampler2D source;
                uniform lowp float qt_Opacity;
                void main() {
                    gl_FragColor = texture2D(source, qt_TexCoord0) * vec4(1.0, 0.0,
↪ 0.0, 1.0) * qt_Opacity;
```

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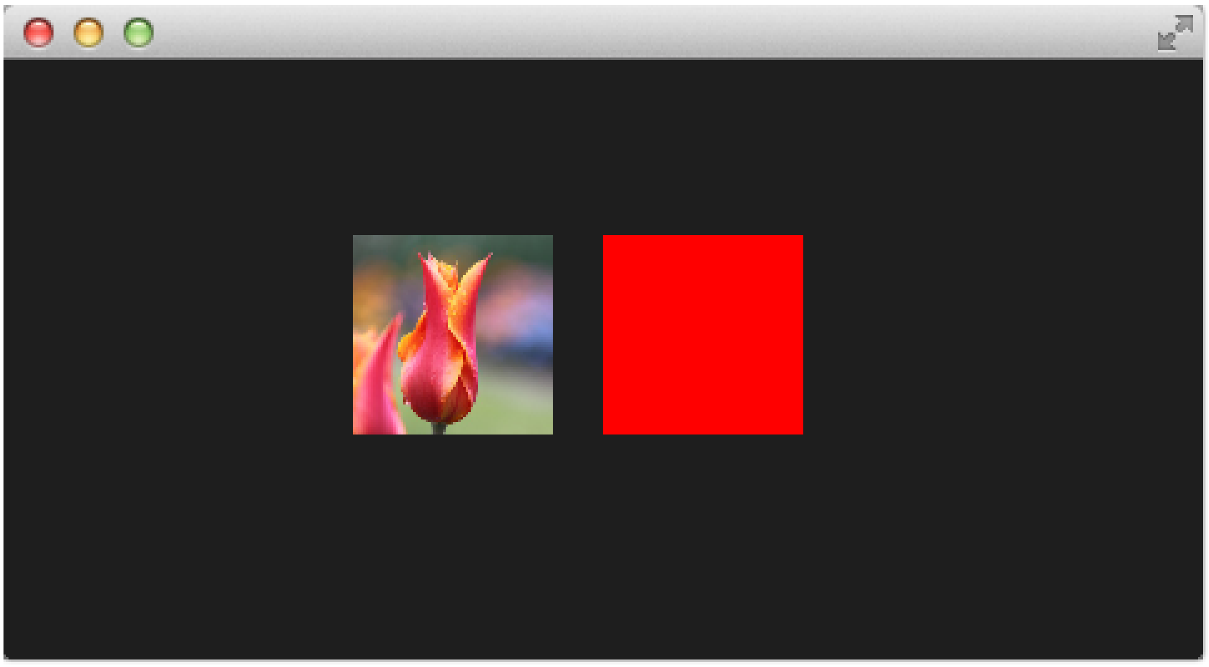

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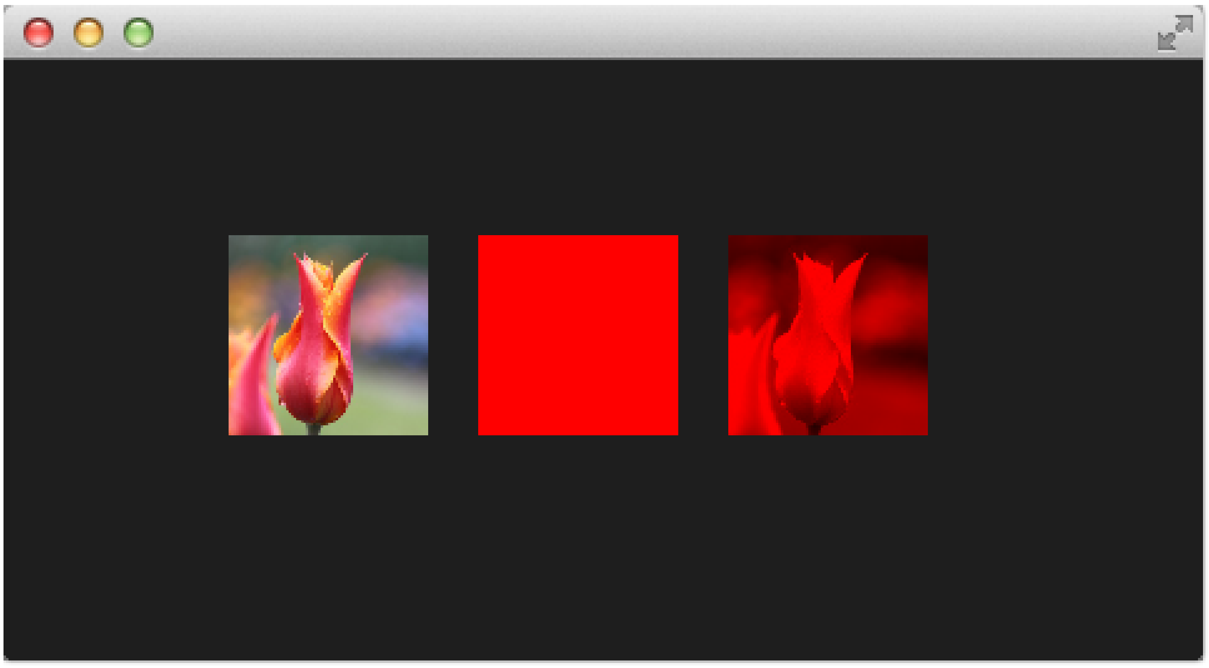
```
                        }"
            }
```

The full shader contains now back our image source as variant property and we have left out the vertex shader, which if not specified is the default vertex shader.

In the fragment shader, we pick the texture fragment *texture2D(source, qt_TexCoord0)* and apply the red color to it.

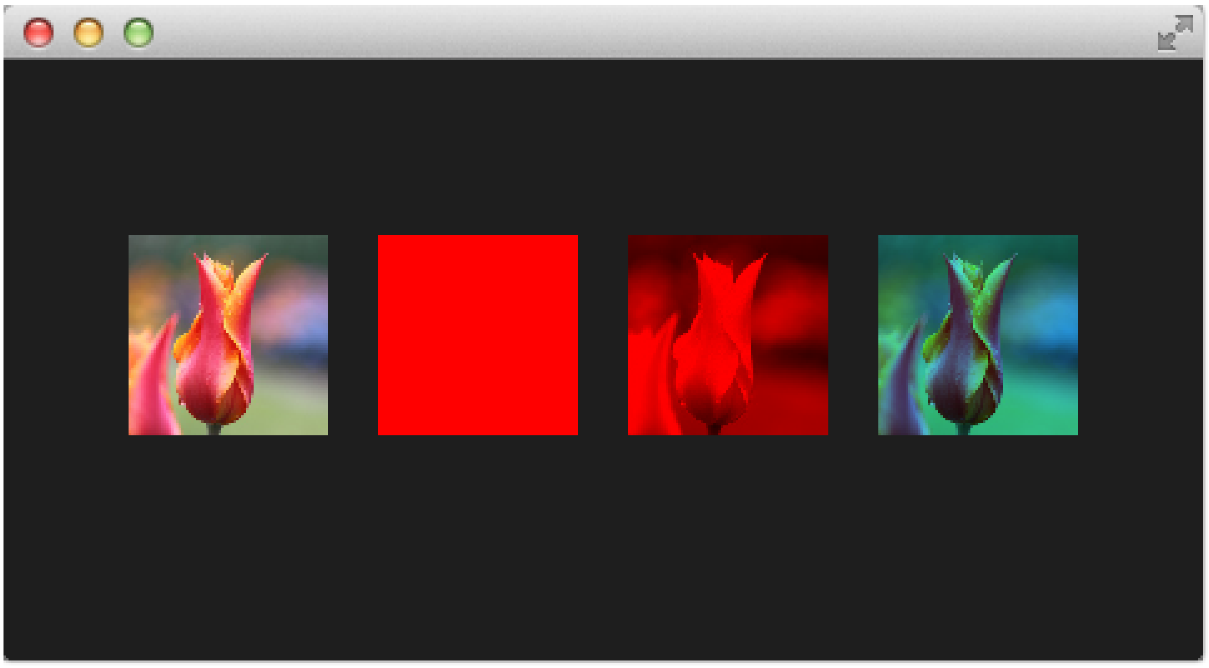


The red channel property

It’s not really nice to hard code the red channel value, so we would like to control the value from the QML side. For this we add a *redChannel* property to our shader effect and also declare a *uniform lowp float redChannel* inside our fragment shader. That’s all to make a value from the shader code available to the QML side. Very simple.

```
        ShaderEffect {
            id: effect3
            width: 80; height: width
            property variant source: sourceImage
            property real redChannel: 0.3
            visible: root.step>2
            fragmentShader: "
                varying highp vec2 qt_TexCoord0;
                uniform sampler2D source;
                uniform lowp float qt_Opacity;
                uniform lowp float redChannel;
                void main() {
                    gl_FragColor = texture2D(source, qt_TexCoord0) *␣
↪vec4(redChannel, 1.0, 1.0, 1.0) * qt_Opacity;
                }"
        }
```

To make the lens really a lens, we change the *vec4* color to be *vec4(redChannel, 1.0, 1.0, 1.0)* so that the other colors are multiplied by 1.0 and only the red portion is multiplied by our *redChannel* variable.



The red channel animated

As the *redChannel* property is just a normal property it can also be animated as all properties in QML. So we can use QML properties to animate values on the GPU to influence our shaders. How cool is that!

```
        ShaderEffect {
            id: effect4
            width: 80; height: width
            property variant source: sourceImage
            property real redChannel: 0.3
```

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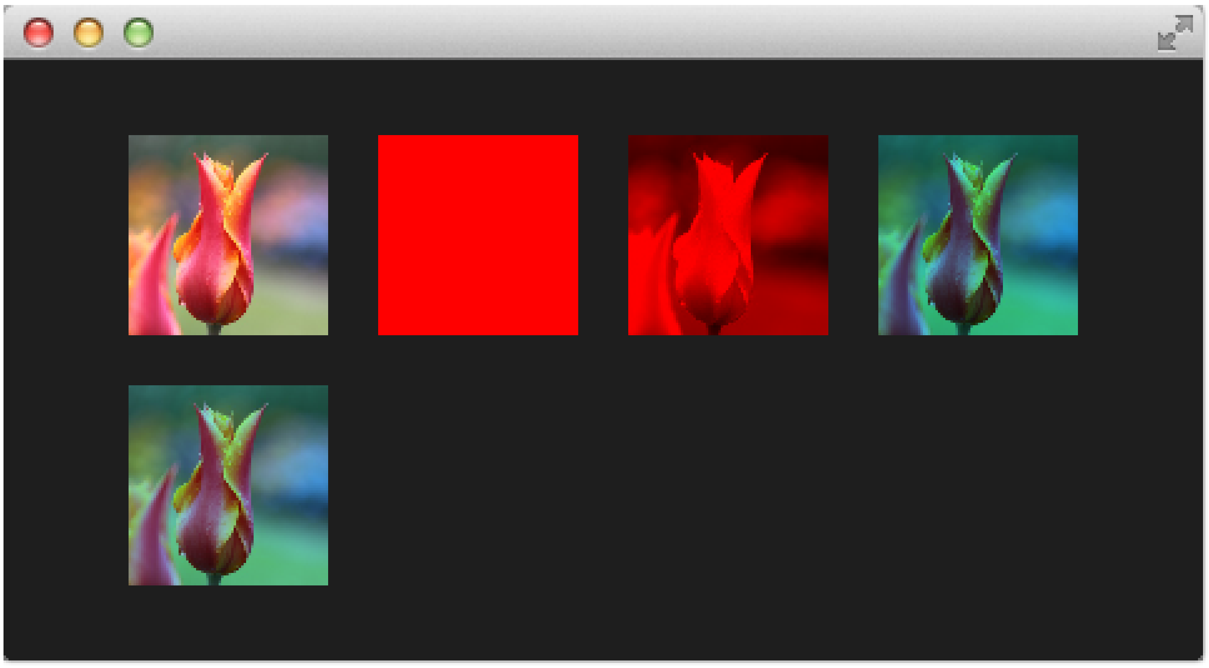
```
            visible: root.step>3
            NumberAnimation on redChannel {
                from: 0.0; to: 1.0; loops: Animation.Infinite; duration: 4000
            }

            fragmentShader: "
                varying highp vec2 qt_TexCoord0;
                uniform sampler2D source;
                uniform lowp float qt_Opacity;
                uniform lowp float redChannel;
                void main() {
                    gl_FragColor = texture2D(source, qt_TexCoord0) *␣
↪vec4(redChannel, 1.0, 1.0, 1.0) * qt_Opacity;
                }"
        }
```

Here the final result.



The shader effect on the 2nd row is animated from 0.0 to 1.0 with a duration of 4 seconds. So the image goes from no red information (0.0 red) over to a normal image (1.0 red).

11.4 Wave Effect

In this more complex example, we will create a wave effect with the fragment shader. The waveform is based on the sinus curve and it influences the texture coordinates used for the color.

```
import QtQuick 2.5

Rectangle {
    width: 480; height: 240
    color: '#1e1e1e'

    Row {
        anchors.centerIn: parent
        spacing: 20
```

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```
        Image {
            id: sourceImage
            width: 160; height: width
            source: "assets/coastline.jpg"
        }
        ShaderEffect {
            width: 160; height: width
            property variant source: sourceImage
            property real frequency: 8
            property real amplitude: 0.1
            property real time: 0.0
            NumberAnimation on time {
                from: 0; to: Math.PI*2; duration: 1000; loops: Animation.Infinite
            }

            fragmentShader: "
                varying highp vec2 qt_TexCoord0;
                uniform sampler2D source;
                uniform lowp float qt_Opacity;
                uniform highp float frequency;
                uniform highp float amplitude;
                uniform highp float time;
                void main() {
                    highp vec2 pulse = sin(time - frequency * qt_TexCoord0);
                    highp vec2 coord = qt_TexCoord0 + amplitude * vec2(pulse.x, -
↪pulse.x);
                    gl_FragColor = texture2D(source, coord) * qt_Opacity;
                }"
        }
    }
}
```

The wave calculation is based on a pulse and the texture coordinate manipulation. The pulse equation gives us a sine wave depending on the current time and the used texture coordinate:

```
highp vec2 pulse = sin(time - frequency * qt_TexCoord0);
```

Without the time factor, we would just have a distortion but not a traveling distortion like waves are.

For the color we use the color at a different texture coordinate:

```
highp vec2 coord = qt_TexCoord0 + amplitude * vec2(pulse.x, -pulse.x);
```

The texture coordinate is influenced by our pulse x-value. The result of this is a moving wave.

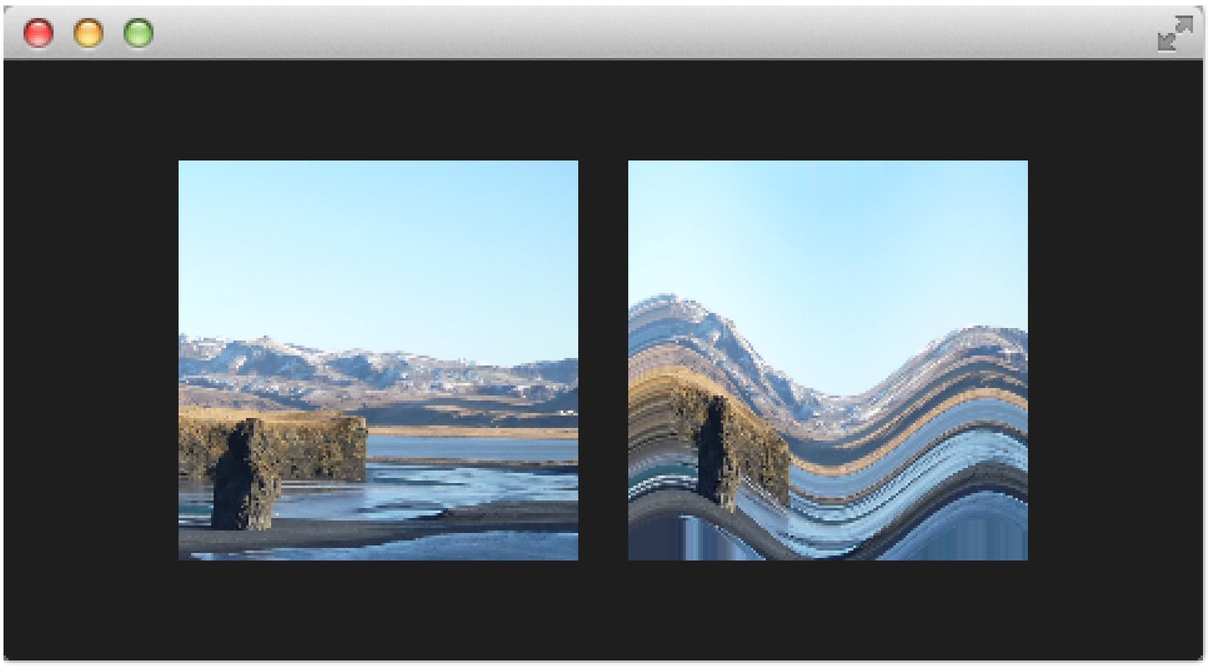
Also if we haven't moved pixels in this fragment shader the effect would look at first like a job for a vertex shader.

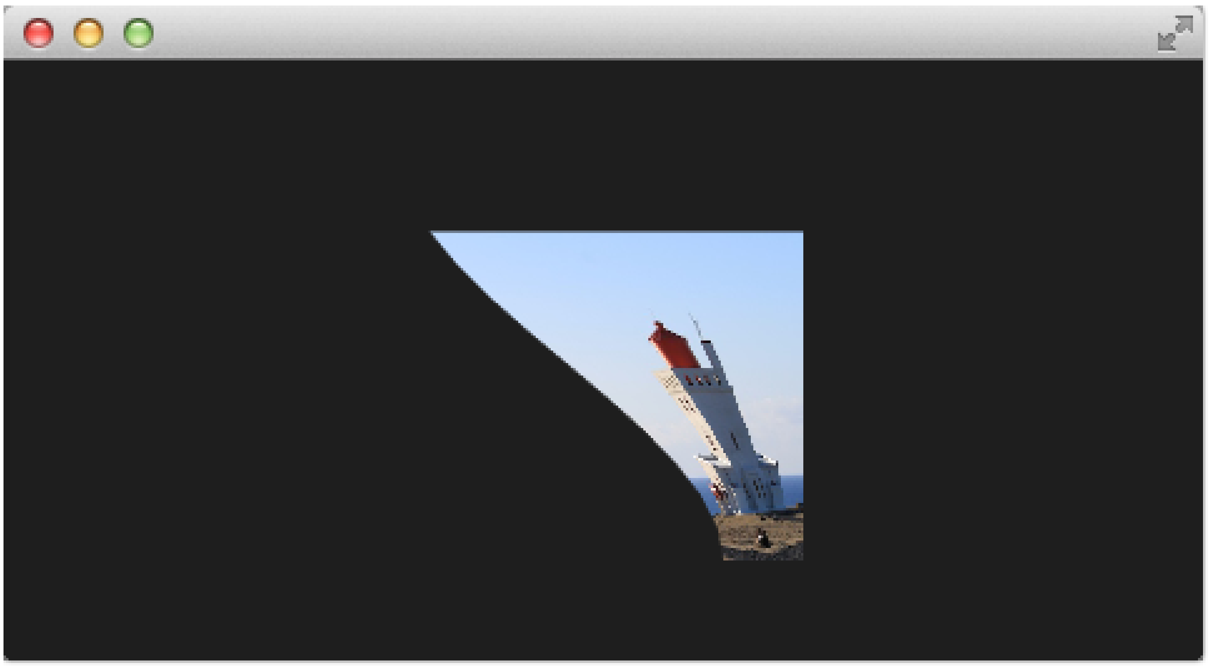
11.5 Vertex Shader

The vertex shader can be used to manipulate the vertexes provided by the shader effect. In normal cases, the shader effect has 4 vertexes (top-left, top-right, bottom-left and bottom-right). Each vertex reported is from type vec4. To visualize the vertex shader we will program a genie effect. This effect is often used to let a rectangular window area vanish into one point.

Setting up the scene

First, we will set up our scene again.



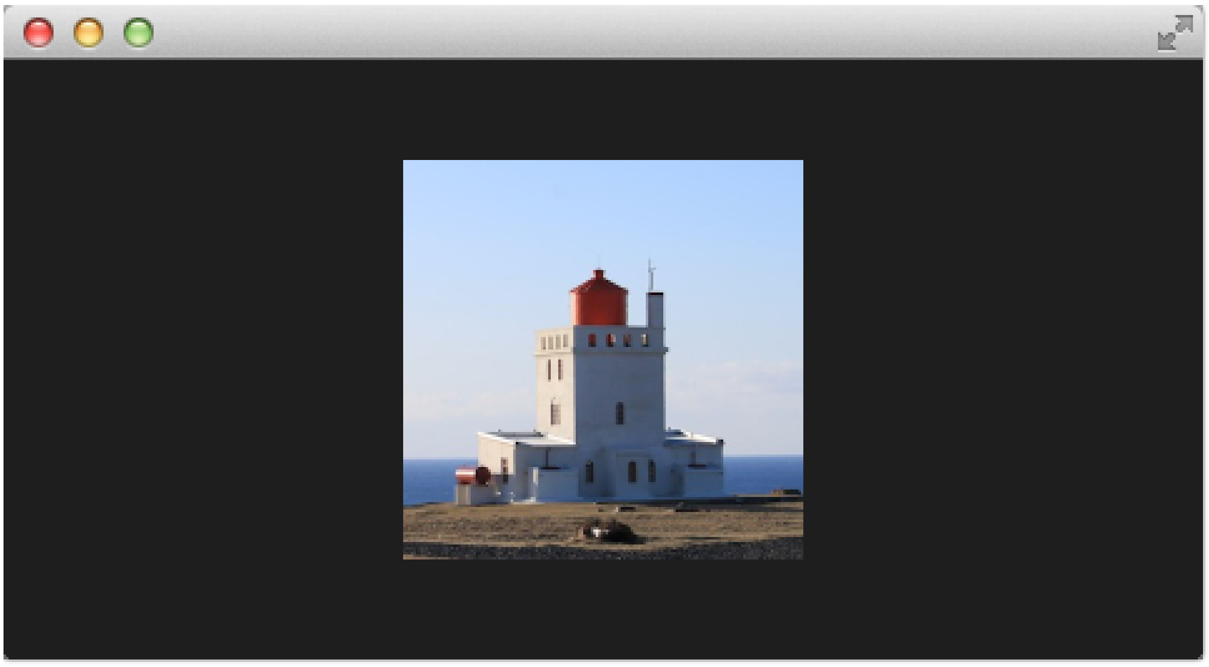


```
import QtQuick 2.5

Rectangle {
    width: 480; height: 240
    color: '#1e1e1e'

    Image {
        id: sourceImage
        width: 160; height: width
        source: "assets/lighthouse.jpg"
        visible: false
    }
    Rectangle {
        width: 160; height: width
        anchors.centerIn: parent
        color: '#333333'
    }
    ShaderEffect {
        id: genieEffect
        width: 160; height: width
        anchors.centerIn: parent
        property variant source: sourceImage
        property bool minimized: false
        MouseArea {
            anchors.fill: parent
            onClicked: genieEffect.minimized = !genieEffect.minimized
        }
    }
}
```

This provides a scene with a dark background and a shader effect using an image as the source texture. The original image is not visible on the image produced by our genie effect. Additional we added a dark rectangle on the same geometry as the shader effect so we can better detect where we need to click to revert the effect.



The effect is triggered by clicking on the image, this is defined by the mouse area covering the effect. In the *onClicked* handler we toggle the custom boolean property *minimized*. We will use this property later to toggle the effect.

Minimize and normalize

After we have set up the scene, we define a property of type real called *minimize*, the property will contain the current value of our minimization. The value will vary from 0.0 to 1.0 and is controlled by a sequential animation.

```
        property real minimize: 0.0

        SequentialAnimation on minimize {
            id: animMinimize
            running: genieEffect.minimized
            PauseAnimation { duration: 300 }
            NumberAnimation { to: 1; duration: 700; easing.type: Easing.InOutSine }
            PauseAnimation { duration: 1000 }
        }

        SequentialAnimation on minimize {
            id: animNormalize
            running: !genieEffect.minimized
            NumberAnimation { to: 0; duration: 700; easing.type: Easing.InOutSine }
            PauseAnimation { duration: 1300 }
        }
```

The animation is triggered by the toggling of the *minimized* property. Now that we have set up all our surroundings we finally can look at our vertex shader.

```
        vertexShader: "
            uniform highp mat4 qt_Matrix;
            attribute highp vec4 qt_Vertex;
            attribute highp vec2 qt_MultiTexCoord0;
            varying highp vec2 qt_TexCoord0;
            uniform highp float minimize;
            uniform highp float width;
            uniform highp float height;
            void main() {
                qt_TexCoord0 = qt_MultiTexCoord0;
                highp vec4 pos = qt_Vertex;
                pos.y = mix(qt_Vertex.y, height, minimize);
                pos.x = mix(qt_Vertex.x, width, minimize);
                gl_Position = qt_Matrix * pos;
            }"
```

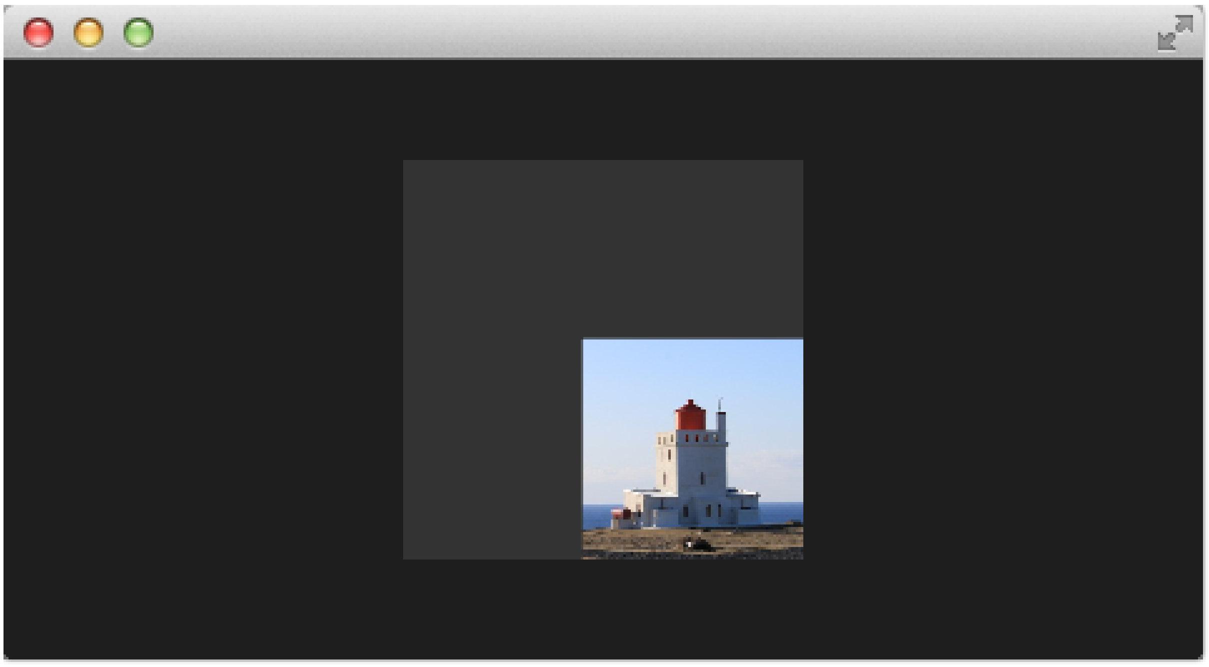
The vertex shader is called for each vertex so four times, in our case. The default qt defined parameters are provided, like *qt_Matrix*, *qt_Vertex*, *qt_MultiTexCoord0*, *qt_TexCoord0*. We have discussed the variable already earlier. Additional we link the *minimize*, *width* and *height* variables from our shader effect into our vertex shader code. In the main function, we store the current texture coordinate in our *qt_TexCoord0* to make it available to the fragment shader. Now we copy the current position and modify the x and y position of the vertex:

```
highp vec4 pos = qt_Vertex;
pos.y = mix(qt_Vertex.y, height, minimize);
pos.x = mix(qt_Vertex.x, width, minimize);
```

The *mix(…)* function provides a linear interpolation between the first 2 parameters on the point (0.0-1.0) provided by the 3rd parameter. So in our case, we interpolate for y between the current y position and the hight based on the current minimized value, similar for x. Bear in mind the minimized value is animated by our sequential animation and travels from 0.0 to 1.0 (or vice versa).

The resulting effect is not really the genie effect but is already a great step towards it.

Todo: better explanation, maybe draw the 4 vertexes and their interpolation

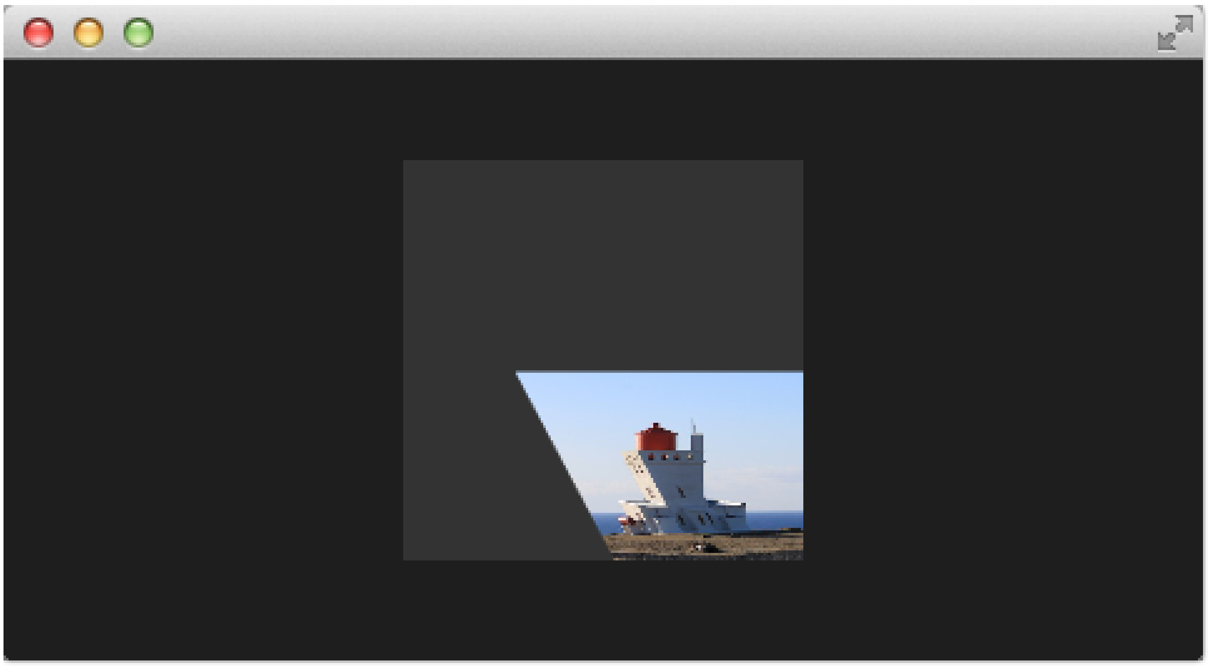


Primitive Bending

So minimized the x and y components of our vertexes. Now we would like to slightly modify the x manipulation and make it depending on the current y value. The needed changes are pretty small. The y-position is calculated as before. The interpolation of the x-position depends now on the vertexes y-position:

```
highp float t = pos.y / height;
pos.x = mix(qt_Vertex.x, width, t * minimize);
```

This results in an x-position tending towards the width when the y-position is larger. In other words, the upper 2 vertexes are not affected at all as they have a y-position of 0 and the lower two vertexes x-positions both bend towards the width, so they bend towards the same x-position.



```
import QtQuick 2.5

Rectangle {
    width: 480; height: 240
    color: "#1e1e1e"

    Image {
        id: sourceImage
        width: 160; height: width
        source: "assets/lighthouse.jpg"
        visible: false
    }
    Rectangle {
        width: 160; height: width
        anchors.centerIn: parent
        color: "#333333"
    }
    ShaderEffect {
        id: genieEffect
        width: 160; height: width
        anchors.centerIn: parent
        property variant source: sourceImage
        property real minimize: 0.0
        property bool minimized: false


        SequentialAnimation on minimize {
            id: animMinimize
            running: genieEffect.minimized
            PauseAnimation { duration: 300 }
            NumberAnimation { to: 1; duration: 700; easing.type: Easing.InOutSine }
            PauseAnimation { duration: 1000 }
        }

        SequentialAnimation on minimize {
            id: animNormalize
            running: !genieEffect.minimized
            NumberAnimation { to: 0; duration: 700; easing.type: Easing.InOutSine }
            PauseAnimation { duration: 1300 }
        }


        vertexShader: "
            uniform highp mat4 qt_Matrix;
            uniform highp float minimize;
            uniform highp float height;
            uniform highp float width;
            attribute highp vec4 qt_Vertex;
            attribute highp vec2 qt_MultiTexCoord0;
            varying highp vec2 qt_TexCoord0;
            void main() {
                qt_TexCoord0 = qt_MultiTexCoord0;
                highp vec4 pos = qt_Vertex;
                pos.y = mix(qt_Vertex.y, height, minimize);
                highp float t = pos.y / height;
                pos.x = mix(qt_Vertex.x, width, t * minimize);
                gl_Position = qt_Matrix * pos;
            }"
        MouseArea {
            anchors.fill: parent
            onClicked: parent.minimized = !parent.minimized
        }
```

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```
    }
}
```

Better Bending

As the bending is not really satisfying currently we will add several parts to improve the situation. First, we enhance our animation to support an own bending property. This is necessary as the bending should happen immediately and the y-minimization should be delayed shortly. Both animations have in the sum the same duration (300+700+1000 and 700+1300).

```
        property real bend: 0.0
        property bool minimized: false


        // change to parallel animation
        ParallelAnimation {
            id: animMinimize
            running: genieEffect.minimized
            SequentialAnimation {
                PauseAnimation { duration: 300 }
                NumberAnimation {
                    target: genieEffect; property: 'minimize';
                    to: 1; duration: 700;
                    easing.type: Easing.InOutSine
                }
                PauseAnimation { duration: 1000 }
            }
            // adding bend animation
            SequentialAnimation {
                NumberAnimation {
                    target: genieEffect; property: 'bend'
                    to: 1; duration: 700;
                    easing.type: Easing.InOutSine }
                PauseAnimation { duration: 1300 }
            }
        }
```

Additional to make the bending a smooth curve the y-effect on the x-position is not modified by a curved function from 0..1 and the `pos.x` depends now on the new bend property animation:

```
highp float t = pos.y / height;
t = (3.0 - 2.0 * t) * t * t;
pos.x = mix(qt_Vertex.x, width, t * bend);
```

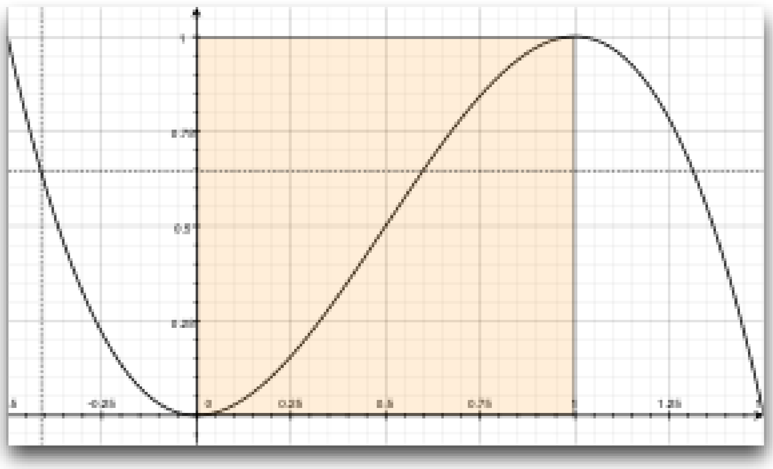
The curve starts smooth at the 0.0 value, grows then and stops smoothly towards the 1.0 value. Here is a plot of the function in the specified range. For us, only the range from 0..1 is from interest.

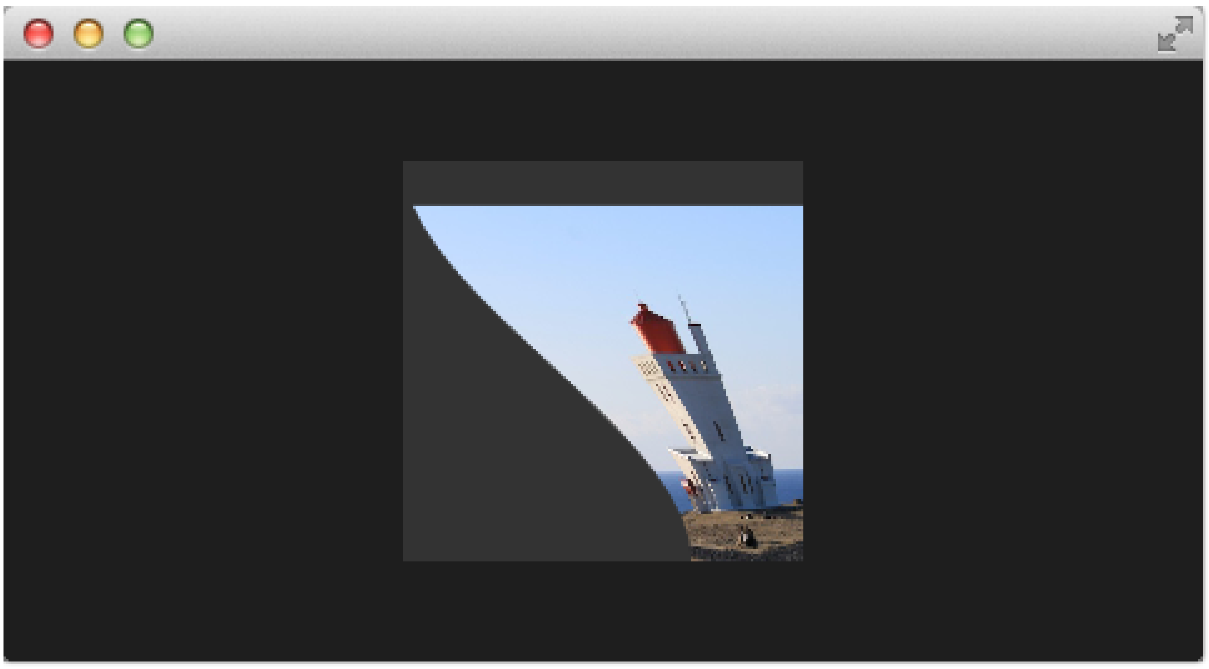
The most visual change is by increasing our amount of vertex points. The vertex points used can be increased by using a mesh:

```
mesh: GridMesh { resolution: Qt.size(16, 16) }
```

The shader effect now has an equality distributed grid of 16x16 vertexes instead of the 2x2 vertexes used before. This makes the interpolation between the vertexes look much smoother.

You can see also the influence of the curve being used, as the bending smoothes at the end nicely. This is where the bending has the strongest effect.


1
0.75
0.5
0.25
-0.25
0
0.25
0.5
0.75
1
1.25

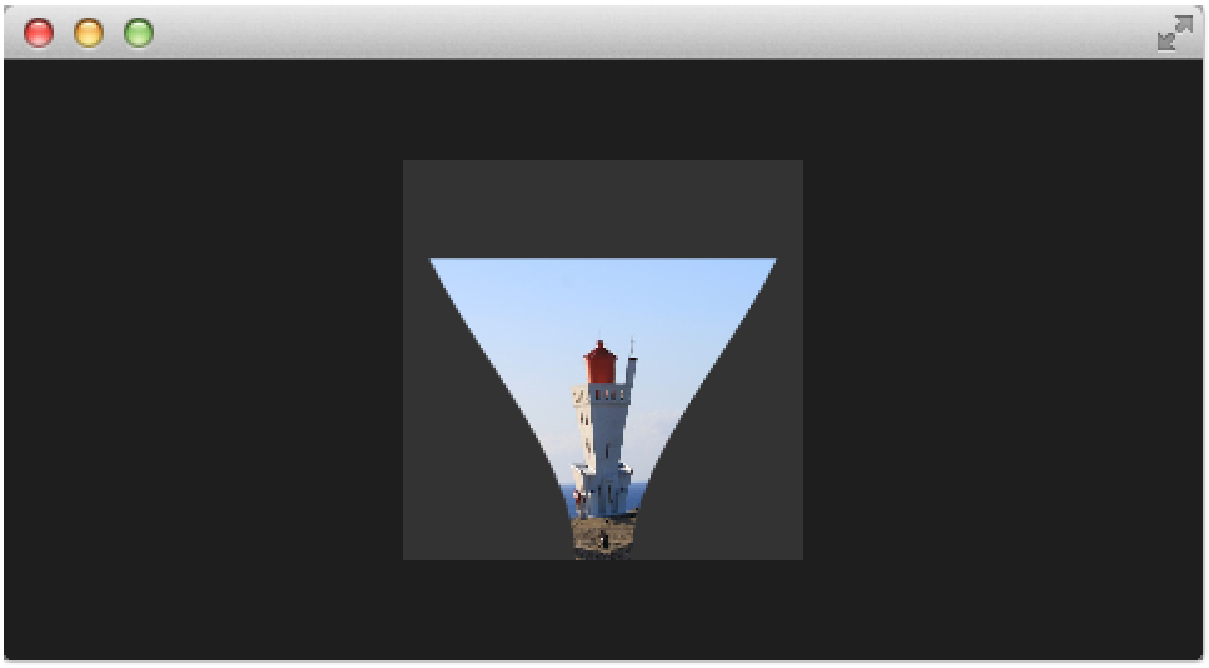


Choosing Sides

As a final enhancement, we want to be able to switch sides. The side is towards which point the genie effect vanishes. Till now it vanishes always towards the width. By adding a *side* property we are able to modify the point between 0 and width.

```
ShaderEffect {
    ...
    property real side: 0.5

    vertexShader: "
        ...
        uniform highp float side;
        ...
        pos.x = mix(qt_Vertex.x, side * width, t * bend);
    "
}
```



Packaging

The last thing to-do is packaging our effect nicely. For this, we extract our genie effect code into an own component called *GenieEffect*. It has the shader effect as the root element. We removed the mouse area as this should not be inside the component as the triggering of the effect can be toggled by the *minimized* property.

```
import QtQuick 2.5

ShaderEffect {
    id: genieEffect
    width: 160; height: width
    anchors.centerIn: parent
    property variant source
    mesh: GridMesh { resolution: Qt.size(10, 10) }
    property real minimize: 0.0
    property real bend: 0.0
    property bool minimized: false
    property real side: 1.0
```

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```
    ParallelAnimation {
        id: animMinimize
        running: genieEffect.minimized
        SequentialAnimation {
            PauseAnimation { duration: 300 }
            NumberAnimation {
                target: genieEffect; property: 'minimize';
                to: 1; duration: 700;
                easing.type: Easing.InOutSine
            }
            PauseAnimation { duration: 1000 }
        }
        SequentialAnimation {
            NumberAnimation {
                target: genieEffect; property: 'bend'
                to: 1; duration: 700;
                easing.type: Easing.InOutSine }
            PauseAnimation { duration: 1300 }
        }
    }

    ParallelAnimation {
        id: animNormalize
        running: !genieEffect.minimized
        SequentialAnimation {
            NumberAnimation {
                target: genieEffect; property: 'minimize';
                to: 0; duration: 700;
                easing.type: Easing.InOutSine
            }
            PauseAnimation { duration: 1300 }
        }
        SequentialAnimation {
            PauseAnimation { duration: 300 }
            NumberAnimation {
                target: genieEffect; property: 'bend'
                to: 0; duration: 700;
                easing.type: Easing.InOutSine }
            PauseAnimation { duration: 1000 }
        }
    }

    vertexShader: "
        uniform highp mat4 qt_Matrix;
        attribute highp vec4 qt_Vertex;
        attribute highp vec2 qt_MultiTexCoord0;
        uniform highp float height;
        uniform highp float width;
        uniform highp float minimize;
        uniform highp float bend;
        uniform highp float side;
        varying highp vec2 qt_TexCoord0;
        void main() {
            qt_TexCoord0 = qt_MultiTexCoord0;
            highp vec4 pos = qt_Vertex;
            pos.y = mix(qt_Vertex.y, height, minimize);
            highp float t = pos.y / height;
            t = (3.0 - 2.0 * t) * t * t;
            pos.x = mix(qt_Vertex.x, side * width, t * bend);
```

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```
            gl_Position = qt_Matrix * pos;
        }"
}
```

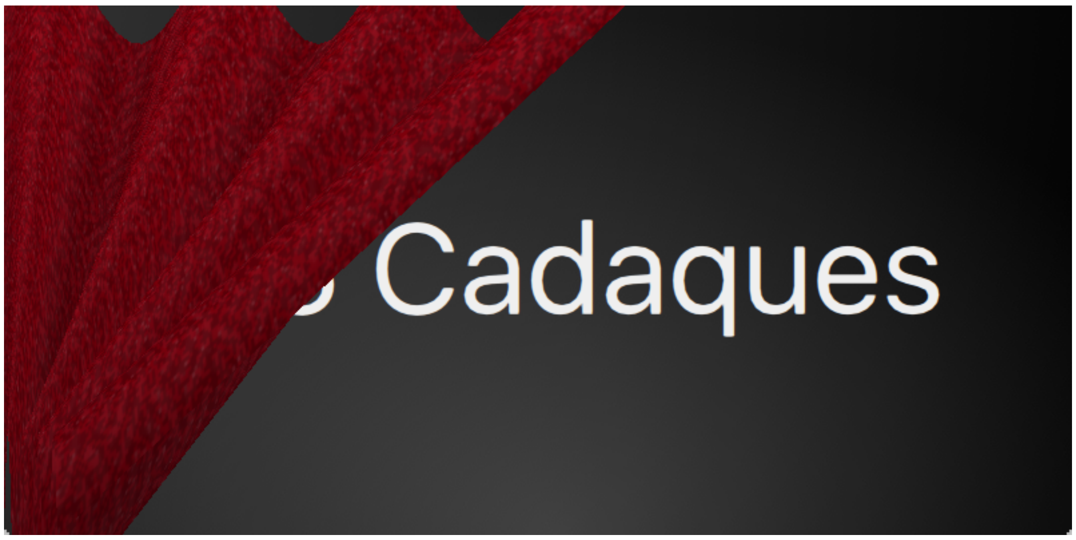
You can use now the effect simply like this:

```
import QtQuick 2.5

Rectangle {
    width: 480; height: 240
    color: '#1e1e1e'

    GenieEffect {
        source: Image { source: 'assets/lighthouse.jpg' }
        MouseArea {
            anchors.fill: parent
            onClicked: parent.minimized = !parent.minimized
        }
    }
}
```

We have simplified the code by removing our background rectangle and we assigned the image directly to the effect, instead of loading it inside a standalone image element.

11.6 Curtain Effect

In the last example for custom shader effects, I would like to bring you the curtain effect. This effect was published first in May 2011 as part of Qt labs for shader effects.

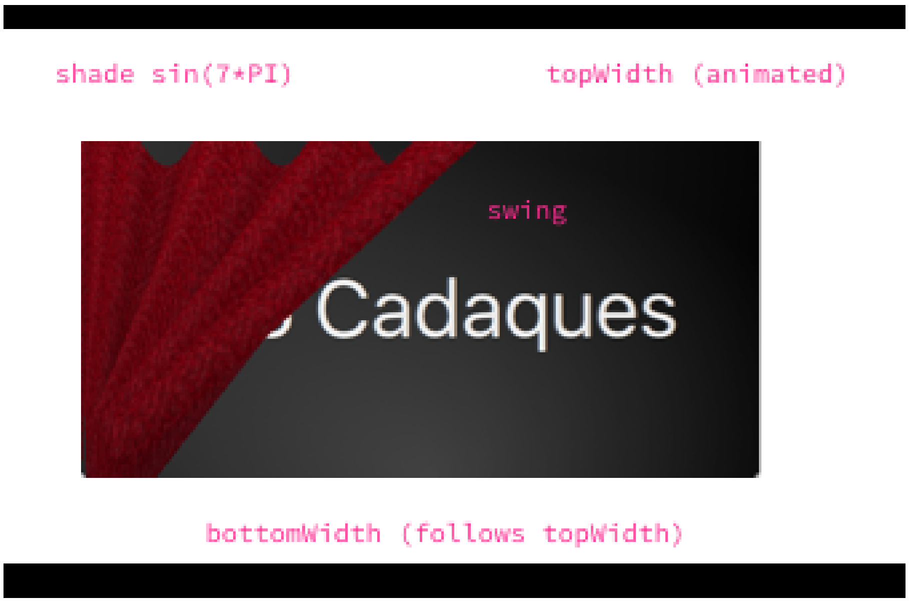


At that time I really loved these effects and the curtain effect was my favorite out of them. I just love how the curtain opens and hide the background object.

I took the code and adapted it towards Qt 5, which was straightforward. Also, I did some simplifications to be able to use it better for a showcase. So if you are interested in the full example, please visit the lab's blog.

Just a little bot for the background, the curtain is actually an image called *fabric.jpg* and it is the source for a shader effect. The effect uses the vertex shader to swing the curtain and uses the fragment shader to provide some shades. Here is a simple diagram to make you hopefully better understand the code.

The waved shades of the curtain are computed through a sin curve with 7 up/downs (7*PI=21.99…) on the width of the curtain. The other important part is the swing. The *topWidth* of the curtain is animated when the curtain is



opened or closed. The *bottomWidth* follows the *topWidth* with a *SpringAnimation*. By this, we create the effect of the swinging bottom part of the curtain. The calculated *swing* provides the strength of this swing interpolated over the y-component of the vertexes.

The curtain effect is located in the `CurtainEffect.qml` component where the fabric image act as the texture source. There is nothing new on the use of shaders here, only a different way to manipulate the *gl_Position* in the vertex shader and the *gl_FragColor* in the fragment shader.

```
import QtQuick 2.5

ShaderEffect {
    anchors.fill: parent

    mesh: GridMesh {
        resolution: Qt.size(50, 50)
    }

    property real topWidth: open?width:20
    property real bottomWidth: topWidth
    property real amplitude: 0.1
    property bool open: false
    property variant source: effectSource

    Behavior on bottomWidth {
        SpringAnimation {
            easing.type: Easing.OutElastic;
            velocity: 250; mass: 1.5;
            spring: 0.5; damping: 0.05
        }
    }

    Behavior on topWidth {
        NumberAnimation { duration: 1000 }
    }


    ShaderEffectSource {
        id: effectSource
        sourceItem: effectImage;
        hideSource: true
```

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```
    }

    Image {
        id: effectImage
        anchors.fill: parent
        source: "assets/fabric.png"
        fillMode: Image.Tile
    }

    vertexShader: "
        attribute highp vec4 qt_Vertex;
        attribute highp vec2 qt_MultiTexCoord0;
        uniform highp mat4 qt_Matrix;
        varying highp vec2 qt_TexCoord0;
        varying lowp float shade;

        uniform highp float topWidth;
        uniform highp float bottomWidth;
        uniform highp float width;
        uniform highp float height;
        uniform highp float amplitude;

        void main() {
            qt_TexCoord0 = qt_MultiTexCoord0;

            highp vec4 shift = vec4(0.0, 0.0, 0.0, 0.0);
            highp float swing = (topWidth - bottomWidth) * (qt_Vertex.y / height);
            shift.x = qt_Vertex.x * (width - topWidth + swing) / width;

            shade = sin(21.9911486 * qt_Vertex.x / width);
            shift.y = amplitude * (width - topWidth + swing) * shade;

            gl_Position = qt_Matrix * (qt_Vertex - shift);

            shade = 0.2 * (2.0 - shade ) * ((width - topWidth + swing) / width);
        }"

    fragmentShader: "
        uniform sampler2D source;
        varying highp vec2 qt_TexCoord0;
        varying lowp float shade;
        void main() {
            highp vec4 color = texture2D(source, qt_TexCoord0);
            color.rgb *= 1.0 - shade;
            gl_FragColor = color;
        }"
}
```

The effect is used in the `curtaindemo.qml` file.

```
import QtQuick 2.5

Item {
    id: root
    width: background.width; height: background.height


    Image {
        id: background
        anchors.centerIn: parent
        source: 'assets/background.png'
```

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```
    }

    Text {
        anchors.centerIn: parent
        font.pixelSize: 48
        color: '#efefef'
        text: 'Qt5 Cadaques'
    }

    CurtainEffect {
        id: curtain
        anchors.fill: parent
    }

    MouseArea {
        anchors.fill: parent
        onClicked: curtain.open = !curtain.open
    }
}
```

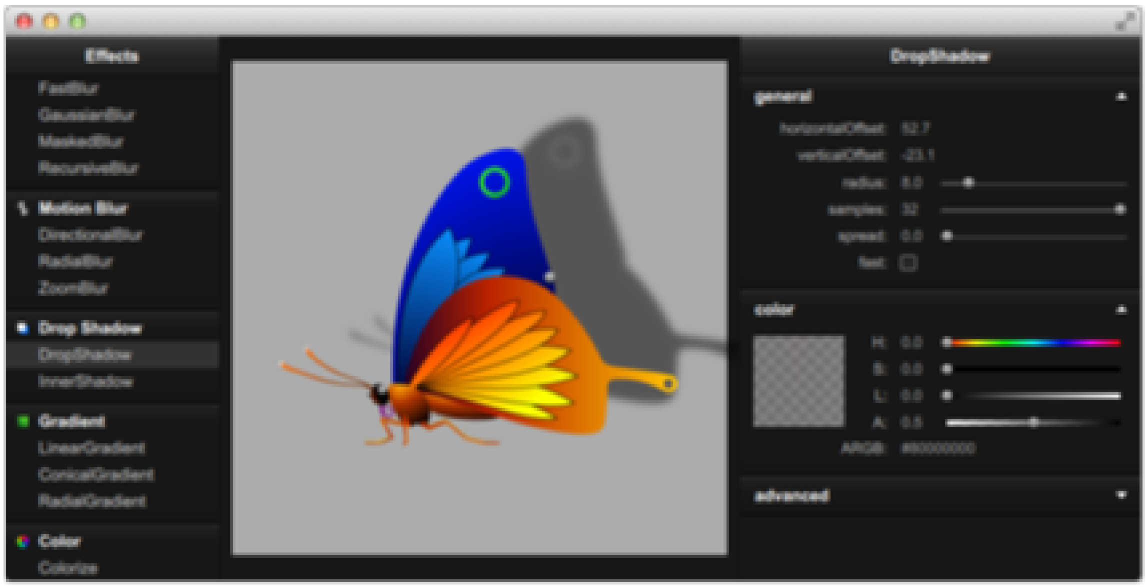
The curtain is opened through a custom *open* property on the curtain effect. We use a *MouseArea* to trigger the opening and closing of the curtain.

11.7 Qt GraphicsEffect Library

The graphics effect library is a collection of shader effects. Ready-made by the Qt developers. It's a great tool-set to be used in your application but also a great source to learn how to build shaders.

The graphics effects library comes with a so-called manual testbed which is a great tool to interactively discover the different effects.

The testbed is located under `$QTDIR/qtgraphicaleffects/tests/manual/testbed`.



horizontalOffset: 52.7
verticalOffset: -23.1
radius: 8.0
samples: 32
spread: 0.0
fast:
H: 0.0
S: 0.0
L: 0.0
A: 0.5
ARGB: #80000000

The effects library contains ca 20 effects. A list of the effect and a short description can be found below.

Graphics Effects List

Table 1: Graphics Effects List

Category	Effect	Description
Blend	*Blend*	merges two source items by using a blend mode
Color	*BrightnessContrast*	adjusts brightness and contrast
	Colorize	sets color in the HSL color space
	ColorOverlay	applies a color layer
	Desaturate	reduces color saturation
	GammaAdjust	adjusts luminance
	HueSaturation	adjusts colors in the HSL color space
	LevelAdjust	adjusts colors in the RGB color space
Gradient	*ConicalGradient*	draws a conical gradient
	LinearGradient	draws a linear gradient
	RadialGradient	draws a radial gradient
Distortion	*Displace*	moves the pixels of the source item according to the specified displacement source
Drop Shadow	*DropShadow*	draws a drop shadow
	InnerShadow	draws an inner shadow
Blur	*FastBlur*	applies a fast blur effect
	GaussianBlur	applies a higher quality blur effect
	MaskedBlur	applies a varying intensity blur effect
	RecursiveBlur	blurs repeatedly, providing a strong blur effect
Motion Blur	*DirectionalBlur*	applies a directional motion blur effect
	RadialBlur	applies a radial motion blur effect
	ZoomBlur	applies a zoom motion blur effect
Glow	*Glow*	draws an outer glow effect
	RectangularGlow	draws a rectangular outer glow effect
Mask	*OpacityMask*	masks the source item with another item
	ThresholdMask	masks the source item with another item and applies a threshold value

Here is a example using the *FastBlur* effect from the *Blur* category:

```
import QtQuick 2.5
import QtGraphicalEffects 1.0

Rectangle {
    width: 480; height: 240
    color: '#1e1e1e'

    Row {
        anchors.centerIn: parent
        spacing: 16

        Image {
            id: sourceImage
            source: "assets/tulips.jpg"
            width: 200; height: width
            sourceSize: Qt.size(parent.width, parent.height)
            smooth: true
        }

        FastBlur {
            width: 200; height: width
            source: sourceImage
            radius: blurred?32:0
```

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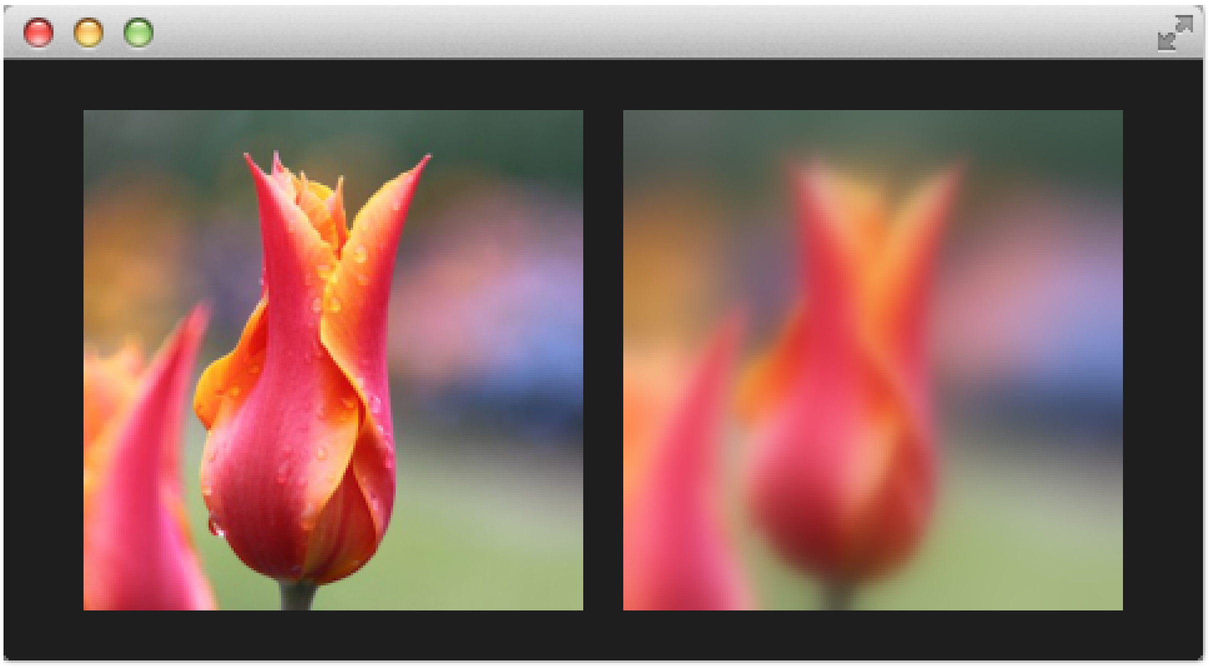
```
                property bool blurred: false

                Behavior on radius {
                    NumberAnimation { duration: 1000 }
                }

                MouseArea {
                    id: area
                    anchors.fill: parent
                    onClicked: parent.blurred = !parent.blurred
                }
            }
        }
}
```

The image to the left is the original image. Clicking the image on the right will toggle blurred property and animated the blur radius from 0 to 32 during 1 second. The image on the left shows the blurred image.



CHAPTER

TWELVE

MULTIMEDIA

Section author: e8johan

Note: Last Build: December 07, 2020 at 10:50 CET

The source code for this chapter can be found in the assets folder.

The multimedia elements in the QtMultimedia makes it possible to playback and record media such as sound, video or pictures. Decoding and encoding are handled through platform-specific backends. For instance, the popular GStreamer framework is used on Linux, while DirectShow is used on Windows and QuickTime on OS X.

The multimedia elements are not a part of the Qt Quick core API. Instead, they are provided through a separate API made available by importing QtMultimedia 5.6 as shown below:

```
import QtMultimedia 5.6
```

12.1 Playing Media

The most basic case of multimedia integration in a QML application is for it to playback media. This is done using the `MediaPlayer` element, optionally in combination with a `VideoOutput` element if the source is an image or video. The `MediaPlayer` element has a `source` property pointing at the media to play. When a media source has been bound, it is simply a matter of calling the `play` function to start playing.

If you want to play visual media, i.e. pictures or video, you must also set up a `VideoOutput` element. The `MediaPlayer` running the playback is bound to the video output through the `source` property.

In the example shown below, the `MediaPlayer` is given a file with video contents as `source`. A `VideoOutput` is created and bound to the media player. As soon as the main component has been fully initialized, i.e. at `Component.onCompleted`, the player's `play` function is called.

```
import QtQuick 2.5
import QtMultimedia 5.6

Item {
    width: 1024
    height: 600

    MediaPlayer {
        id: player
        source: "trailer_400p.ogg"
    }

    VideoOutput {
        anchors.fill: parent
        source: player
    }
```

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```
    Component.onCompleted: {
        player.play();
    }
}
```

Basic operations such as altering the volume when playing media are controlled through the `volume` property of the `MediaPlayer` element. There are other useful properties as well. For instance, the `duration` and `position` properties can be used to build a progress bar. If the `seekable` property is `true`, it is even possible to update the `position` when the progress bar is tapped. However, the `position` property is read-only, instead we must use the `seek` method. The example below shows how this is added to the basic playback example above.

```
    Rectangle {
        id: progressBar

        anchors.left: parent.left
        anchors.right: parent.right
        anchors.bottom: parent.bottom
        anchors.margins: 100

        height: 30

        color: "lightGray"

        Rectangle {
            anchors.left: parent.left
            anchors.top: parent.top
            anchors.bottom: parent.bottom

            width: player.duration>0?parent.width*player.position/player.duration:0

            color: "darkGray"
        }

        MouseArea {
            anchors.fill: parent

            onClicked: {
                if (player.seekable) {
                    player.seek(player.duration * mouse.x/width);
                }
            }
        }
    }
```

The `position` property is only updated once per second in the default case. This means that the progress bar will update in large steps unless the duration of the media is long enough, compared to the number of pixels that the progress bar is wide. This can, however, be changed through accessing the `mediaObject` property and its `notifyInterval` property. It can be set to the number of milliseconds between each position update, increasing the smoothness of the user interface.

```
    Connections {
        target: player
        onMediaObjectChanged: {
            if (player.mediaObject) {
                player.mediaObject.notifyInterval = 50;
            }
        }
    }
```

Todo: The code above does not have any effect on the update interval! There seems to be no media object…

When using MediaPlayer to build a media player, it is good to monitor the status property of the player. It is an enumeration of the possible statuses, ranging from MediaPlayer.Buffered to MediaPlayer.InvalidMedia. The possible values are summarized in the bullets below:

- MediaPlayer.UnknownStatus. The status is unknown.
- MediaPlayer.NoMedia. The player has no media source assigned. Playback is stopped.
- MediaPlayer.Loading. The player is loading the media.
- MediaPlayer.Loaded. The media has been loaded. Playback is stopped.
- MediaPlayer.Stalled. The loading of media has stalled.
- MediaPlayer.Buffering. The media is being buffered.
- MediaPlayer.Buffered. The media has been buffered, this means that the player can start playing the media.
- MediaPlayer.EndOfMedia. The end of the media has been reached. Playback is stopped.
- MediaPlayer.InvalidMedia. The media cannot be played. Playback is stopped.

As mentioned in the bullets above, the playback state can vary over time. Calling play, pause or stop alters the state, but the media in question can also have an effect. For example, the end can be reached, or it can be invalid, causing playback to stop. The current playback state can be tracked through the playbackState property. The values can be MediaPlayer.PlayingState, MediaPlayer.PausedState or MediaPlayer.StoppedState.

Using the autoPlay property, the MediaPlayer can be made to attempt go to the playing state as soon as the source property is changed. A similar property is the autoLoad causing the player to try to load the media as soon as the source property is changed. The latter property is enabled by default.

It is also possible to let the MediaPlayer to loop a media item. The loops property controls how many times the source is to be played. Setting the property to MediaPlayer.Infinite causes endless looping. Great for continuous animations or a looping background song.

12.2 Sound Effects

When playing sound effects, the response time from requesting playback until actually playing becomes important. In this situation, the SoundEffect element comes in handy. By setting up the source property, a simple call to the play function immediately starts playback.

This can be utilized for audio feedback when tapping the screen, as shown below.

```
    SoundEffect {
        id: beep
        source: "beep.wav"
    }

    Rectangle {
        id: button

        anchors.centerIn: parent

        width: 200
        height: 100

        color: "red"
```

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```
        MouseArea {
            anchors.fill: parent
            onClicked: beep.play()
        }
    }
```

The element can also be utilized to accompany a transition with audio. To trigger playback from a transition, the `ScriptAction` element is used.

```
    SoundEffect {
        id: swosh
        source: "swosh.wav"
    }

    transitions: [
        Transition {
            ParallelAnimation {
                ScriptAction { script: swosh.play(); }
                PropertyAnimation { properties: "rotation"; duration: 200; }
            }
        }
    ]
```

In addition to the `play` function, a number of properties similar to the ones offered by `MediaPlayer` are available. Examples are `volume` and `loops`. The latter can be set to `SoundEffect.Infinite` for infinite playback. To stop playback, call the `stop` function.

Note: When the PulseAudio backend is used, `stop` will not stop instantaneously, but only prevent further loops. This is due to limitations in the underlying API.

12.3 Video Streams

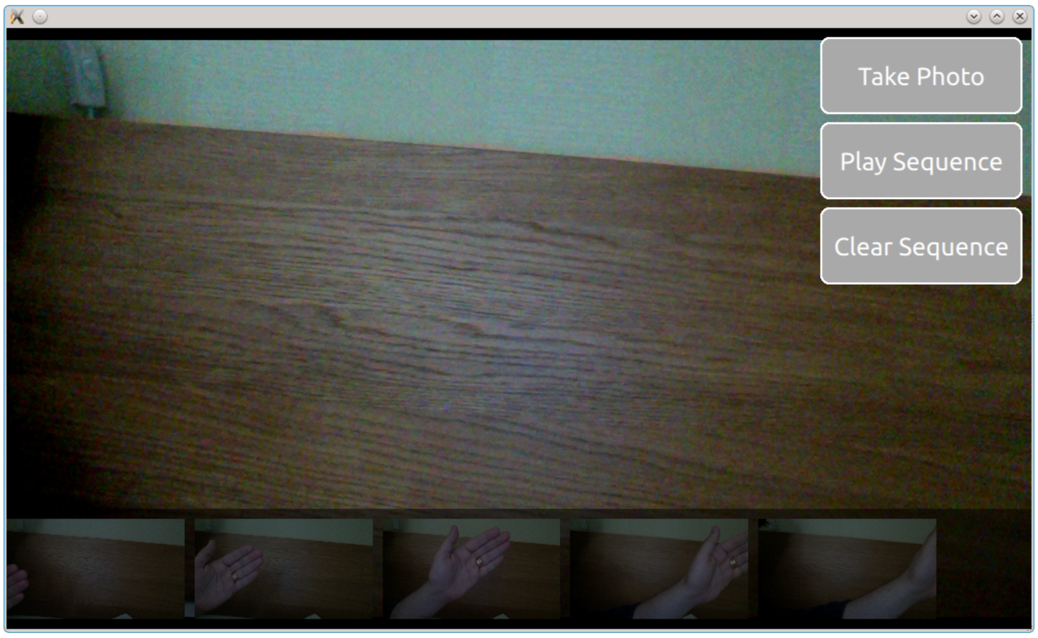
The `VideoOutput` element is not limited to usage in combination with `MediaPlayer` elements. It can also be used directly with video sources to show a live video stream. Using a `Camera` element as `source` and the application is complete. The video stream from a `Camera` can be used to provide a live stream to the user. This stream works as the search view when capturing photos.

```
import QtQuick 2.5
import QtMultimedia 5.6

Item {
    width: 1024
    height: 600

    VideoOutput {
        anchors.fill: parent
        source: camera
    }

    Camera {
        id: camera
    }
}
```

12.4 Capturing Images

One of the key features of the `Camera` element is that is can be used to take pictures. We will use this in a simple stop-motion application. In it, you will learn how to show a viewfinder, snap photos and keep track of the pictures taken.

The user interface is shown below. It consists of three major parts. In the background, you will find the viewfinder, to the right, a column of buttons and at the bottom, a list of images taken. The idea is to take a series of photos, then click the Play Sequence button. This will play the images back, creating a simple stop-motion film.



The viewfinder part of the camera is simply a `Camera` element used as `source` in a `VideoOutput`. This will show the user a live video stream from the camera.

```
    VideoOutput {
        anchors.fill: parent
        source: camera
    }

    Camera {
        id: camera
    }
```

Note: For more control over the camera behaviour, for instance to control exposure or focus settings, use the `exposure` and `focus` properties of the `Camera` object. These expose a whole range of settings made available through the CameraExposure and CameraFocus elements.

The list of photos is a `ListView` oriented horizontally shows images from a `ListModel` called `imagePaths`. In the background, a semi-transparent black `Rectangle` is used.

```
    ListModel {
        id: imagePaths
    }

    ListView {
        id: listView

        anchors.left: parent.left
```

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```
        anchors.right: parent.right
        anchors.bottom: parent.bottom
        anchors.bottomMargin: 10

        height: 100

        orientation: ListView.Horizontal
        spacing: 10

        model: imagePaths

        delegate: Image {
            height: 100
            source: path
            fillMode: Image.PreserveAspectFit
        }

        Rectangle {
            anchors.fill: parent
            anchors.topMargin: -10

            color: "black"
            opacity: 0.5
        }
    }
```

For the shooting of images, you need to know that the `Camera` element contains a set of sub-elements for various tasks. To capture still pictures, the `Camera.imageCapture` element is used. When you call the `capture` method, a picture is taken. This results in the `Camera.imageCapture` emitting first the `imageCaptured` signal followed by the `imageSaved` signal.

```
        Button {
            id: shotButton

            text: "Take Photo"
            onClicked: {
                camera.imageCapture.capture();
            }
        }
```

To intercept the signals of a sub-element, a `Connections` element is needed. In this case, we don't need to show a preview image, but simply add the resulting image to the `ListView` at the bottom of the screen. Shown in the example below, the path to the saved image is provided as the `path` argument with the signal.

```
    Connections {
        target: camera.imageCapture

        onImageSaved: {
            imagePaths.append({"path": path})
            listView.positionViewAtEnd();
        }
    }
```

For showing a preview, connect to the `imageCaptured` signal and use the `preview` signal argument as `source` of an `Image` element. A `requestId` signal argument is sent along both the `imageCaptured` and `imageSaved`. This value is returned from the `capture` method. Using this, the capture of an image can be traced through the complete cycle. This way, the preview can be used first and then be replaced by the properly saved image. This, however, is nothing that we do in the example.

The last part of the application is the actual playback. This is driven using a `Timer` element and some JavaScript. The `_imageIndex` variable is used to keep track of the currently shown image. When the last image has been shown, the playback is stopped. In the example, the `root.state` is used to hide parts of the user interface when playing the sequence.

```
    property int _imageIndex: -1

    function startPlayback()
    {
        root.state = "playing";
        setImageIndex(0);
        playTimer.start();
    }

    function setImageIndex(i)
    {
        _imageIndex = i;

        if (_imageIndex >= 0 && _imageIndex < imagePaths.count)
            image.source = imagePaths.get(_imageIndex).path;
        else
            image.source = "";
    }

    Timer {
        id: playTimer

        interval: 200
        repeat: false

        onTriggered: {
            if (_imageIndex + 1 < imagePaths.count)
            {
                setImageIndex(_imageIndex + 1);
                playTimer.start();
            }
            else
            {
                setImageIndex(-1);
                root.state = "";
            }
        }
    }
```

12.5 Advanced Techniques

12.5.1 Using a Playlist

Since Qt 5.6 the QML multimedia API supports playlists. Simply assign a `Playlist` instance to the `playlist` property of your `MediaPlayer`. The `Playlist` element will then take care of setting the `source` of the `MediaPlayer`, while the play state is controlled via the player.

```
    MediaPlayer {
        id: player
        playlist: Playlist {
            PlaylistItem { source: "trailer_400p.ogg" }
            PlaylistItem { source: "trailer_400p.ogg" }
            PlaylistItem { source: "trailer_400p.ogg" }
        }
    }
```

To make the player start playing, simply set the playlist currentIndex and tell the MediaPlayer to start playing.

```
    Component.onCompleted: {
        player.playlist.currentIndex = 0;
        player.play();
    }
```

12.6 Summary

The media API provided by Qt provides mechanisms for playing and capturing video and audio. Through the VideoOutput element and video, the source can be displayed in the user interface. Through the MediaPlayer element, most playback can be handled, even though the SoundEffect can be used for low-latency sounds. For capturing, or only showing a live video stream, the Camera element is used.

CHAPTER

THIRTEEN

NETWORKING

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The source code for this chapter can be found in the assets folder.

Qt 5 comes with a rich set of networking classes on the C++ side. There are for example high-level classes on the HTTP protocol layer in a request-reply fashion such as `QNetworkRequest`, `QNetworkReply` and `QNetworkAccessManager`. But also lower levels classes on the TCP/IP or UDP protocol layer such as `QTcpSocket`, `QTcpServer` and `QUdpSocket`. Additional classes exist to manage proxies, network cache and also the systems network configuration.

This chapter will not be about C++ networking, this chapter is about Qt Quick and networking. So how can I connect my QML/JS user interface directly with a network service or how can I serve my user interface via a network service? There are good books and references out there to cover network programming with Qt/C++. Then it is just a manner to read the chapter about C++ integration to come up with an integration layer to feed your data into the Qt Quick world.

13.1 Serving UI via HTTP

To load a simple user interface via HTTP we need to have a web-server, which serves the UI documents. We start off with our own simple web-server using a python one-liner. But first, we need to have our demo user interface. For this, we create a small `main.qml` file in our project folder and create a red rectangle inside.

```
// main.qml
import QtQuick 2.5

Rectangle {
    width: 320
    height: 320
    color: '#ff0000'
}
```

To serve this file we launch a small python script:

```
$ cd <PROJECT>
$ python -m SimpleHTTPServer 8080
```

Now our file should be reachable via `http://localhost:8080/main.qml`. You can test it with:

```
$ curl http://localhost:8080/main.qml
```

Or just point your browser to the location. Your browser does not understand QML and will not be able to render the document through. We need to create now such a browser for QML documents. To render the document we need to point our `qmlscene` to the location. Unfortunately the `qmlscene` is limited to local files only. We could overcome this limitation by writing our own `qmlscene` replacement or simple dynamically load it using QML. We choose the dynamic loading as it works just fine. For this, we use a loader element to retrieve for us the remote document.

```
// remote.qml
import QtQuick 2.5

Loader {
    id: root
    source: 'http://localhost:8080/main2.qml'
    onLoaded: {
        root.width = item.width
        root.height = item.height
    }
}
```

Now we can ask the `qmlscene` to load the local `remote.qml` loader document. There is one glitch still. The loader will resize to the size of the loaded item. And our `qmlscene` needs also to adapt to that size. This can be accomplished using the `--resize-to-root` option to the `qmlscene`,

```
$ qmlscene --resize-to-root remote.qml
```

Resize to root tells the qml scene to resize its window to the size of the root element. The remote is now loading the `main.qml` from our local server and resizes itself to the loaded user interface. Sweet and simple.

Note: If you do not want to run a local server you can also use the gist service from GitHub. The gist is a clipboard like online services like Pastebin and others. It is available under https://gist.github.com. I created for this example a small gist under the URL https://gist.github.com/jryannel/7983492. This will reveal a green rectangle. As the gist URL will provide the website as HTML code we need to attach a `/raw` to the URL to retrieve the raw file and not the HTML code.

```
// remote.qml
import QtQuick 2.5

Loader {
    id: root
    source: 'https://gist.github.com/jryannel/7983492/raw'
    onLoaded: {
        root.width = item.width
        root.height = item.height
    }
}
```

To load another file over the network you just need to reference the component name. For example a `Button.qml` can be accessed as normal, as long it is in the same remote folder.

Todo: Is this true? What are the rules?

13.1.1 Networked Components

Let us create a small experiment. We add to our remote side a small button as a reusable component.

```
- src/main.qml
- src/Button.qml
```

We modify our `main.qml` to use the button and save it as `main2.qml`:

```
import QtQuick 2.5

Rectangle {
    width: 320
    height: 320
    color: '#ff0000'

    Button {
        anchors.centerIn: parent
        text: 'Click Me'
        onClicked: Qt.quit()
    }
}
```

And launch our web-server again

```
$ cd src
$ python -m SimpleHTTPServer 8080
```

And our remote loader loads the main QML via HTTP again

```
$ qmlscene --resize-to-root remote.qml
```

What we see is an error

```
http://localhost:8080/main2.qml:11:5: Button is not a type
```

So QML cannot resolve the button component when it is loaded remotely. If the code would be local `qmlscene src/main.qml` this would be no issue. Locally Qt can parse the directory and detect which components are available but remotely there is no "list-dir" function for HTTP. We can force QML to load the element using the import statement inside `main.qml`:

```
import "http://localhost:8080" as Remote

...

Remote.Button { ... }
```

This will work then when the `qmlscene` is run again:

```
$ qmlscene --resize-to-root remote.qml
```

Here the full code:

```
// main2.qml
import QtQuick 2.5
import "http://localhost:8080" 1.0 as Remote

Rectangle {
    width: 320
    height: 320
    color: '#ff0000'

    Remote.Button {
        anchors.centerIn: parent
        text: 'Click Me'
        onClicked: Qt.quit()
    }
}
```

A better option is to use the `qmldir` file on the server side to control the export.

```
// qmldir
Button 1.0 Button.qml
```

And then updating the `main.qml`:

```
import "http://localhost:8080" 1.0 as Remote

...

Remote.Button { ... }
```

Note: Loading

When using components from a local file system, they are created immediately without a latency. When components are loaded via the network they are created asynchronously. This has the effect that the time of creation is unknown and an element may not yet be fully loaded when others are already completed. Take this into account when working with components loaded over the network.

13.2 Templating

When working with HTML projects they often use template driven development. A small HTML stub is expanded on the server side with code generated by the server using a template mechanism. For example, for a photo list, the list header would be coded in HTML and the dynamic image list would be dynamically generated using a template mechanism. In general, this can also be done using QML but there are some issues with it.

First, it is not necessary. The reason HTML developers are doing this is to overcome limitations on the HTML backend. There is no component model yet in HTML so dynamic aspects have to be covered using these mechanisms or using programmatically javascript on the client side. Many JS frameworks are out there (jQuery, dojo, backbone, angular, …) to solve this issue and put more logic into the client-side browser to connect with a network service. The client would then just use a web-service API (e.g. serving JSON or XML data) to communicate with the server. This seems also the better approach for QML.

The second issue is the component cache from QML. When QML accesses a component it caches the render-tree and just loads the cached version for rendering. A modified version on disk or remote would not be detected without restarting the client. To overcome this issue we could use a trick. We could use URL fragments to load the URL (e.g. http://localhost:8080/main.qml#1234), where '#1234' is the fragment. The HTTP server serves always the same document but QML would store this document using the full URL, including the fragment. Every time we would access this URL the fragment would need to change and the QML cache would not get a positive hit. A fragment could be for example the current time in milliseconds or a random number.

```
Loader {
    source: 'http://localhost:8080/main.qml#' + new Date().getTime()
}
```

In summary templating is possible but not really recommended and does not play to the strength of QML. A better approach is to use web-services which serve JSON or XML data.

13.3 HTTP Requests

An HTTP request is in Qt typically done using `QNetworkRequest` and `QNetworkReply` from the c++ site and then the response would be pushed using the Qt/C++ integration into the QML space. So we try to push the envelope here a little bit to use the current tools Qt Quick gives us to communicate with a network endpoint. For this, we use a helper object to make an HTTP request, response cycle. It comes in the form of the javascript `XMLHttpRequest` object.

The `XMLHttpRequest` object allows the user to register a response handler function and a URL. A request can be sent using one of the HTTP verbs (get, post, put, delete, ...) to make the request. When the response arrives the handler function is called. The handler function is called several times. Every-time the request state has changed (for example headers have arrived or request is done).

Here a short example:

```
function request() {
    var xhr = new XMLHttpRequest();
    xhr.onreadystatechange = function() {
        if (xhr.readyState === XMLHttpRequest.HEADERS_RECEIVED) {
            print('HEADERS_RECEIVED');
        } else if(xhr.readyState === XMLHttpRequest.DONE) {
            print('DONE');
        }
    }
    xhr.open("GET", "http://example.com");
    xhr.send();
}
```

For a response, you can get the XML format or just the raw text. It is possible to iterate over the resulting XML but more commonly used is the raw text nowadays for a JSON formatted response. The JSON document will be used to convert text to a JS object using `JSON.parse(text)`.

```
...
} else if(xhr.readyState === XMLHttpRequest.DONE) {
    var object = JSON.parse(xhr.responseText.toString());
    print(JSON.stringify(object, null, 2));
}
```

In the response handler, we access the raw response text and convert it into a javascript object. This JSON object is now a valid JS object (in javascript an object can be an object or an array).

Note: It seems the `toString()` conversion first makes the code more stable. Without the explicit conversion, I had several times parser errors. Not sure what the cause it.

13.3.1 Flickr Calls

Let us have a look on a more real-world example. A typical example is to use the Flickr service to retrieve a public feed of the newly uploaded pictures. For this, we can use the `http://api.flickr.com/services/feeds/photos_public.gne` URL. Unfortunately, it returns by default an XML stream, which could be easily parsed by the `XmlListModel` in qml. For the sake of the example, we would like to concentrate on JSON data. To become a clean JSON response we need to attach some parameters to the request: `http://api.flickr.com/services/feeds/photos_public.gne?format=json&nojsoncallback=1`. This will return a JSON response without the JSON callback.

Note: A JSON callback wraps the JSON response into a function call. This is a shortcut used on HTML programming where a script tag is used to make a JSON request. The response will trigger a local function defined by the callback. There is no mechanism which works with JSON callbacks in QML.

Let us first examine the response by using curl:

```
curl "http://api.flickr.com/services/feeds/photos_public.gne?format=json&
→nojsoncallback=1&tags=munich"
```

The response will be something like this:

```
{
    "title": "Recent Uploads tagged munich",
    ...
    "items": [
        {
        "title": "Candle lit dinner in Munich",
        "media": {"m":"http://farm8.staticflickr.com/7313/11444882743_2f5f87169f_m.
↪jpg"},
        ...
        },{
        "title": "Munich after sunset: a train full of \"must haves\" =",
        "media": {"m":"http://farm8.staticflickr.com/7394/11443414206_a462c80e83_m.
↪jpg"},
        ...
        }
    ]
    ...
}
```

The returned JSON document has a defined structure. An object which has a title and an items property. Where the title is a string and items is an array of objects. When converting this text into a JSON document you can access the individual entries, as it is a valid JS object/array structure.

```
// JS code
obj = JSON.parse(response);
print(obj.title) // => "Recent Uploads tagged munich"
for(var i=0; i<obj.items.length; i++) {
    // iterate of the items array entries
    print(obj.items[i].title) // title of picture
    print(obj.items[i].media.m) // url of thumbnail
}
```

As a valid JS array, we can use the `obj.items` array also as a model for a list view. We will try to accomplish this now. First, we need to retrieve the response and convert it into a valid JS object. And then we can just set the `response.items` property as a model to a list view.

```
function request() {
    var xhr = new XMLHttpRequest();
    xhr.onreadystatechange = function() {
        if(...) {
            ...
        } else if(xhr.readyState === XMLHttpRequest.DONE) {
            var response = JSON.parse(xhr.responseText.toString());
            // set JS object as model for listview
            view.model = response.items;
        }
    }
    xhr.open("GET", "http://api.flickr.com/services/feeds/photos_public.gne?
↪format=json&nojsoncallback=1&tags=munich");
    xhr.send();
}
```

Here is the full source code, where we create the request when the component is loaded. The request response is then used as the model for our simple list view.

```
import QtQuick 2.5

Rectangle {
    width: 320
    height: 480
    ListView {
```

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```
        id: view
        anchors.fill: parent
        delegate: Thumbnail {
            width: view.width
            text: modelData.title
            iconSource: modelData.media.m
        }
    }

    function request() {
        var xhr = new XMLHttpRequest();
        xhr.onreadystatechange = function() {
            if (xhr.readyState === XMLHttpRequest.HEADERS_RECEIVED) {
                print('HEADERS_RECEIVED')
            } else if(xhr.readyState === XMLHttpRequest.DONE) {
                print('DONE')
                var json = JSON.parse(xhr.responseText.toString())
                view.model = json.items
            }
        }
        xhr.open("GET", "http://api.flickr.com/services/feeds/photos_public.gne?
↪format=json&nojsoncallback=1&tags=munich");
        xhr.send();
    }

    Component.onCompleted: {
        request()
    }
}
```

When the document is fully loaded (`Component.onCompleted`) we request the latest feed content from Flickr. On arrival, we parse the JSON response and set the `items` array as the model for our view. The list view has a delegate, which displays the thumbnail icon and the title text in a row.

The other option would be to have a placeholder `ListModel` and append each item onto the list model. To support larger models it is required to support pagination (e.g page 1 of 10) and lazy content retrieval.

13.4 Local files

Is it also possible to load local (XML/JSON) files using the XMLHttpRequest. For example a local file named "colors.json" can be loaded using:

```
xhr.open("GET", "colors.json");
```

We use this to read a color table and display it as a grid. It is not possible to modify the file from the Qt Quick side. To store data back to the source we would need a small REST based HTTP server or a native Qt Quick extension for file access.

```
import QtQuick 2.5

Rectangle {
    width: 360
    height: 360
    color: '#000'

    GridView {
        id: view
        anchors.fill: parent
        cellWidth: width/4
```

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```
        cellHeight: cellWidth
        delegate: Rectangle {
            width: view.cellWidth
            height: view.cellHeight
            color: modelData.value
        }
    }

    function request() {
        var xhr = new XMLHttpRequest();
        xhr.onreadystatechange = function() {
            if (xhr.readyState === XMLHttpRequest.HEADERS_RECEIVED) {
                print('HEADERS_RECEIVED')
            } else if(xhr.readyState === XMLHttpRequest.DONE) {
                print('DONE');
                var obj = JSON.parse(xhr.responseText.toString());
                view.model = obj.colors
            }
        }
        xhr.open("GET", "colors.json");
        xhr.send();
    }

    Component.onCompleted: {
        request()
    }
}
```

Instead of using the `XMLHttpRequest` it is also possible to use the XmlListModel to access local files.

```
import QtQuick.XmlListModel 2.0

XmlListModel {
    source: "http://localhost:8080/colors.xml"
    query: "/colors"
    XmlRole { name: 'color'; query: 'name/string()' }
    XmlRole { name: 'value'; query: 'value/string()' }
}
```

With the XmlListModel it is only possible to read XML files and not JSON files.

13.5 REST API

To use a web-service, we first need to create one. We will use Flask (http://flask.pocoo.org) a simple HTTP app server based on python to create a simple color web-service. You could also use every other web server which accepts and returns JSON data. The idea is to have a list of named colors, which can be managed via the web-service. Managed in this case means CRUD (create-read-update-delete).

A simple web-service in Flask can be written in one file. We start with an empty `server.py` file. Inside this file, we create some boiler-code and load our initial colors from an external JSON file. See also the Flask quickstart documentation.

```
from flask import Flask, jsonify, request
import json

colors = json.load(file('colors.json', 'r'))

app = Flask(__name__)
```

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```
# ... service calls go here

if __name__ == '__main__':
    app.run(debug = True)
```

When you run this script, it will provide a web-server at http://localhost:5000, which does not serve anything useful yet.

We will now start adding our CRUD (Create,Read,Update,Delete) endpoints to our little web-service.

13.5.1 Read Request

To read data from our web-server, we will provide a GET method for all colors.

```
@app.route('/colors', methods = ['GET'])
def get_colors():
    return jsonify( { "colors" :  colors })
```

This will return the colors under the '/colors' endpoint. To test this we can use curl to create an HTTP request.

```
curl -i -GET http://localhost:5000/colors
```

Which will return us the list of colors as JSON data?

13.5.2 Read Entry

To read an individual color by name we provide the details endpoint, which is located under '/colors/<name>'. The name is a parameter to the endpoint, which identifies an individual color.

```
@app.route('/colors/<name>', methods = ['GET'])
def get_color(name):
    for color in colors:
        if color["name"] == name:
            return jsonify( color )
```

And we can test it with using curl again. For example to get the red color entry.

```
$ curl -i -GET http://localhost:5000/colors/red
```

It will return one color entry as JSON data.

13.5.3 Create Entry

Till now we have just used HTTP GET methods. To create an entry on the server side, we will use a POST method and pass the new color information with the POST data. The endpoint location is the same as to get all colors. But this time we expect a POST request.

```
@app.route('/colors', methods= ['POST'])
def create_color():
    color = {
        'name': request.json['name'],
        'value': request.json['value']
    }
    colors.append(color)
    return jsonify( color ), 201
```

Curl is flexible enough to allow us to provide JSON data as the new entry inside the POST request.

```
curl -i -H "Content-Type: application/json" -X POST -d '{"name":"gray1","value":"
↪#333"}' http://localhost:5000/colors
```

13.5.4 Update Entry

To update an individual entry we use the PUT HTTP method. The endpoint is the same as to retrieve an individual color entry. When the color was updated successfully we return the updated color as JSON data.

```
@app.route('/colors/<name>', methods= ['PUT'])
def update_color(name):
    for color in colors:
        if color["name"] == name:
            color['value'] = request.json.get('value', color['value'])
            return jsonify( color )
```

In the curl request, we only provide the values to be updated as JSON data and then a named endpoint to identify the color to be updated.

```
curl -i -H "Content-Type: application/json" -X PUT -d '{"value":"#666"}' http://
↪localhost:5000/colors/red
```

13.5.5 Delete Entry

Deleting an entry is done using the DELETE HTTP verb. It also uses the same endpoint for an individual color, but this time the DELETE HTTP verb.

```
@app.route('/colors/<name>', methods=['DELETE'])
def delete_color(name):
    success = False
    for color in colors:
        if color["name"] == name:
            colors.remove(color)
            success = True
    return jsonify( { 'result' : success } )
```

This request looks similar to the GET request for an individual color.

```
curl -i -X DELETE http://localhost:5000/colors/red
```

Now we can read all colors, read a specific color, create a new color, update a color and delete a color. Also, we know the HTTP endpoints to our API.

Action	HTTP	Endpoint
Read All	GET	http://localhost:5000/colors
Create Entry	POST	http://localhost:5000/colors
Read Entry	GET	http://localhost:5000/colors/<name>
Update Entry	PUT	http://localhost:5000/colors/<name>
Delete Entry	DELETE	http://localhost:5000/colors/<name>

Our little REST server is complete now and we can focus on QML and the client side. To create an easy to use API we need to map each action to an individual HTTP request and provide a simple API to our users.

13.5.6 Client REST

To demonstrate a REST client we write a small color grid. The color grid displays the colors retrieved from the web-service via HTTP requests. Our user interface provides the following commands:

- Get a color list
- Create color
- Read the last color
- Update last color
- Delete the last color

We bundle our API into an own JS file called `colorservice.js` and import it into our UI as `Service`. Inside the service module, we create a helper function to make the HTTP requests for us:

```
// colorservice.js
function request(verb, endpoint, obj, cb) {
    print('request: ' + verb + ' ' + BASE + (endpoint?'/' + endpoint:''))
    var xhr = new XMLHttpRequest();
    xhr.onreadystatechange = function() {
        print('xhr: on ready state change: ' + xhr.readyState)
        if(xhr.readyState === XMLHttpRequest.DONE) {
            if(cb) {
                var res = JSON.parse(xhr.responseText.toString())
                cb(res);
            }
        }
    }
    xhr.open(verb, BASE + (endpoint?'/' + endpoint:''));
    xhr.setRequestHeader('Content-Type', 'application/json');
    xhr.setRequestHeader('Accept', 'application/json');
    var data = obj?JSON.stringify(obj):''
    xhr.send(data)
}
```

It takes four arguments. The `verb`, which defines the HTTP verb to be used (GET, POST, PUT, DELETE). The second parameter is the endpoint to be used as a postfix to the BASE address (e.g. 'http://localhost:5000/colors'). The third parameter is the optional obj, to be sent as JSON data to the service. The last parameter defines a callback to be called when the response returns. The callback receives a response object with the response data. Before we send the request, we indicate that we send and accept JSON data by modifying the request header.

Using this request helper function we can implement the simple commands we defined earlier (create, read, update, delete):

```
// colorservice.js
function get_colors(cb) {
    // GET http://localhost:5000/colors
    request('GET', null, null, cb)
}

function create_color(entry, cb) {
    // POST http://localhost:5000/colors
    request('POST', null, entry, cb)
}

function get_color(name, cb) {
    // GET http://localhost:5000/colors/<name>
    request('GET', name, null, cb)
}

function update_color(name, entry, cb) {
    // PUT http://localhost:5000/colors/<name>
    request('PUT', name, entry, cb)
}

function delete_color(name, cb) {
```

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```
    // DELETE http://localhost:5000/colors/<name>
    request('DELETE', name, null, cb)
}
```

This code resides in the service implementation. In the UI we use the service to implement our commands. We have a `ListModel` with the id `gridModel` as a data provider for the `GridView`. The commands are indicated using a `Button` UI element.

Reading the color list from the server.

```
// rest.qml
import "colorservice.js" as Service
...
// read colors command
Button {
    text: 'Read Colors';
    onClicked: {
        Service.get_colors( function(resp) {
            print('handle get colors resp: ' + JSON.stringify(resp));
            gridModel.clear();
            var entries = resp.data;
            for(var i=0; i<entries.length; i++) {
                gridModel.append(entries[i]);
            }
        });
    }
}
```

Create a new color entry on the server.

```
// rest.qml
import "colorservice.js" as Service
...
// create new color command
Button {
    text: 'Create New';
    onClicked: {
        var index = gridModel.count-1
        var entry = {
            name: 'color-' + index,
            value: Qt.hsla(Math.random(), 0.5, 0.5, 1.0).toString()
        }
        Service.create_color(entry, function(resp) {
            print('handle create color resp: ' + JSON.stringify(resp))
            gridModel.append(resp)
        });
    }
}
```

Reading a color based on its name.

```
// rest.qml
import "colorservice.js" as Service
...
// read last color command
Button {
    text: 'Read Last Color';
    onClicked: {
        var index = gridModel.count-1
        var name = gridModel.get(index).name
        Service.get_color(name, function(resp) {
```

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```
            print('handle get color resp:' + JSON.stringify(resp))
            message.text = resp.value
        });
    }
}
```

Update a color entry on the server based on the color name.

```
// rest.qml
import "colorservice.js" as Service
...
// update color command
Button {
    text: 'Update Last Color'
    onClicked: {
        var index = gridModel.count-1
        var name = gridModel.get(index).name
        var entry = {
            value: Qt.hsla(Math.random(), 0.5, 0.5, 1.0).toString()
        }
        Service.update_color(name, entry, function(resp) {
            print('handle update color resp: ' + JSON.stringify(resp))
            var index = gridModel.count-1
            gridModel.setProperty(index, 'value', resp.value)
        });
    }
}
```

Delete a color by the color name.

```
// rest.qml
import "colorservice.js" as Service
...
// delete color command
Button {
    text: 'Delete Last Color'
    onClicked: {
        var index = gridModel.count-1
        var name = gridModel.get(index).name
        Service.delete_color(name)
        gridModel.remove(index, 1)
    }
}
```

This concludes the CRUD (create, read, update, delete) operations using a REST API. There are also other possibilities to generate a Web-Service API. One could be module based and each module would have one endpoint. And the API could be defined using JSON RPC (http://www.jsonrpc.org/). Sure also XML based API is possible and but the JSON approach has great advantages as the parsing is built into the QML/JS as part of JavaScript.

13.6 Authentication using OAuth

OAuth is an open protocol to allow secure authorization in a simple and standard method from web, mobile, and desktop applications. OAuth is used to authenticate a client against common web-services such as Google, Facebook, and Twitter.

Note: For a custom web-service you could also use the standard HTTP authentication for example by using the `XMLHttpRequest` username and password in the get method (e.g. `xhr.open(verb, url, true,`

```
username, password))
```

OAuth is currently not part of a QML/JS API. So you would need to write some C++ code and export the authentication to QML/JS. Another issue would be the secure storage of the access token.

Here are some links which we find useful:

- http://oauth.net/
- http://hueniverse.com/oauth/
- https://github.com/pipacs/o2
- http://www.johanpaul.com/blog/2011/05/oauth2-explained-with-qt-quick/

13.7 Web Sockets

The WebSockets module provides an implementation of the WebSockets protocol for WebSockets clients and servers. It mirrors the Qt CPP module. It allows sending a string and binary messages using a full duplex communication channel. A WebSocket is normally established by making an HTTP connection to the server and the server then "upgrades" the connection to a WebSocket connection.

In Qt/QML you can also simply use the *WebSocket* and *WebSocketServer* objects to creates direct WebSocket connection. The WebSocket protocol uses the "ws" URL schema or "wss" for a secure connection.

You can use the web socket qml module by importing it first.

```
import Qt.WebSockets 1.0

WebSocket {
    id: socket
}
```

To test your web socket we will use the echo server from http://websocket.org.

```
import QtQuick 2.5
import Qt.WebSockets 1.0

Text {
    width: 480
    height: 48

    horizontalAlignment: Text.AlignHCenter
    verticalAlignment: Text.AlignVCenter

    WebSocket {
        id: socket
        url: "ws://echo.websocket.org"
        active: true
        onTextMessageReceived: {
            text = message
        }
        onStatusChanged: {
            if (socket.status == WebSocket.Error) {
                console.log("Error: " + socket.errorString)
            } else if (socket.status == WebSocket.Open) {
                socket.sendTextMessage("ping")
            } else if (socket.status == WebSocket.Closed) {
                text += "\nSocket closed"
            }
        }
```

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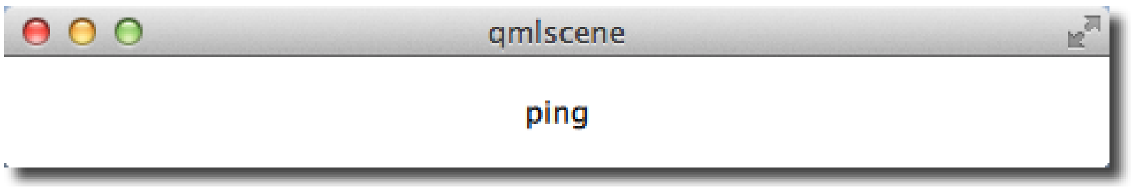
```
    }
}
```

You should see the ping message we send `socket.sendTextMessage("ping")` as response in the text field.



ping

13.7.1 WS Server

You can easily create your own WS server using the C++ part of the Qt WebSocket or use a different WS implementation, which I find very interesting. It is interesting because it allows connecting the amazing rendering quality of QML with the great expanding web application servers. In this example, we will use a Node JS based web socket server using the ws module. For this, you first need to install node js. Then, create a `ws_server` folder and install the ws package using the node package manager (npm).

The code shall create a simple echo server in NodeJS to echo our messages back to our QML client.

```
$ cd ws_server
$ npm install ws
```

The npm tool downloads and installs the ws package and dependencies into your local folder.

A `server.js` file will be our server implementation. The server code will create a web socket server on port 3000 and listens to an incoming connection. On an incoming connection, it will send out a greeting and waits for client messages. Each message a client sends on a socket will be sent back to the client.

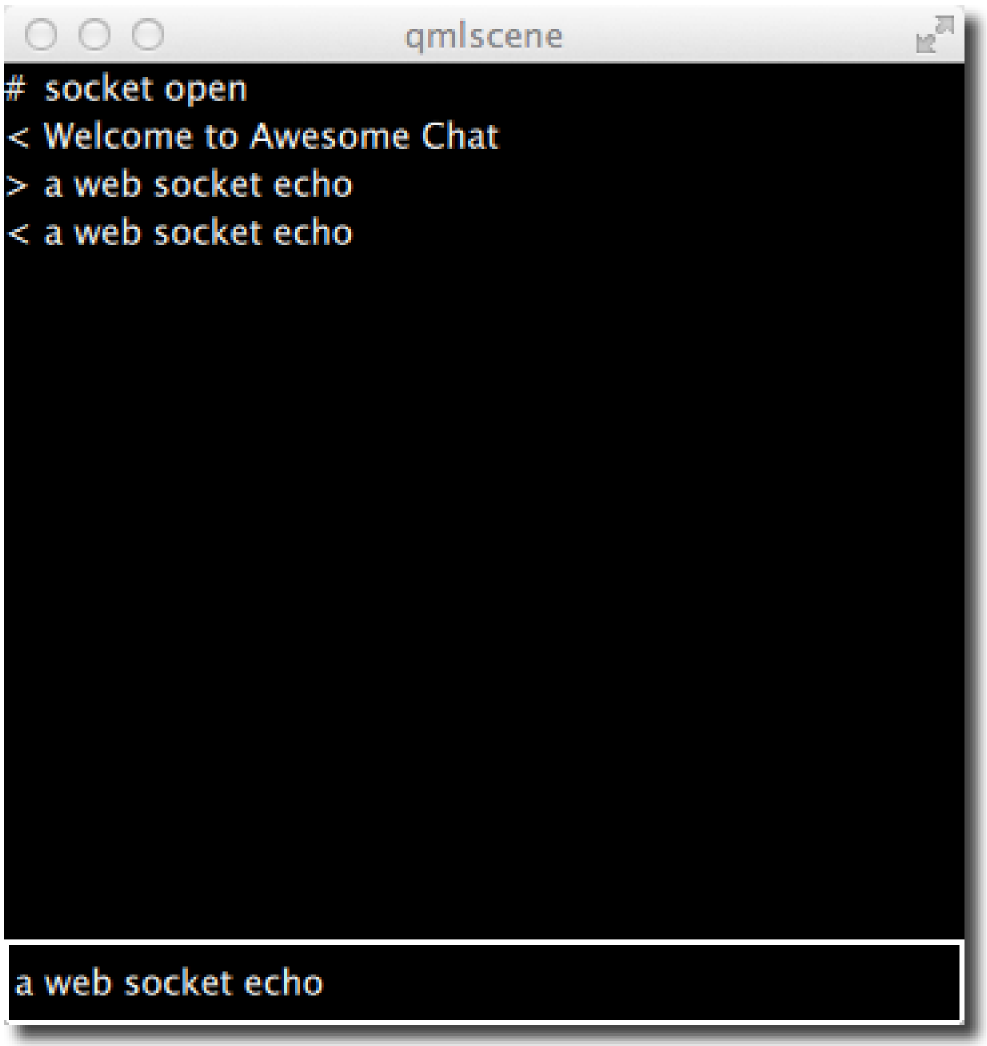
```
var WebSocketServer = require('ws').Server;

var server = new WebSocketServer({ port : 3000 });

server.on('connection', function(socket) {
        console.log('client connected');
        socket.on('message', function(msg) {
                console.log('Message: %s', msg);
                socket.send(msg);
        });
        socket.send('Welcome to Awesome Chat');
});

console.log('listening on port ' + server.options.port);
```

You need to get used to the notation of JavaScript and the function callbacks.

13.7.2 WS Client

On the client side, we need a list view to display the messages and a TextInput for the user to enter a new chat message.

We will use a label with white color in the example.



```
#  socket open
< Welcome to Awesome Chat
> a web socket echo
< a web socket echo
```

```
a web socket echo
```

```
// Label.qml
import QtQuick 2.5

Text {
    color: '#fff'
    horizontalAlignment: Text.AlignLeft
    verticalAlignment: Text.AlignVCenter
}
```

Our chat view is a list view, where the text is appended to a list model. Each entry is displayed using a row of prefix and message label. We use a cell width `cw` factor to split the with into 24 columns.

```
// ChatView.qml
import QtQuick 2.5

ListView {
    id: root
    width: 100
    height: 62

    model: ListModel {}

    function append(prefix, message) {
        model.append({prefix: prefix, message: message})
    }

    delegate: Row {
        width: root.width
        height: 18
        property real cw: width/24
        Label {
            width: cw*1
            height: parent.height
            text: model.prefix
        }
        Label {
            width: cw*23
            height: parent.height
            text: model.message
        }
    }
}
```

The chat input is just a simple text input wrapped with a colored border.

```
// ChatInput.qml
import QtQuick 2.5

FocusScope {
    id: root
    width: 240
    height: 32
    Rectangle {
        anchors.fill: parent
        color: '#000'
        border.color: '#fff'
        border.width: 2
    }

    property alias text: input.text

    signal accepted(string text)
```

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```
    TextInput {
        id: input
        anchors.left: parent.left
        anchors.right: parent.right
        anchors.verticalCenter: parent.verticalCenter
        anchors.leftMargin: 4
        anchors.rightMargin: 4
        onAccepted: root.accepted(text)
        color: '#fff'
        focus: true
    }
}
```

When the web socket receives a message it appends the message to the chat view. Same applies for a status change. Also when the user enters a chat message a copy is appended to the chat view on the client side and the message is sent to the server.

```
// ws_client.qml
import QtQuick 2.5
import Qt.WebSockets 1.0

Rectangle {
    width: 360
    height: 360
    color: '#000'

    ChatView {
        id: box
        anchors.left: parent.left
        anchors.right: parent.right
        anchors.top: parent.top
        anchors.bottom: input.top
    }
    ChatInput {
        id: input
        anchors.left: parent.left
        anchors.right: parent.right
        anchors.bottom: parent.bottom
        focus: true
        onAccepted: {
            print('send message: ' + text)
            socket.sendTextMessage(text)
            box.append('>', text)
            text = ''
        }
    }
    WebSocket {
        id: socket

        url: "ws://localhost:3000"
        active: true
        onTextMessageReceived: {
            box.append('<', message)
        }
        onStatusChanged: {
            if (socket.status == WebSocket.Error) {
                box.append('#', 'socket error ' + socket.errorString)
            } else if (socket.status == WebSocket.Open) {
                box.append('#', 'socket open')
            } else if (socket.status == WebSocket.Closed) {
```

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```
                    box.append('#', 'socket closed')
                }
            }
        }
}
```

You need first run the server and then the client. There is no retry connection mechanism in our simple client.

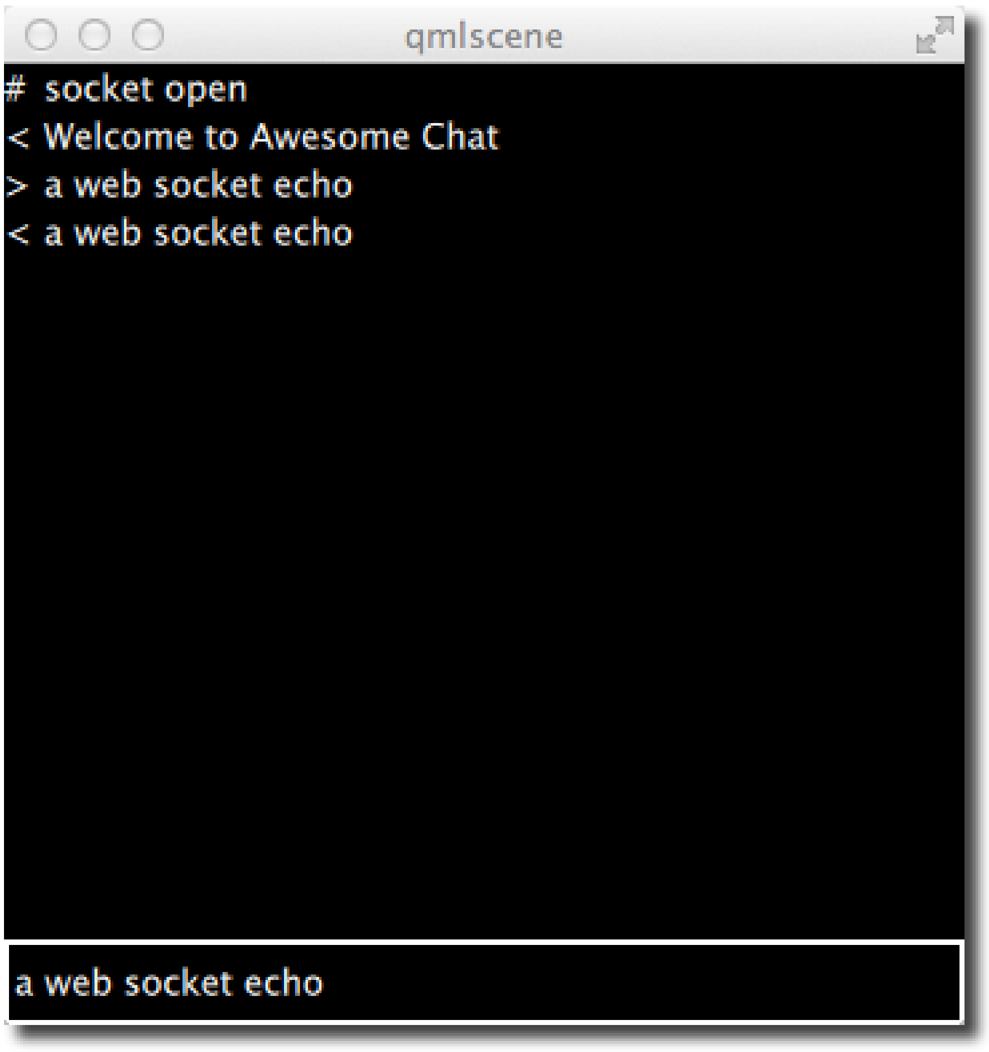
Running the server

```
$ cd ws_server
$ node server.js
```

Running the client

```
$ cd ws_client
$ qmlscene ws_client.qml
```

When entering text and pressing enter you should see something like this.



```
# socket open
< Welcome to Awesome Chat
> a web socket echo
< a web socket echo
```

```
a web socket echo
```

13.8 Summary

This concludes our chapter about QML networking. Please bear in mind Qt has on the native side a much richer networking API as on the QML side currently. But the idea of the chapter is to push the boundaries of QML networking and how to integrate with cloud-based services.

CHAPTER

FOURTEEN

STORAGE

Section author: jryannel@LinkedIn

Note: Last Build: December 07, 2020 at 10:50 CET

The source code for this chapter can be found in the assets folder.

This chapter will cover storing data using Qt Quick in Qt 5. Qt Quick offers only limited ways of storing local data directly. In this sense, it acts more like a browser. In many projects storing data is handled by the C++ backend and the required functionality is exported to the Qt Quick frontend side. Qt Quick does not provide you with access to the host file system to read and write files as you are used from the Qt C++ side. So it would be the task of the backend engineer to write such a plugin or maybe use a network channel to communicate with a local server, which provides these capabilities.

Every application needs to store smaller and larger information persistently. This can be done locally on the file system or remote on a server. Some information will be structured and simple (e.g. settings), some will be large and complicated for example documentation files and some will be large and structured and will require some sort of database connection. Here we will mainly cover the built-in capabilities of Qt Quick to store data as also the networked ways.

14.1 Settings

Qt comes on its native side with the C++ `QSettings` class, which allows you to store the application settings (aka options, preferences) in a system-dependent way. It uses the infrastructure available from your OS. Additional it supports a common INI file format for handling cross-platform settings files.

In Qt 5.2 `Settings` have entered the QML world. The API is still in the lab's module, which means the API may break in the future. So be aware.

Here is a small example, which applies a color value to a base rectangle. Every time the user clicks on the window a new random color is generated. When the application is closed and relaunched again you should see your last color. The default color should be the color initially set on the root rectangle.

```
import QtQuick 2.5
import Qt.labs.settings 1.0

Rectangle {
    id: root
    width: 320; height: 240
    color: '#000000'
    Settings {
        id: settings
        property alias color: root.color
    }
    MouseArea {
        anchors.fill: parent
```

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```
        onClicked: root.color = Qt.hsla(Math.random(), 0.5, 0.5, 1.0);
    }
}
```

The settings value are stored every time the value changes. This might be not always what you want. To store the settings only when required you can use standard properties.

```
Rectangle {
    id: root
    color: settings.color
    Settings {
        id: settings
        property color color: '#000000'
    }
    function storeSettings() { // executed maybe on destruction
        settings.color = root.color
    }
}
```

It is also possible to store settings into different categories using the `category` property.

```
Settings {
    category: 'window'
    property alias x: window.x
    property alias y: window.x
    property alias width: window.width
    property alias height: window.height
}
```

The settings are stored according to your application name, organization, and domain. This information is normally set in the main function of your c++ code.

```
int main(int argc, char** argv) {
    ...
    QCoreApplication::setApplicationName("Awesome Application");
    QCoreApplication::setOrganizationName("Awesome Company");
    QCoreApplication::setOrganizationDomain("org.awesome");
    ...
}
```

14.2 Local Storage - SQL

Qt Quick supports a local storage API known from the web browsers the local storage API. the API is available under “import QtQuick.LocalStorage 2.0”.

In general, it stores the content into an SQLite database in a system-specific location in a unique ID based file based on the given database name and version. It is not possible to list or delete existing databases. You can find the storage location from `QQmlEngine::offlineStoragePath()`.

You use the API by first creating a database object and then creating transactions on the database. Each transaction can contain one or more SQL queries. The transaction will roll-back when a SQL query will fail inside the transaction.

For example, to read from a simple notes table with a text column you could use the local storage like this:

```
import QtQuick 2.5
import QtQuick.LocalStorage 2.0

Item {
```

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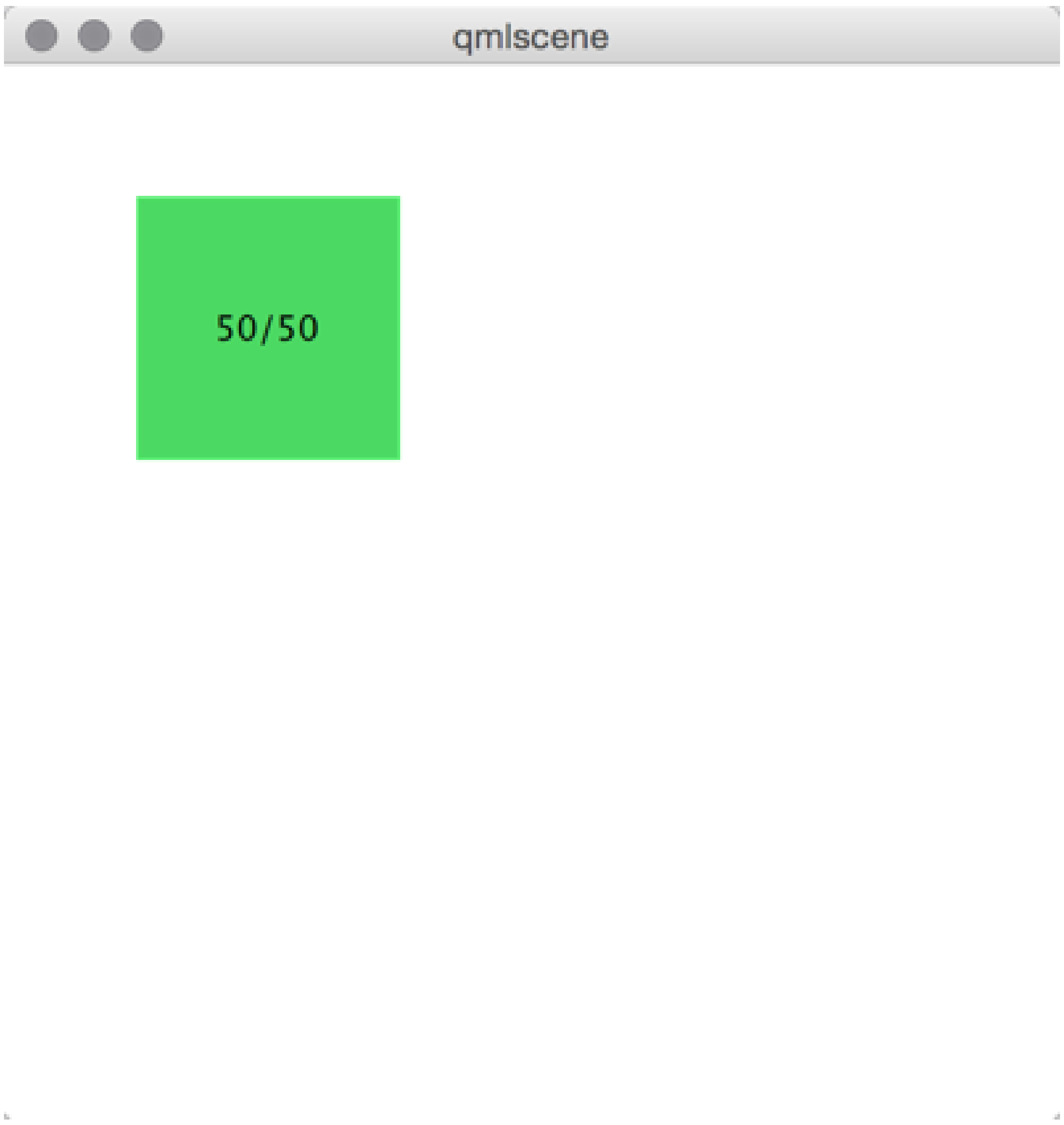
```
    Component.onCompleted: {
        var db = LocalStorage.openDatabaseSync("MyExample", "1.0", "Example␣
↪database", 10000);
        db.transaction( function(tx) {
            var result = tx.executeSql('select * from notes');
            for(var i = 0; i < result.rows.length; i++) {
                    print(result.rows[i].text);
                }
            }
        });
    }
}
```

Crazy Rectangle

As an example assume we would like to store the position of a rectangle on our scene.



Here our base example.

```
import QtQuick 2.5

Item {
    width: 400
    height: 400

    Rectangle {
        id: crazy
        objectName: 'crazy'
        width: 100
        height: 100
        x: 50
        y: 50
        color: "#53d769"
        border.color: Qt.lighter(color, 1.1)
        Text {
            anchors.centerIn: parent
            text: Math.round(parent.x) + '/' + Math.round(parent.y)
        }
        MouseArea {
            anchors.fill: parent
            drag.target: parent
        }
    }
}
```

You can drag the rectangle freely around. When you close the application and launch it again the rectangle is at the same position.

Now we would like to add that the x/y position of the rectangle is stored inside the SQL DB. For this, we need to add an `init`, `read` and `store` database function. These functions are called when on component completed and on component destruction.

```
import QtQuick 2.5
import QtQuick.LocalStorage 2.0

Item {
    // reference to the database object
    property var db;

    function initDatabase() {
        // initialize the database object
    }

    function storeData() {
        // stores data to DB
    }

    function readData() {
        // reads and applies data from DB
    }


    Component.onCompleted: {
        initDatabase();
        readData();
    }

    Component.onDestruction: {
        storeData();
    }
}
```

You could also extract the DB code in an own JS library, which does all the logic. This would be the preferred way if the logic gets more complicated.

In the database initialization function, we create the DB object and ensure the SQL table is created.

```
function initDatabase() {
    print('initDatabase()')
    db = LocalStorage.openDatabaseSync("CrazyBox", "1.0", "A box who remembers its␣
↪position", 100000);
    db.transaction( function(tx) {
        print('... create table')
        tx.executeSql('CREATE TABLE IF NOT EXISTS data(name TEXT, value TEXT)');
    });
}
```

The application next calls the read function to read existing data back from the database. Here we need to differentiate if there is already data in the table. To check we look into how many rows the select clause has returned.

```
function readData() {
    print('readData()')
    if(!db) { return; }
    db.transaction( function(tx) {
        print('... read crazy object')
        var result = tx.executeSql('select * from data where name="crazy"');
        if(result.rows.length === 1) {
            print('... update crazy geometry')
            // get the value column
            var value = result.rows[0].value;
            // convert to JS object
            var obj = JSON.parse(value)
            // apply to object
            crazy.x = obj.x;
            crazy.y = obj.y;
        }
    });
}
```

We expect the data is stored in a JSON string inside the value column. This is not typical SQL like, but works nicely with JS code. So instead of storing the x,y as properties in the table, we store them as a complete JS object using the JSON stringify/parse methods. In the end, we get a valid JS object with x and y properties, which we can apply on our crazy rectangle.

To store the data, we need to differentiate the update and insert cases. We use update when a record already exists and insert if no record under the name "crazy" exists.

```
function storeData() {
    print('storeData()')
    if(!db) { return; }
    db.transaction( function(tx) {
        print('... check if a crazy object exists')
        var result = tx.executeSql('SELECT * from data where name = "crazy"');
        // prepare object to be stored as JSON
        var obj = { x: crazy.x, y: crazy.y };
        if(result.rows.length === 1) {// use update
            print('... crazy exists, update it')
            result = tx.executeSql('UPDATE data set value=? where name="crazy"',␣
↪[JSON.stringify(obj)]);
        } else { // use insert
            print('... crazy does not exists, create it')
            result = tx.executeSql('INSERT INTO data VALUES (?,?)', ['crazy', JSON.
↪stringify(obj)]);
        }
```

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```
    });
}
```

Instead of selecting the whole recordset we could also use the SQLite count function like this: `SELECT COUNT(*) from data where name = "crazy"` which would return use one row with the number of rows affected by the select query. Otherwise, this is common SQL code. As an additional feature, we use the SQL value binding using the `?` in the query.

Now you can drag the rectangle and when you quit the application the database stores the x/y position and applies it on the next application run.

14.3 Other Storage APIs

To store directly from within QML these are the major storage types. The real strength of Qt Quick comes from the fact to extend it with C++ to interface with your native storage systems or use the network API to interface with a remote storage system, like the Qt cloud.

CHAPTER

FIFTEEN

DYNAMIC QML

Section author: e8johan

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The source code for this chapter can be found in the assets folder.

Until now, we have treated QML as a tool for constructing a static set of scenes and navigating between them. Depending on various states and logic rules, a living and dynamic user interface is constructed. By working with QML and JavaScript in a more dynamic manner, the flexibility and possibilities expand even further. Components can be loaded and instantiated at run-time, elements can be destroyed. Dynamically created user interfaces can be saved to disk and later restored.

15.1 Loading Components Dynamically

The easiest way to dynamically load different parts of QML is to use the `Loader` element. It serves as a placeholder to the item that is being loaded. The item to load is controlled through either the `source` property or the `sourceComponent` property. The former loads the item from a given URL, while the latter instantiates a component.

As the loader serves as a placeholder for the item being loaded, its size depends on the size of the item, and vice versa. If the `Loader` element has a size, either by having set `width` and `height` or through anchoring, the loaded item will be given the loader's size. If the `Loader` has no size, it is resized in accordance to the size of the item being loaded.

The example described below demonstrates how two separate user interface parts can be loaded into the same space using a `Loader` element. The idea is to have a speed dial that can be either digital or analog, as shown in the illustration below. The code surrounding the dial is unaffected by which item that is loaded for the moment.

The first step in the application is to declare a `Loader` element. Notice that the `source` property is left out. This is because the `source` depends on which state the user interface is in.

```
Loader {
    id: dialLoader

    anchors.fill: parent
}
```

In the `states` property of the parent of `dialLoader` a set of `PropertyChanges` elements drives the loading of different QML files depending on the `state`. The `source` property happens to be a relative file path in this example, but it can just as well be a full URL, fetching the item over the web.

```
    states: [
        State {
            name: "analog"
            PropertyChanges { target: analogButton; color: "green"; }
```

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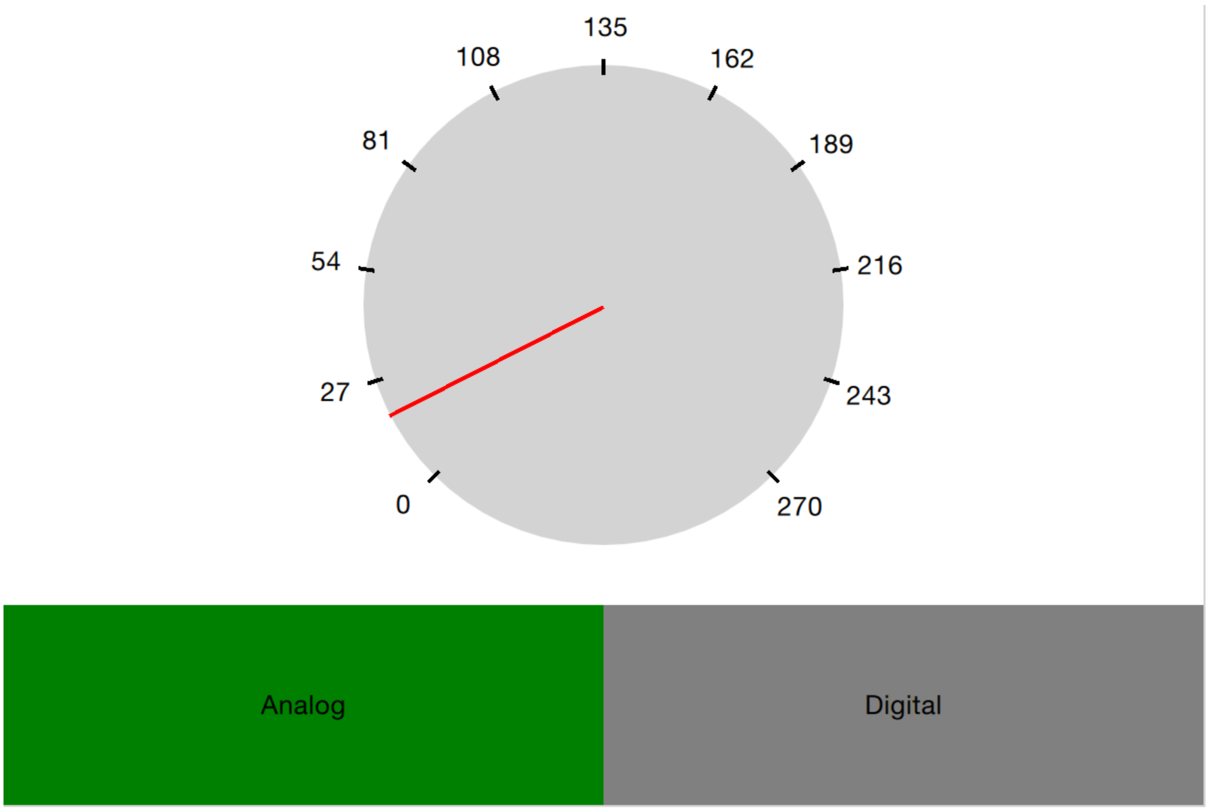
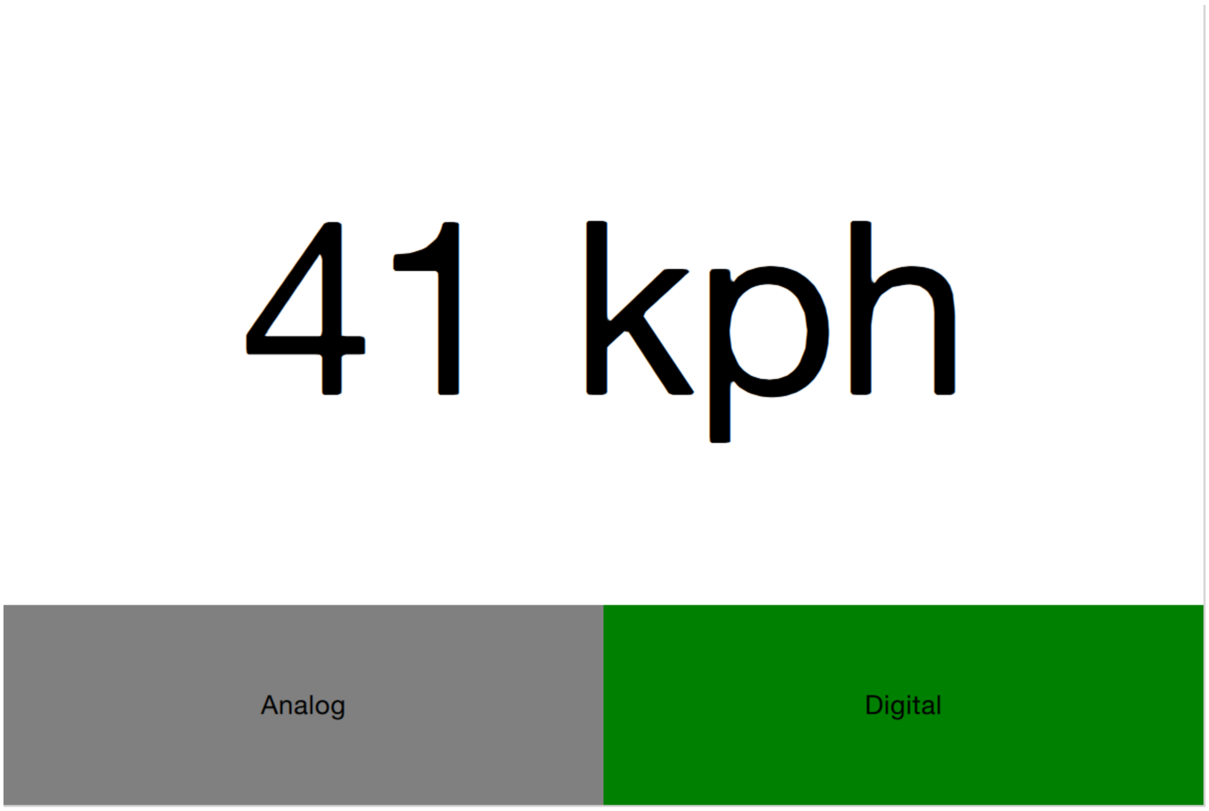

135
108
162
81
189
54
216
27
243
0
270
Analog
Digital


41 kph
Analog
Digital

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```
            PropertyChanges { target: dialLoader; source: "Analog.qml"; }
        },
        State {
            name: "digital"
            PropertyChanges { target: digitalButton; color: "green"; }
            PropertyChanges { target: dialLoader; source: "Digital.qml"; }
        }
    ]
```

In order to make the loaded item come alive, it is `speed` property must be bound to the root `speed` property. This cannot be done as a direct binding as the item not always is loaded and changes over time. Instead, a `Binding` element must be used. The `target` property of the binding is changed every time the `Loader` triggers the `onLoaded` signal.

```
    Loader {
        id: dialLoader

        anchors.left: parent.left
        anchors.right: parent.right
        anchors.top: parent.top
        anchors.bottom: analogButton.top

        onLoaded: {
            binder.target = dialLoader.item;
        }
    }

    Binding {
        id: binder

        property: "speed"
        value: speed
    }
```

The `onLoaded` signal lets the loading QML act when the item has been loaded. In a similar fashion, the QML being loaded can rely on the `Component.onCompleted` signal. This signal is actually available for all components, regardless of how they are loaded. For instance, the root component of an entire application can use it to kick-start itself when the entire user interface has been loaded.

15.1.1 Connecting Indirectly

When creating QML elements dynamically, you cannot connect to signals using the `onSignalName` approach used for static setup. Instead, the `Connections` element must be used. It connects to any number of signals of a `target` element.

Having set the `target` property of a `Connections` element, the signals can be connected, as usual, that is, using the `onSignalName` approach. However, by altering the `target` property, different elements can be monitored at different times.

In the example shown above, a user interface consisting of two clickable areas is presented to the user. When either area is clicked, it is flashed using an animation. The left area is shown in the code snippet below. In the `MouseArea`, the `leftClickedAnimation` is triggered, causing the area to flash.

```
        Rectangle {
            id: leftRectangle

            width: 290
            height: 200
```

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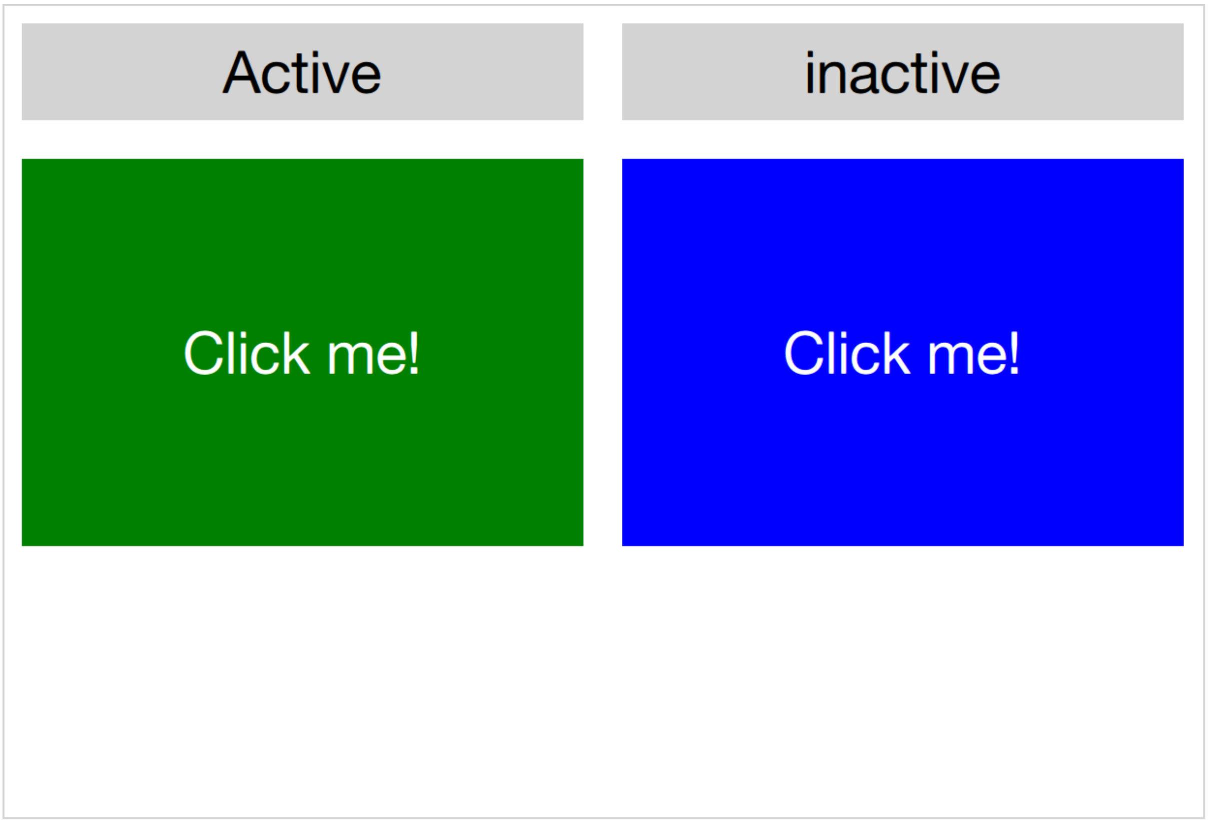

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```
            color: "green"

            MouseArea {
                id: leftMouseArea
                anchors.fill: parent
                onClicked: leftClickedAnimation.start();
            }

            Text {
                anchors.centerIn: parent
                font.pixelSize: 30
                color: "white"
                text: "Click me!"
            }
        }
```

In addition to the two clickable areas, a `Connections` element is used. This triggers the third animation when the active, i.e. the `target` of the element, is clicked.

```
    Connections {
        id: connections
        onClicked: activeClickedAnimation.start();
    }
```

To determine which `MouseArea` to target, two states are defined. Notice that we cannot set the `target` property using a `PropertyChanges` element, as it already contains a `target` property. Instead a `StateChangeScript` is utilized.

```
    states: [
        State {
            name: "left"
```

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```
            StateChangeScript {
                script: connections.target = leftMouseArea
            }
        },
        State {
            name: "right"
            StateChangeScript {
                script: connections.target = rightMouseArea
            }
        }
    ]
```

When trying out the example, it is worth noticing that when multiple signal handlers are used, all are invoked. The execution order of these is, however, undefined.

When creating a `Connections` element without setting the `target` property, the property defaults to `parent`. This means that it has to be explicitly set to `null` to avoid catching signals from the `parent` until the `target` is set. This behavior does make it possible to create custom signal handler components based on a `Connections` element. This way, the code reacting to the signals can be encapsulated and re-used.

In the example below, the `Flasher` component can be put inside any `MouseArea`. When clicked, it triggers an animation, causing the parent to flash. In the same `MouseArea` the actual task being triggered can also be carried out. This separates the standardized user feedback, i.e. the flashing, from the actual action.

```
import QtQuick 2.5

Connections {
        onClicked: {
                // Automatically targets the parent
        }
}
```

To use the `Flasher`, simply instantiate a Flasher within each MouseArea, and it all works.

```
import QtQuick 2.5

Item {
        // A background flasher that flashes the background of any parent MouseArea
}
```

When using a `Connections` element to monitor the signals of multiple types of `target` elements, you sometimes find yourself in a situation where the available signals vary between the targets. This results in the `Connections` element outputting run-time errors as signals are missed. To avoid this, the `ignoreUnknownSignal` property can be set to `true`. This ignores all such errors.

Note: It is usually a bad idea to suppress error messages.

15.1.2 Binding Indirectly

Just as it is not possible to connect to signals of dynamically created elements directly, nor it is possible to bind properties of a dynamically created element without working with a bridge element. To bind a property of any element, including dynamically created elements, the `Binding` element is used.

The `Binding` element lets you specify a `target` element, a `property` to bind and a `value` to bind it to. Through using a *Binding*‘ element, it is, for instance, possible to bind properties of a dynamically loaded element. This was demonstrated in the introductory example in this chapter, as shown below.

```
    Loader {
        id: dialLoader

        anchors.left: parent.left
        anchors.right: parent.right
        anchors.top: parent.top
        anchors.bottom: analogButton.top

        onLoaded: {
            binder.target = dialLoader.item;
        }
    }

    Binding {
        id: binder

        property: "speed"
        value: speed
    }
```

As the `target` element of a `Binding` not always is set, and perhaps not always has a given property, the `when` property of the `Binding` element can be used to limit the time when the binding is active. For instance, it can be limited to specific modes in the user interface.

The `Binding` element also comes with a `delayed` property. When this property is set to `true` the binding is not propagated to the `target` until the event queue has been emptied. In high load situations this can serve as an optimization as intermediate values are not pushed to the `target`.

15.2 Creating and Destroying Objects

The `Loader` element makes it possible to populate part of a user interface dynamically. However, the overall structure of the interface is still static. Through JavaScript, it is possible to take one more step and to instantiate QML elements completely dynamically.

Before we dive into the details of creating elements dynamically, we need to understand the workflow. When loading a piece of QML from a file or even over the Internet, a component is created. The component encapsulates the interpreted QML code and can be used to create items. This means that loading a piece of QML code and instantiating items from it is a two-stage process. First, the QML code is parsed into a component. Then the component is used to instantiate actual item objects.

In addition to creating elements from QML code stored in files or on servers, it is also possible to create QML objects directly from text strings containing QML code. The dynamically created items are then treated in a similar fashion once instantiated.

15.2.1 Dynamically Loading and Instantiating Items

When loading a piece of QML, it is first interpreted as a component. This includes loading dependencies and validating the code. The location of the QML being loaded can be either a local file, a Qt resource, or even a distance network location specified by a URL. This means that the loading time can be everything from instant, for instance, a Qt resource located in RAM without any non-loaded dependencies, to very long, meaning a piece of code located on a slow server with multiple dependencies that need to be loaded.

The status of a component being created can be tracked by it is `status` property. The available values are `Component.Null`, `Component.Loading`, `Component.Ready` and `Component.Error`. The `Null` to `Loading` to `Ready` is the usual flow. At any stage, the `status` can change to `Error`. In that case, the component cannot be used to create new object instances. The `Component.errorString()` function can be used to retrieve a user-readable error description.

When loading components over slow connections, the `progress` property can be of use. It ranges from `0.0`, meaning nothing has been loaded, to `1.0` indicating that all have been loaded. When the component's `status` changes to `Ready`, the component can be used to instantiate objects. The code below demonstrates how that can be achieved, taking into account the event of the component becoming ready or failing to be created directly, as well as the case where a component is ready slightly later.

```
var component;

function createImageObject() {
    component = Qt.createComponent("dynamic-image.qml");
    if (component.status === Component.Ready || component.status === Component.
→Error) {
        finishCreation();
    } else {
        component.statusChanged.connect(finishCreation);
    }
}

function finishCreation() {
    if (component.status === Component.Ready) {
        var image = component.createObject(root, {"x": 100, "y": 100});
        if (image === null) {
            console.log("Error creating image");
        }
    } else if (component.status === Component.Error) {
        console.log("Error loading component:", component.errorString());
    }
}
```

The code above is kept in a separate JavaScript source file, referenced from the main QML file.

```
import QtQuick 2.5
import "create-component.js" as ImageCreator

Item {
    id: root

    width: 1024
    height: 600

    Component.onCompleted: ImageCreator.createImageObject();
}
```

The `createObject` function of a component is used to create object instances, as shown above. This not only applies to dynamically loaded components but also `Component` elements inlined in the QML code. The resulting object can be used in the QML scene like any other object. The only difference is that it does not have an `id`.

The `createObject` function takes two arguments. The first is a `parent` object of the type `Item`. The second is a list of properties and values on the format `{"name": value, "name": value}`. This is demonstrated in the example below. Notice that the properties argument is optional.

```
var image = component.createObject(root, {"x": 100, "y": 100});
```

Note: A dynamically created component instance is not different to an in-line `Component` element. The in-line `Component` element also provides functions to instantiate objects dynamically.

Incubating Components

When components are created using `createObject` the creation of the object component is blocking. This means that the instantiation of a complex element may block the main thread, causing a visible glitch. Alternatively, complex components may have to be broken down and loaded in stages using `Loader` elements.

To resolve this problem, a component can be instantiated using the `incubateObject` method. This might work just as `createObject` and return an instance immediately, or it may call back when the component is ready. Depending on your exact setup, this may or may not be a good way to solve instantiation related animation glitches.

To use an incubator, simply use it as `createComponent`. However, the returned object is an incubator and not the object instance itself. When the incubator's status is `Component.Ready`, the object is available through the `object` property of the incubator. All this is shown in the example below:

```
function finishCreationg() {
    if (component.status === Component.Ready) {
        var incubator = component.incubateObject(root, {"x": 100, "y": 100});
        if (incubator.status === Component.Ready) {
            var image = incubator.object; // Created at once
        } else {
            incubator.onStatusChanged = function(status) {
                if (status === Component.Ready) {
                    var image = incubator.object; // Created async
                }
            };
        }
    }
}
```

15.2.2 Dynamically Instantiating Items from Text

Sometimes, it is convenient to be able to instantiate an object from a text string of QML. If nothing else, it is quicker than putting the code in a separate source file. For this, the `Qt.createQmlObject` function is used.

The function takes three arguments: `qml`, `parent` and `filepath`. The `qml` argument contains the string of QML code to instantiate. The `parent` argument provides a parent object to the newly created object. The `filepath` argument is used when reporting any errors from the creation of the object. The result returned from the function is either a new object or `null`.

Warning: The `createQmlObject` function always returns immediately. For the function to succeed, all the dependencies of the call must be loaded. This means that if the code passed to the function refers to a non-loaded component, the call will fail and return `null`. To better handle this, the `createComponent` / `createObject` approach must be used.

The objects created using the `Qt.createQmlObject` function resembles any other dynamically created object. That means that it is identical to every other QML object, apart from not having an `id`. In the example below, a new `Rectangle` element is instantiated from in-line QML code when the `root` element has been created.

```
import QtQuick 2.5

Item {
    id: root

    width: 1024
    height: 600

    function createItem() {
        Qt.createQmlObject("import QtQuick 2.5; Rectangle { x: 100; y: 100; width:␣
↪100; height: 100; color: \"blue\" }", root, "dynamicItem");
    }

```

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```
    Component.onCompleted: root.createItem();
}
```

15.2.3 Managing Dynamically Created Elements

Dynamically created objects can be treated as any other object in a QML scene. However, there are some pitfalls that we need to be aware of. The most important is the concept of the creation contexts.

The creation context of a dynamically created object is the context within it is being created. This is not necessarily the same context as the parent exists in. When the creation context is destroyed, so are the bindings concerning the object. This means that it is important to implement the creation of dynamic objects in a place in the code which will be instantiated during the entire lifetime of the objects.

Dynamically created objects can also be dynamically destroyed. When doing this, there is a rule of thumb: never attempt to destroy an object that you have not created. This also includes elements that you have created, but not using a dynamic mechanism such as `Component.createObject` or `createQmlObject`.

An object is destroyed by calling its `destroy` function. The function takes an optional argument which is an integer specifying how many milliseconds the objects shall exist before being destroyed. This is useful too, for instance, let the object complete a final transition.

```
item = Qt.createQmlObject(...);
...
item.destroy();
```

Note: It is possible to destroy an object from within, making it possible to create self-destroying popup windows for instance.

15.3 Tracking Dynamic Objects

Working with dynamic objects, it is often necessary to track the created objects. Another common feature is to be able to store and restore the state of the dynamic objects. Both these tasks are easily handled using a `ListModel` that we populate dynamically.

In the example shown below two types of elements, rockets and ufos can be created and moved around by the user. In order to be able to manipulate the entire scene of dynamically created elements, we use a model to track the items.

Todo: illustration

The model, a `ListModel`, is populated as the items are created. The object reference is tracked alongside the source URL used when instantiating it. The latter is not strictly needed for tracking the objects but will come in handy later.

```
import QtQuick 2.5
import "create-object.js" as CreateObject

Item {
    id: root

    ListModel {
        id: objectsModel
    }
```

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```
    function addUfo() {
        CreateObject.create("ufo.qml", root, itemAdded);
    }

    function addRocket() {
        CreateObject.create("rocket.qml", root, itemAdded);
    }

    function itemAdded(obj, source) {
        objectsModel.append({"obj": obj, "source": source})
    }
```

As you can tell from the example above, the `create-object.js` is a more generalized form of the JavaScript introduced earlier. The `create` method uses three arguments: a source URL, a root element, and a callback to invoke when finished. The callback gets called with two arguments: a reference to the newly created object and the source URL used.

This means that each time `addUfo` or `addRocket` functions are called, the `itemAdded` function will be called when the new object has been created. The latter will append the object reference and source URL to the `objectsModel` model.

The `objectsModel` can be used in many ways. In the example in question, the `clearItems` function relies on it. This function demonstrates two things. First, how to iterate over the model and perform a task, i.e. calling the `destroy` function for each item to remove it. Secondly, it highlights the fact that the model is not updated as objects are destroyed. Instead of removing the model item connected to the object in question, the `obj` property of that model item is set to `null`. To remedy this, the code explicitly has to clear the model item as the objects are removed.

```
    function clearItems() {
        while(objectsModel.count > 0) {
            objectsModel.get(0).obj.destroy();
            objectsModel.remove(0);
        }
    }
```

Having a model representing all dynamically created items, it is easy to create a function that serializes the items. In the example code, the serialized information consists of the source URL of each object along its `x` and `y` properties. These are the properties that can be altered by the user. The information is used to build an XML document string.

```
    function serialize() {
        var res = "<?xml version=\"1.0\" encoding=\"utf-8\"?>\n<scene>\n";

        for(var ii=0; ii < objectsModel.count; ++ii) {
            var i = objectsModel.get(ii);
            res += "  <item>\n    <source>" + i.source + "</source>\n    <x>" + i.
↪obj.x + "</x>\n    <y>" + i.obj.y + "</y>\n  </item>\n"
        }

        res += "</scene>";

        return res;
    }
```

The XML document string can be used with an `XmlListModel` by setting the `xml` property of the model. In the code below, the model is shown along the `deserialize` function. The `deserialize` function kickstarts the deserialization by setting the `dsIndex` to refer to the first item of the model and then invoking the creation of that item. The callback, `dsItemAdded` then sets that `x` and `y` properties of the newly created object. It then updates the index and creates the next object, if any.

```
    XmlListModel {
        id: xmlModel
        query: "/scene/item"
        XmlRole { name: "source"; query: "source/string()" }
        XmlRole { name: "x"; query: "x/string()" }
        XmlRole { name: "y"; query: "y/string()" }
    }

    function deserialize() {
        dsIndex = 0;
        CreateObject.create(xmlModel.get(dsIndex).source, root, dsItemAdded);
    }

    function dsItemAdded(obj, source) {
        itemAdded(obj, source);
        obj.x = xmlModel.get(dsIndex).x;
        obj.y = xmlModel.get(dsIndex).y;

        dsIndex ++;

        if (dsIndex < xmlModel.count)
            CreateObject.create(xmlModel.get(dsIndex).source, root, dsItemAdded);
    }

    property int dsIndex
```

The example demonstrates how a model can be used to track created items, and how easy it is to serialize and deserialize such information. This can be used to store a dynamically populated scene such as a set of widgets. In the example, a model was used to track each item.

An alternate solution would be to use the `children` property of the root of a scene to track items. This, however, requires the items themselves to know the source URL to use to re-create them. It also requires the scene to consist only of dynamically created items, to avoid attempting to serialize and later deserialize any statically allocated objects.

15.4 Summary

In this chapter, we have looked at creating QML elements dynamically. This lets us create QML scenes freely, opening the door for user configurable and plug-in based architectures.

The easiest way to dynamically load a QML element is to use a `Loader` element. This acts as a placeholder for the contents being loaded.

For a more dynamic approach, the `Qt.createQmlObject` function can be used to instantiate a string of QML. This approach does, however, have limitations. The full-blown solution is to dynamically create a `Component` using the `Qt.createComponent` function. Objects are then created by calling the `createObject` function of a `Component`.

As bindings and signal connections rely on the existence of an object `id`, or access to the object instantiation, an alternate approach must be used for dynamically created objects. To create a binding, the `Binding` element is used. The `Connections` element makes it possible to connect to signals of a dynamically created object.

One of the challenges of working with dynamically created items is to keep track of them. This can be done using a `ListModel`. By having a model tracking the dynamically created items, it is possible to implement functions for serialization and deserialization, making it possible to store and restore dynamically created scenes.

CHAPTER

SIXTEEN

JAVASCRIPT

Section author: jryannel@LinkedIn

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The source code for this chapter can be found in the assets folder.

JavaScript is the lingua-franca on web client development. It also starts to get traction on web server development mainly by node js. As such it is a well-suited addition as an imperative language onto the side of declarative QML language. QML itself as a declarative language is used to express the user interface hierarchy but is limited to express operational code. Sometimes you need a way to express operations, here JavaScript comes into play.

Note: There is an open question in the Qt community about the right mixture about QML/JS/QtC++ in a modern Qt application. The commonly agreed recommended mixture is to limit the JS part of your application to a minimum and do your business logic inside QtC++ and the UI logic inside QML/JS.

This book pushes the boundaries, which is not always the right mix for a product development and not for everyone. It is important to follow your team skills and your personal taste. In doubt follow the recommendation.

Here a short example of how JS used in QML looks like:

```
Button {
  width: 200
  height: 300
  property bool checked: false
  text: "Click to toggle"

  // JS function
  function doToggle() {
    checked = !checked
  }

  onTriggered: {
    // this is also JavaScript
    doToggle();
    console.log('checked: ' + checked)
  }
}
```

So JavaScript can come in many places inside QML as a standalone JS function, as a JS module and it can be on every right side of a property binding.

```
import "util.js" as Util // import a pure JS module

Button {
  width: 200
  height: width*2 // JS on the right side of property binding
```

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```
  // standalone function (not really useful)
  function log(msg) {
    console.log("Button> " + msg);
  }

  onTriggered: {
    // this is JavaScript
    log();
    Qt.quit();
  }
}
```

Within QML you declare the user interface, with JavaScript you make it functional. So how much JavaScript should you write? It depends on your style and how familiar you are with JS development. JS is a loosely typed language, which makes it difficult to spot type defects. Also, functions expect all argument variations, which can be a very nasty bug to spot. The way to spot defects is rigorous unit testing or acceptance testing. So if you develop real logic (not some glue lines of code) in JS you should really start using the test-first approach. In generally mixed teams (Qt/C++ and QML/JS) are very successful when they minimize the amount of JS in the frontend as the domain logic and do the heavy lifting in Qt C++ in the backend. The backend should then be rigorous unit tested so that the frontend developers can trust the code and focus on all these little user interface requirements.

Note: In general: backend developers are functional driven and frontend developers are user story driven.

16.1 Browser/HTML vs QtQuick/QML

The browser is the runtime to render HTML and execute the Javascript associated with the HTML. Nowadays modern web applications contain much more JavaScript than HTML. The Javascript inside the browser is a standard ECMAScript environment with some additional browser APIs. A typical JS environment inside the browser has a global object named `window` which is used to interact with the browser window (title, location URL, DOM tree etc.) Browsers provide functions to access DOM nodes by their id, class etc. (which were used by jQuery to provide the CSS selectors) and recently also by CSS selectors (`querySelector`, `querySelectorAll`). Additionally, there is a possibility to call a function after a certain amount of time (`setTimeout`) and to call it repeatedly (`setInterval`). Besides these (and other browser APIs), the environment is similar to QML/JS.

Another difference is how JS can appear inside HTML and QML. In HTML, you can execute JS only during the initial page load or in event handlers (e.g. page loaded, mouse pressed). For example, your JS initializes normally on page load, which is comparable to `Component.onCompleted` in QML. By default, you cannot use JS for property bindings in a browser (AngularJS enhances the DOM tree to allow these, but this is far away from standard HTML).

In QML, JS is a much more of a first-class citizen and is much deeper integrated into the QML render tree. Which makes the syntax much more readable. Besides this differences, people who have developed HTML/JS applications should feel at home using QML/JS.

16.2 The Language

This chapter will not give you a general introduction to JavaScript. There are other books out there for a general introduction to JavaScript, please visit this great side on Mozilla Developer Network.

On the surface JavaScript is a very common language and does not differ a lot from other languages:

```
function countDown() {
  for(var i=0; i<10; i++) {
```

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```
    console.log('index: ' + i)
  }
}

function countDown2() {
  var i=10;
  while( i>0 ) {
    i--;
  }
}
```

But be warned JS has function scope and not block scope as in C++ (see Functions and function scope).

The statements `if ... else`, `break`, `continue` also work as expected. The switch case can also compare other types and not just integer values:

```
function getAge(name) {
  // switch over a string
  switch(name) {
  case "father":
    return 58;
  case "mother":
    return 56;
  }
  return unknown;
}
```

JS knows several values which can be false, e.g. `false`, `0`, `""`, `undefined`, `null`). For example, a function returns by default `undefined`. To test for false use the === identity operator. The == equality operator will do type conversion to test for equality. If possible use the faster and better === strict equality operator which will test for identity (see Comparison operators.

Under the hood, javascript has its own ways of doing things. For example arrays:

```
function doIt() {
  var a = [] // empty arrays
  a.push(10) // addend number on arrays
  a.push("Monkey") // append string on arrays
  console.log(a.length) // prints 2
  a[0] // returns 10
  a[1] // returns Monkey
  a[2] // returns undefined
  a[99] = "String" // a valid assignment
  console.log(a.length) // prints 100
  a[98] // contains the value undefined
}
```

Also for people coming from C++ or Java which are used to an OO language JS just works differently. JS is not purely an OO language it is a so-called prototype based language. Each object has a prototype object. An object is created based on his prototype object. Please read more about this in the book Javascript the Good Parts by Douglas Crockford or watch the video below.

To test some small JS snippets you can use the online JS Console or just build a little piece of QML code:

```
import QtQuick 2.5

Item {
  function runJS() {
    console.log("Your JS code goes here");
  }
  Component.onCompleted: {
```

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```
    runJS();
  }
}
```

16.3 JS Objects

While working with JS there are some objects and methods which are more frequently used. This is a small collection of them.

- `Math.floor(v)`, `Math.ceil(v)`, `Math.round(v)` - largest, smallest, rounded integer from float
- `Math.random()` - create a random number between 0 and 1
- `Object.keys(o)` - get keys from object (including QObject)
- `JSON.parse(s)`, `JSON.stringify(o)` - conversion between JS object and JSON string
- `Number.toFixed(p)` - fixed precision float
- `Date` - Date manipulation

You can find them also at: JavaScript reference

Here some small and limited examples of how to use JS with QML. They should give you an idea how you can use JS inside QML

Print all keys from QML Item

```
Item {
  id: root
  Component.onCompleted: {
    var keys = Object.keys(root);
    for(var i=0; i<keys.length; i++) {
      var key = keys[i];
      // prints all properties, signals, functions from object
      console.log(key + ' : ' + root[key]);
    }
  }
}
```

Parse an object to a JSON string and back

```
Item {
  property var obj: {
    key: 'value'
  }

  Component.onCompleted: {
    var data = JSON.stringify(obj);
    console.log(data);
    var obj = JSON.parse(data);
    console.log(obj.key); // > 'value'
  }
}
```

Current Date

```
Item {
  Timer {
    id: timeUpdater
    interval: 100
    running: true
    repeat: true
    onTriggered: {
      var d = new Date();
      console.log(d.getSeconds());
    }
  }
}
```

Call a function by name

```
Item {
  id: root

  function doIt() {
    console.log("doIt()")
  }

  Component.onCompleted: {
    // Call using function execution
    root["doIt"]();
    var fn = root["doIt"];
    // Call using JS call method (could pass in a custom this object and arguments)
    fn.call()
  }
}
```

16.4 Creating a JS Console

As a little example, we will create a JS console. We need an input field where the user can enter his JS expressions and ideally there should be a list of output results. As this should more look like a desktop application we use the QtQuick Controls module.

Note: A JS console inside your next project can be really beneficial for testing. Enhanced with a Quake-Terminal effect it is also good to impress customers. To use it wisely you need to control the scope the JS console evaluates in, e.g. the currently visible screen, the main data model, a singleton core object or all together.

We use Qt Creator to create a Qt Quick UI project using QtQuick controls. We call the project *JSConsole*. After the wizard has finished we have already a basic structure for the application with an application window and a menu to exit the application.

For the input, we use a TextField and a Button to send the input for evaluation. The result of the expression evaluation is displayed using a ListView with a ListModel as the model and two labels to display the expression and the evaluated result.

```
// part of JSConsole.qml
ApplicationWindow {
  id: root
```

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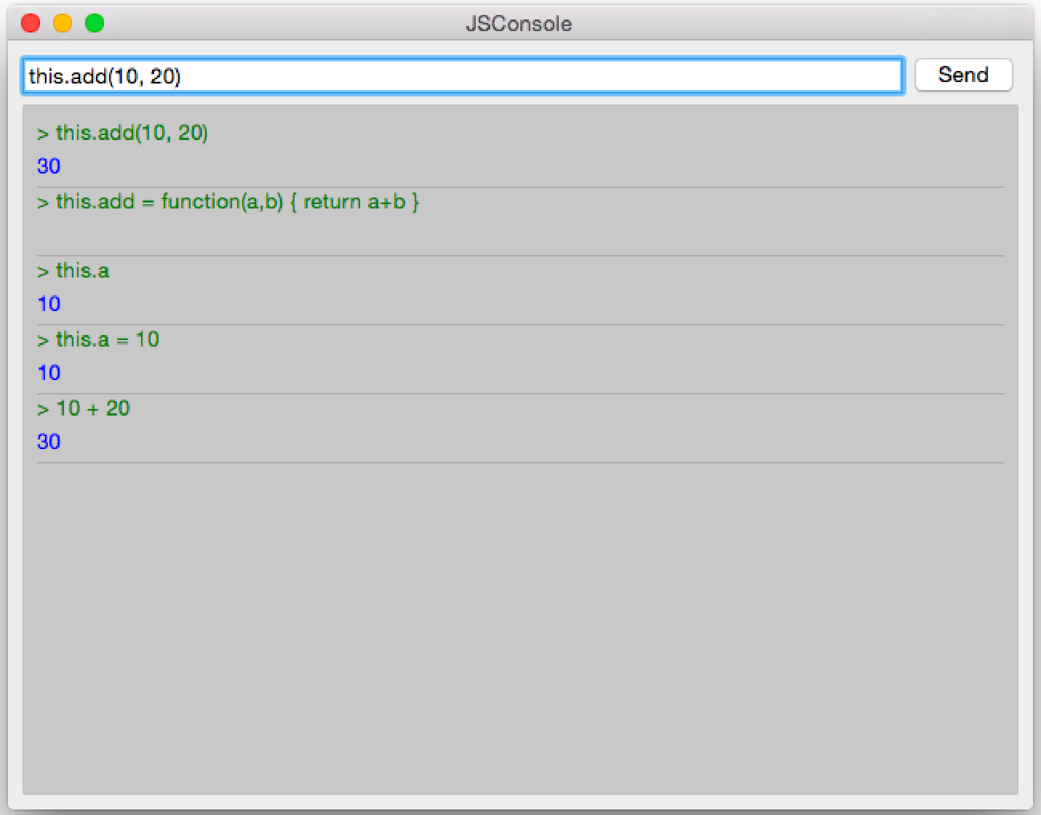

```
this.add(10, 20)
```

```
> this.add(10, 20)
30
> this.add = function(a,b) { return a+b }

> this.a
10
> this.a = 10
10
> 10 + 20
30
```

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```
...

ColumnLayout {
    anchors.fill: parent
    anchors.margins: 9
    RowLayout {
        Layout.fillWidth: true
        TextField {
            id: input
            Layout.fillWidth: true
            focus: true
            onAccepted: {
                // call our evaluation function on root
                root.jsCall(input.text)
            }
        }
        Button {
            text: qsTr("Send")
            onClicked: {
                // call our evaluation function on root
                root.jsCall(input.text)
            }
        }
    }
    Item {
        Layout.fillWidth: true
        Layout.fillHeight: true
        Rectangle {
            anchors.fill: parent
            color: '#333'
            border.color: Qt.darker(color)
            opacity: 0.2
            radius: 2
        }

        ScrollView {
            id: scrollView
            anchors.fill: parent
            anchors.margins: 9
            ListView {
                id: resultView
                model: ListModel {
                    id: outputModel
                }
                delegate: ColumnLayout {
                    width: ListView.view.width
                    Label {
                        Layout.fillWidth: true
                        color: 'green'
                        text: "> " + model.expression
                    }
                    Label {
                        Layout.fillWidth: true
                        color: 'blue'
                        text: "" + model.result
                    }
                    Rectangle {
                        height: 1
                        Layout.fillWidth: true
                        color: '#333'
                        opacity: 0.2
```

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```
                        }
                    }
                }
            }
        }
    }
}
```

The evaluation function `jsCall` does the evaluation not by itself this has been moved to a JS module (`jsconsole.js`) for clearer separation.

```
// part of JSConsole.qml

import "jsconsole.js" as Util

...

ApplicationWindow {
  id: root

  ...

  function jsCall(exp) {
      var data = Util.call(exp);
      // insert the result at the beginning of the list
      outputModel.insert(0, data)
  }
}
```

For safety, we do not use the `eval` function from JS as this would allow the user to modify the local scope. We use the Function constructor to create a JS function on runtime and pass in our scope as this variable. As the function is created every time it does not act as a closure and stores its own scope, we need to use `this.a = 10` to store the value inside this scope of the function. This scope is set by the script to the scope variable.

```
// jsconsole.js
.pragma library

var scope = {
  // our custom scope injected into our function evaluation
}

function call(msg) {
    var exp = msg.toString();
    console.log(exp)
    var data = {
        expression : msg
    }
    try {
        var fun = new Function('return (' + exp + ');');
        data.result = JSON.stringify(fun.call(scope), null, 2)
        console.log('scope: ' + JSON.stringify(scope, null, 2) + 'result: ' +␣
↪result)
    } catch(e) {
        console.log(e.toString())
        data.error = e.toString();
    }
    return data;
}
```

The data return from the call function is a JS object with a result, expression and error property: `data: { expression: {}, result: {}, error: {} }`. We can use this JS object directly inside the List-

Model and access it then from the delegate, e.g. `model.expression` gives us the input expression. For the simplicity of the example, we ignore the error result.

CHAPTER

SEVENTEEN

QT AND C++

Section author: jryannel@LinkedIn

Note: Last Build: December 07, 2020 at 10:50 CET

The source code for this chapter can be found in the assets folder.

Qt is a C++ toolkit with an extension for QML and Javascript. There exist many language bindings for Qt, but as Qt is developed in C++, the spirit of C++ can be found throughout the classes. In this section, we will look at Qt from a C++ perspective to build a better understanding of how to extend QML with native plugins developed using C++. Through C++, it is possible to extend and control the execution environment provided to QML.

This chapter will, just as Qt, require the reader to have some basic knowledge of C++. Qt does not rely on advanced C++ features, and I generally consider the Qt style of C++ to be very readable, so do not worry if you feel that your C++ knowledge is shaky.

Approaching Qt from a C++ direction, you will find that Qt enriches C++ with a number of modern language features enabled through making introspection data available. This is made possible through the use of the `QObject` base class. Introspection data, or metadata, maintains information of the classes at run-time, something that ordinary C++ does not do. This makes it possible to dynamically probe objects for information about such details as their properties and available methods.

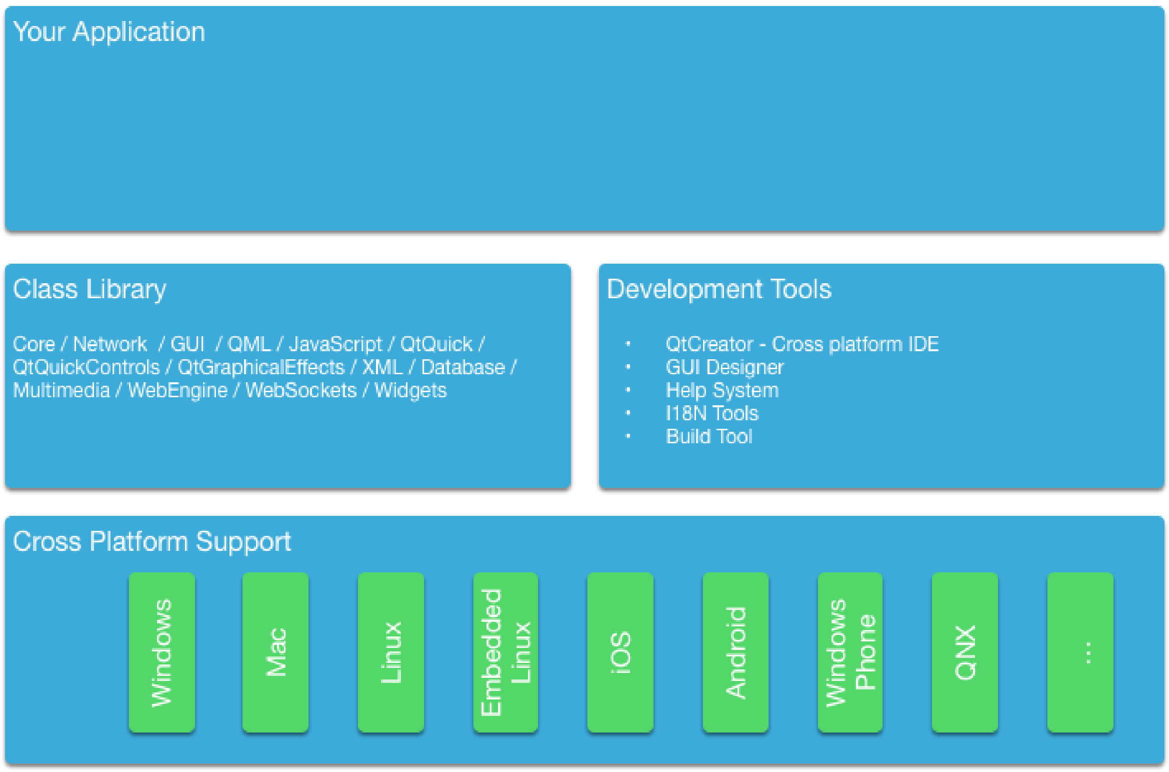
Qt uses this meta information to enable a very loosely bound callback concept using signals and slots. Each signal can be connected to any number of slots or even other signals. When a signal is emitted from an object instance, the connected slots are invoked. As the signal emitting object does not need to know anything about the object owning the slot and vice versa, this mechanism is used to create very reusable components with very few inter-component dependencies.

The introspection features are also used to create dynamic language bindings, making it possible to expose a C++ object instance to QML and making C++ functions callable from Javascript. Other bindings for Qt C++ exist and besides the standard Javascript binding, a popular one is the Python binding called PyQt.

In addition to this central concept, Qt makes it possible to develop cross-platform applications using C++. Qt C++ provides a platform abstraction on the different operating systems, which allows the developer to concentrate on the task at hand and not the details of how you open a file on different operating systems. This means you can re-compile the same source code for Windows, OS X, and Linux and Qt takes care of the different OS ways of handling certain things. The end result is natively built applications with the look and feel of the target platform. As the mobile is the new desktop, newer Qt versions can also target a number of mobile platforms using the same source code, e.g. iOS, Android, Jolla, BlackBerry, Ubuntu Phone, Tizen.

When it comes to re-using, not only can source code be re-used but developer skills are also reusable. A team knowing Qt can reach out to far more platforms then a team just focusing on a single platform specific technology and as Qt is so flexible the team can create different system components using the same technology.

For all platform, Qt offers a set of basic types, e.g. strings with full Unicode support, lists, vectors, buffers. It also provides a common abstraction to the target platform's main loop, and cross-platform threading and networking support. The general philosophy is that for an application developer Qt comes with all required functionality included. For domain-specific tasks such as to interface to your native libraries, Qt comes with several helper classes to make this easier.


Your Application
Class Library
Core / Network / GUI / QML / JavaScript / QtQuick / QtQuickControls / QtGraphicalEffects / XML / Database / Multimedia / WebEngine / WebSockets / Widgets
Development Tools
QtCreator - Cross platform IDE
GUI Designer
Help System
I18N Tools
Build Tool
Cross Platform Support
Windows
Mac
Linux
Embedded Linux
iOS
Android
Windows Phone
QNX
...

17.1 A Boilerplate Application

The best way to understand Qt is to start from a small demonstration application. This application creates a simple `"Hello World!"` string and writes it into a file using Unicode characters.

```
#include <QCoreApplication>
#include <QString>
#include <QFile>
#include <QDir>
#include <QTextStream>
#include <QDebug>


int main(int argc, char *argv[])
{
    QCoreApplication app(argc, argv);

    // prepare the message
    QString message("Hello World!");

    // prepare a file in the users home directory named out.txt
    QFile file(QDir::home().absoluteFilePath("out.txt"));
    // try to open the file in write mode
    if(!file.open(QIODevice::WriteOnly)) {
        qWarning() << "Can not open file with write access";
        return -1;
    }
    // as we handle text we need to use proper text codecs
    QTextStream stream(&file);
    // write message to file via the text stream
    stream << message;
```

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```
    // do not start the eventloop as this would wait for external IO
    // app.exec();

    // no need to close file, closes automatically when scope ends
    return 0;
}
```

The simple example demonstrates the use of file access and the correct way of writing text into a file using text codecs via the text stream. For binary data, there is a cross-platform binary stream called `QDataStream`. The different classes we use are included using their class name. Another possibility would be to use a module and class name e.g. `#include <QtCore/QFile>`. For the lazy, there is also the possibility to include a whole module using `#include <QtCore>`. E.g. in `QtCore` you have the most common classes used for an application, which are not UI dependent. Have a look at the QtCore class list or the QtCore overview.

You build the application using qmake and make. QMake reads a project file and generates a Makefile which then can be called using make. The project file is platform independent and qmake has some rules to apply the platform specific settings to the generated makefile. The project can also contain platform scopes for platform-specific rules, which are required in some specific cases. Here is an example of a simple project file.

```
# build an application
TEMPLATE = app

# use the core module and do not use the gui module
QT         += core
QT         -= gui

# name of the executable
TARGET = CoreApp

# allow console output
CONFIG    += console

# for mac remove the application bundling
macx {
    CONFIG    -= app_bundle
}

# sources to be build
SOURCES += main.cpp
```

We will not go into depth into this topic. Just remember Qt uses project files for projects and qmake generates the platform-specific makefiles from these project files.

The simple code example above just writes the text and exits the application. For a command line tool, this is good enough. For a user interface you would need an event loop which waits for user input and somehow schedules re-draw operations. So here follows the same example now uses a desktop button to trigger the writing.

Our `main.cpp` surprisingly got smaller. We moved code into an own class to be able to use signal/slots for the user input, e.g. the button click. The signal/slot mechanism normally needs an object instance as you will see shortly.

```
#include <QtCore>
#include <QtGui>
#include <QtWidgets>
#include "mainwindow.h"


int main(int argc, char** argv)
{
    QApplication app(argc, argv);

```

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```
    MainWindow win;
    win.resize(320, 240);
    win.setVisible(true);

    return app.exec();
}
```

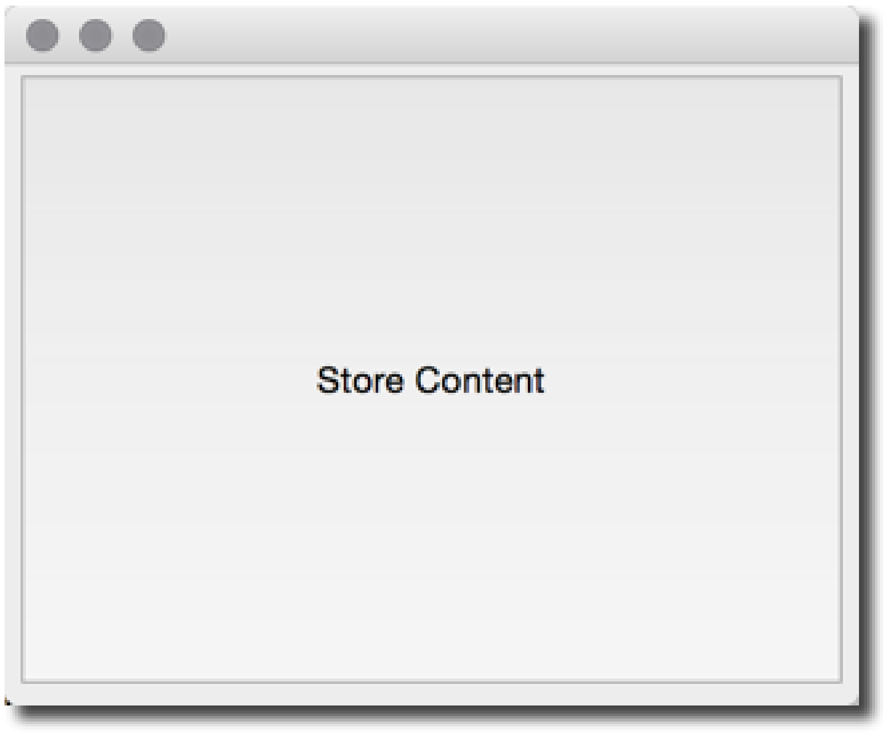
In the `main` function we simply create the application object and start the event loop using `exec()`. For now, the application sits in the event loop and waits for user input.

```
int main(int argc, char** argv)
{
    QApplication app(argc, argv); // init application

    // create the ui

    return app.exec(); // execute event loop
}
```

Qt offers several UI technologies. For this example, we use the Desktop Widgets user interface library using pure Qt C++. We create the main window which will host a push button to trigger the functionality and also the main window will host our core functionality which we know from the previous example.



The main window itself is a widget. It becomes a top-level window as it does not have any parent. This comes from how Qt sees a user interface as a tree of UI elements. In this case, the main window is the root element, thus becomes a window, while the push button a child of the main window and becomes a widget inside the window.

```
#ifndef MAINWINDOW_H
#define MAINWINDOW_H

#include <QtWidgets>

class MainWindow : public QMainWindow
{
public:
```

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```
    MainWindow(QWidget* parent=0);
    ~MainWindow();
public slots:
    void storeContent();
private:
    QPushButton *m_button;
};

#endif // MAINWINDOW_H
```

Additionally, we define a public slot called `storeContent()` which shall be called when the button is clicked. A slot is a C++ method which is registered with the Qt meta object system and can be dynamically called.

```
#include "mainwindow.h"

MainWindow::MainWindow(QWidget *parent)
    : QMainWindow(parent)
{
    m_button = new QPushButton("Store Content", this);

    setCentralWidget(m_button);
    connect(m_button, &QPushButton::clicked, this, &MainWindow::storeContent);
}

MainWindow::~MainWindow()
{

}

void MainWindow::storeContent()
{
    qDebug() << "... store content";
    QString message("Hello World!");
    QFile file(QDir::home().absoluteFilePath("out.txt"));
    if(!file.open(QIODevice::WriteOnly)) {
        qWarning() << "Can not open file with write access";
        return;
    }
    QTextStream stream(&file);
    stream << message;
}
```

In the main window, we first create the push button and then register the signal `clicked()` with the slot `storeContent()` using the connect method. Every time the signal clicked is emitted the slot `storeContent()` is called. As simple as this, objects communicate via signal and slots with loose coupling.

17.2 The QObject

As described in the introduction, the `QObject` is what enables Qt's introspection. It is the base class of almost all classes in Qt. Exceptions are value types such as `QColor`, `QString` and `QList`.

A Qt object is a standard C++ object, but with more abilities. These can be divided into two groups: introspection and memory management. The first means that a Qt object is aware of its class name, its relationship to other classes, as well as its methods and properties. The memory management concept means that each Qt object can be the parent of child objects. The parent *owns* the children, and when the parent is destroyed, it is responsible for destroying its children.

The best way of understanding how the `QObject` abilities affect a class is to take a standard C++ class and Qt enables it. The class shown below represents an ordinary such class.

The person class is a data class with a name and gender properties. The person class uses Qt's object system to add meta information to the c++ class. It allows users of a person object to connect to the slots and get notified when the properties get changed.

```
class Person : public QObject
{
    Q_OBJECT // enabled meta object abilities

    // property declarations required for QML
    Q_PROPERTY(QString name READ name WRITE setName NOTIFY nameChanged)
    Q_PROPERTY(Gender gender READ gender WRITE setGender NOTIFY genderChanged)

    // enables enum introspections
    Q_ENUMS(Gender)

public:
    // standard Qt constructor with parent for memory management
    Person(QObject *parent = 0);

    enum Gender { Unknown, Male, Female, Other };

    QString name() const;
    Gender gender() const;

public slots: // slots can be connected to signals
    void setName(const QString &);
    void setGender(Gender);

signals: // signals can be emitted
    void nameChanged(const QString &name);
    void genderChanged(Gender gender);

private:
    // data members
    QString m_name;
    Gender m_gender;
};
```

The constructor passes the parent to the superclass and initializes the members. Qt's value classes are automatically initialized. In this case `QString` will initialize to a null string (`QString::isNull()`) and the gender member will explicitly initialize to the unknown gender.

```
Person::Person(QObject *parent)
    : QObject(parent)
    , m_gender(Person::Unknown)
{
}
```

The getter function is named after the property and is normally a simple `const` function. The setter emits the changed signal when the property really has changed. For this, we insert a guard to compare the current value with the new value. And only when the value differs we assign it to the member variable and emit the changed signal.

```
QString Person::name() const
{
    return m_name;
}

void Person::setName(const QString &name)
{
    if (m_name != name) // guard
    {
        m_name = name;
```

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```
        emit nameChanged(m_name);
    }
}
```

Having a class derived from `QObject`, we have gained more meta object abilities we can explore using the `metaObject()` method. For example, retrieving the class name from the object.

```
Person* person = new Person();
person->metaObject()->className(); // "Person"
Person::staticMetaObject.className(); // "Person"
```

There are many more features which can be accessed by the `QObject` base class and the meta object. Please check out the `QMetaObject` documentation.

Note: `QObject`, and the `Q_OBJECT` macro has a lightweight sibling: `Q_GADGET`. The `Q_GADGET` macro can be inserted in the private section of non-`QObject`-derived classes to expose properties and invokable methods. Beware that a `Q_GADGET` object cannot have signals, so the properties cannot provide a change notification signal. Still, this can be useful to provide a QML-like interface to data structures exposed from C++ to QML without invoking the cost of a fully fledged `QObject`.

17.3 Build Systems

Building software reliably on different platforms can be a complex task. You will encounter different environments with different compilers, paths, and library variations. The purpose of Qt is to shield the application developer from these cross-platform issues. For this Qt introduced the `qmake` build file generator. `qmake` operates on a project file with the ending `.pro`. This project file contains instructions about the application and the sources to be used. Running qmake on this project file will generate a `Makefile` for you on Unix and MacOS and even under windows if the MinGW compiler toolchain is being used. Otherwise, it may create a visual studio project or an Xcode project.

A typical build flow in Qt under Unix would be:

```
$ edit myproject.pro
$ qmake // generates Makefile
$ make
```

Qt allows you also to use shadow builds. A shadow build is a build outside of your source code location. Assume we have a myproject folder with a `myproject.pro` file. The flow would be like this:

```
$ mkdir build
$ cd build
$ qmake ../myproject/myproject.pro
```

We create a build folder and then call qmake from inside the build folder with the location of our project folder. This will set up the makefile in a way that all build artifacts are stored under the build folder instead of inside our source code folder. This allows us to create builds for different qt versions and build configurations at the same time and also it does not clutter our source code folder which is always a good thing.

When you are using Qt Creator it does these things behind the scenes for you and you do not have to worry about these steps usually. For larger projects and for a deeper understanding of the flow, it is recommended that you learn to build your Qt project from the command line.

17.3.1 QMake

QMake is the tool which reads your project file and generates the build file. A project file is a simplified write-down of your project configuration, external dependencies, and your source files. The simplest project file is probably this:

```
// myproject.pro

SOURCES += main.cpp
```

Here we build an executable application which will have the name `myproject` based on the project file name. The build will only contain the `main.cpp` source file. And by default, we will use the QtCore and QtGui module for this project. If our project were a QML application we would need to add the QtQuick and QtQml module to the list:

```
// myproject.pro

QT += qml quick

SOURCES += main.cpp
```

Now the build file knows to link against the QtQml and QtQuick Qt modules. QMake uses the concept of =, += and -= to assign, add, remove elements from a list of options, respectively. For a pure console build without UI dependencies you would remove the QtGui module:

```
// myproject.pro

QT -= gui

SOURCES += main.cpp
```

When you want to build a library instead of an application, you need to change the build template:

```
// myproject.pro
TEMPLATE = lib

QT -= gui

HEADERS += utils.h
SOURCES += utils.cpp
```

Now the project will build as a library without UI dependencies and used the `utils.h` header and the `utils.cpp` source file. The format of the library will depend on the OS you are building the project.

Often you will have more complicated setups and need to build a set of projects. For this, qmake offers the `subdirs` template. Assume we would have a mylib and a myapp project. Then our setup could be like this:

```
my.pro
mylib/mylib.pro
mylib/utils.h
mylib/utils.cpp
myapp/myapp.pro
myapp/main.cpp
```

We know already how the mylib.pro and myapp.pro would look like. The my.pro as the overarching project file would look like this:

```
// my.pro
TEMPLATE = subdirs

subdirs = mylib \
    myapp

myapp.depends = mylib
```

This declares a project with two subprojects: `mylib` and `myapp`, where `myapp` depends on `mylib`. When you run qmake on this project file it will generate file a build file for each project in a corresponding folder. When you run the makefile for `my.pro`, all subprojects are also built.

Sometimes you need to do one thing on one platform and another thing on other platforms based on your configuration. For this qmake introduces the concept of scopes. A scope is applied when a configuration option is set to true.

For example, to use a Unix specific utils implementation you could use:

```
unix {
    SOURCES += utils_unix.cpp
} else {
    SOURCES += utils.cpp
}
```

What it says is if the CONFIG variable contains a Unix option then apply this scope otherwise use the else path. A typical one is to remove the application bundling under mac:

```
macx {
    CONFIG -= app_bundle
}
```

This will create your application as a plain executable under mac and not as a `.app` folder which is used for application installation.

QMake based projects are normally the number one choice when you start programming Qt applications. There are also other options out there. All have their benefits and drawbacks. We will shortly discuss these other options next.

References

- QMake Manual - Table of contents of the qmake manual
- QMake Language - Value assignment, scopes and so like
- QMake Variables - Variables like TEMPLATE, CONFIG, QT is explained here

17.3.2 CMake

CMake is a tool created by Kitware. Kitware is very well known for their 3D visualization software VTK and also CMake, the cross-platform makefile generator. It uses a series of `CMakeLists.txt` files to generate platform-specific makefiles. CMake is used by the KDE project and as such has a special relationship with the Qt community.

The `CMakeLists.txt` is the file used to store the project configuration. For a simple hello world using QtCore the project file would look like this:

```
// ensure cmake version is at least 3.0
cmake_minimum_required(VERSION 3.0)
// adds the source and build location to the include path
set(CMAKE_INCLUDE_CURRENT_DIR ON)
// Qt's MOC tool shall be automatically invoked
set(CMAKE_AUTOMOC ON)
// using the Qt5Core module
find_package(Qt5Core)
// create excutable helloworld using main.cpp
add_executable(helloworld main.cpp)
// helloworld links against Qt5Core
target_link_libraries(helloworld Qt5::Core)
```

This will build a helloworld executable using main.cpp and linked agains the external Qt5Core library. The build file can be modified to be more generic:

```
// sets the PROJECT_NAME variable
project(helloworld)
cmake_minimum_required(VERSION 3.0)
set(CMAKE_INCLUDE_CURRENT_DIR ON)
set(CMAKE_AUTOMOC ON)
find_package(Qt5Core)

// creates a SRC_LIST variable with main.cpp as single entry
set(SRC_LIST main.cpp)
// add an executable based on the project name and source list
add_executable(${PROJECT_NAME} ${SRC_LIST})
// links Qt5Core to the project executable
target_link_libraries(${PROJECT_NAME} Qt5::Core)
```

You can see that CMake is quite powerful. It takes some time to get used to the syntax. In general, it is said that CMake is better suited for large and complex projects.

References

- CMake Help - available online but also as QtHelp format
- Running CMake
- KDE CMake Tutorial
- CMake Book
- CMake and Qt

17.4 Common Qt Classes

The `QObject` class forms the foundations of Qt, but there are many more classes in the framework. Before we continue looking at QML and how to extend it, we will look at some basic Qt classes that are useful to know about.

The code examples shown in this section are written using the Qt Test library. It offers a great way to explore the Qt API and store it for later reference. `QVERIFY`, `QCOMPARE` are functions provided by the test library to assert a certain condition. We will use `{}` scopes to avoid name collisions. So do not get confused.

17.4.1 QString

In general, text handling in Qt is Unicode based. For this, you use the `QString` class. It comes with a variety of great functions which you would expect from a modern framework. For 8-bit data, you would use normally the `QByteArray` class and for ASCII identifiers the `QLatin1String` to preserve memory. For a list of strings you can use a `QList<QString>` or simply the `QStringList` class (which is derived from `QList<QString>`).

Here are some examples of how to use the `QString` class. QString can be created on the stack but it stores its data on the heap. Also when assigning one string to another, the data will not be copied - only a reference to the data. So this is really cheap and lets the developer concentrate on the code and not on the memory handling. `QString` uses reference counters to know when the data can be safely deleted. This feature is called Implicit Sharing and it is used in many Qt classes.

```
    QString data("A,B,C,D"); // create a simple string
    // split it into parts
    QStringList list = data.split(",");
    // create a new string out of the parts
    QString out = list.join(",");
    // verify both are the same
    QVERIFY(data == out);
```

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```
    // change the first character to upper case
    QVERIFY(QString("A") == out[0].toUpper());
```

Here we will show how to convert a number to a string and back. There are also conversion functions for float or double and other types. Just look for the function in the Qt documentation used here and you will find the others.

```
    // create some variables
    int v = 10;
    int base = 10;
    // convert an int to a string
    QString a = QString::number(v, base);
    // and back using and sets ok to true on success
    bool ok(false);
    int v2 = a.toInt(&ok, base);
    // verify our results
    QVERIFY(ok == true);
    QVERIFY(v = v2);
```

Often in a text, you need to have parameterized text. One option could be to use `QString("Hello" + name)` but a more flexible method is the `arg` marker approach. It preserves the order also during translation when the order might change.

```
    // create a name
    QString name("Joe");
    // get the day of the week as string
    QString weekday = QDate::currentDate().toString("dddd");
    // format a text using paramters (%1, %2)
    QString hello = QString("Hello %1. Today is %2.").arg(name).arg(weekday);
    // This worked on Monday. Promise!
    if(Qt::Monday == QDate::currentDate().dayOfWeek()) {
        QCOMPARE(QString("Hello Joe. Today is Monday."), hello);
    } else {
        QVERIFY(QString("Hello Joe. Today is Monday.") !=  hello);
    }
```

Sometimes you want to use Unicode characters directly in your code. For this, you need to remember how to mark them for the `QChar` and `QString` classes.

```
    // Create a unicode character using the unicode for smile :-)
    QChar smile(0x263A);
    // you should see a :-) on you console
    qDebug() << smile;
    // Use a unicode in a string
    QChar smile2 = QString("\u263A").at(0);
    QVERIFY(smile == smile2);
    // Create 12 smiles in a vector
    QVector<QChar> smilies(12);
    smilies.fill(smile);
    // Can you see the smiles
    qDebug() << smilies;
```

This gives you some examples of how to easily treat Unicode aware text in Qt. For non-Unicode, the `QByteArray` class also has many helper functions for conversion. Please read the Qt documentation for `QString` as it contains tons of good examples.

17.4.2 Sequential Containers

A list, queue, vector or linked-list is a sequential container. The mostly used sequential container is the `QList` class. It is a template based class and needs to be initialized with a type. It is also implicit shared and stores the data internally on the heap. All container classes should be created on the stack. Normally you never want to use `new QList<T>()`, which means never use `new` with a container.

The `QList` is as versatile as the `QString` class and offers a great API to explore your data. Below is a small example of how to use and iterate over a list using some new C++ 11 features.

```
    // Create a simple list of ints using the new C++11 initialization
    // for this you need to add "CONFIG += c++11" to your pro file.
    QList<int> list{1,2};

    // append another int
    list << 3;

    // We are using scopes to avoid variable name clashes

    { // iterate through list using Qt for each
        int sum(0);
        foreach (int v, list) {
            sum += v;
        }
        QVERIFY(sum == 6);
    }
    { // iterate through list using C++ 11 range based loop
        int sum = 0;
        for(int v : list) {
            sum+= v;
        }
        QVERIFY(sum == 6);
    }

    { // iterate through list using JAVA style iterators
        int sum = 0;
        QListIterator<int> i(list);

        while (i.hasNext()) {
            sum += i.next();
        }
        QVERIFY(sum == 6);
    }

    { // iterate through list using STL style iterator
        int sum = 0;
        QList<int>::iterator i;
        for (i = list.begin(); i != list.end(); ++i) {
            sum += *i;
        }
        QVERIFY(sum == 6);
    }


    // using std::sort with mutable iterator using C++11
    // list will be sorted in descending order
    std::sort(list.begin(), list.end(), [](int a, int b) { return a > b; });
    QVERIFY(list == QList<int>({3,2,1}));


    int value = 3;
    { // using std::find with const iterator
        QList<int>::const_iterator result = std::find(list.constBegin(), list.
↪constEnd(), value);
        QVERIFY(*result == value);
    }
```

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```
    { // using std::find using C++ lambda and C++ 11 auto variable
        auto result = std::find_if(list.constBegin(), list.constBegin(),␣
↪[value](int v) { return v == value; });
        QVERIFY(*result == value);
    }
```

17.4.3 Associative Containers

A map, a dictionary, or a set are examples of associative containers. They store a value using a key. They are known for their fast lookup. We demonstrate the use of the most used associative container the `QHash` also demonstrating some new C++ 11 features.

```
    QHash<QString, int> hash({{"b",2},{"c",3},{"a",1}});
    qDebug() << hash.keys(); // a,b,c - unordered
    qDebug() << hash.values(); // 1,2,3 - unordered but same as order as keys

    QVERIFY(hash["a"] == 1);
    QVERIFY(hash.value("a") == 1);
    QVERIFY(hash.contains("c") == true);

    { // JAVA iterator
        int sum =0;
        QHashIterator<QString, int> i(hash);
        while (i.hasNext()) {
            i.next();
            sum+= i.value();
            qDebug() << i.key() << " = " << i.value();
        }
        QVERIFY(sum == 6);
    }

    { // STL iterator
        int sum = 0;
        QHash<QString, int>::const_iterator i = hash.constBegin();
        while (i != hash.constEnd()) {
            sum += i.value();
            qDebug() << i.key() << " = " << i.value();
            i++;
        }
        QVERIFY(sum == 6);
    }

    hash.insert("d", 4);
    QVERIFY(hash.contains("d") == true);
    hash.remove("d");
    QVERIFY(hash.contains("d") == false);

    { // hash find not successfull
        QHash<QString, int>::const_iterator i = hash.find("e");
        QVERIFY(i == hash.end());
    }

    { // hash find successfull
        QHash<QString, int>::const_iterator i = hash.find("c");
        while (i != hash.end()) {
            qDebug() << i.value() << " = " << i.key();
            i++;
        }
    }
```

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```
    // QMap
    QMap<QString, int> map({{"b",2},{"c",2},{"a",1}});
    qDebug() << map.keys(); // a,b,c - ordered ascending

    QVERIFY(map["a"] == 1);
    QVERIFY(map.value("a") == 1);
    QVERIFY(map.contains("c") == true);

    // JAVA and STL iterator work same as QHash
```

17.4.4 File IO

It is often required to read and write from files. `QFile` is actually a `QObject` but in most cases, it is created on the stack. `QFile` contains signals to inform the user when data can be read. This allows reading chunks of data asynchronously until the whole file is read. For convenience, it also allows reading data in blocking mode. This should only be used for smaller amounts of data and not large files. Luckily we only use small amounts of data in these examples.

Besides reading raw data from a file into a `QByteArray` you can also read data types using the `QDataStream` and Unicode string using the `QTextStream`. We will show you how.

```
    QStringList data({"a", "b", "c"});
    { // write binary files
        QFile file("out.bin");
        if(file.open(QIODevice::WriteOnly)) {
            QDataStream stream(&file);
            stream << data;
        }
    }
    { // read binary file
        QFile file("out.bin");
        if(file.open(QIODevice::ReadOnly)) {
            QDataStream stream(&file);
            QStringList data2;
            stream >> data2;
            QCOMPARE(data, data2);
        }
    }
    { // write text file
        QFile file("out.txt");
        if(file.open(QIODevice::WriteOnly)) {
            QTextStream stream(&file);
            QString sdata = data.join(",");
            stream << sdata;
        }
    }
    { // read text file
        QFile file("out.txt");
        if(file.open(QIODevice::ReadOnly)) {
            QTextStream stream(&file);
            QStringList data2;
            QString sdata;
            stream >> sdata;
            data2 = sdata.split(",");
            QCOMPARE(data, data2);
        }
    }
```

17.4.5 More Classes

Qt is a rich application framework. As such it has thousands of classes. It takes some time to get used to all of these classes and how to use them. Luckily Qt has a very good documentation with many useful examples includes. Most of the time you search for a class and the most common use cases are already provided as snippets. Which means you just copy and adapt these snippets. Also, Qt's examples in the Qt source code are a great help. Make sure you have them available and searchable to make your life more productive. Do not waste time. The Qt community is always helpful. When you ask, it is very helpful to ask exact questions and provide a simple example which displays your needs. This will drastically improve the response time of others. So invest a little bit of time to make the life of others who want to help you easier :-).

Here some classes whose documentation the author thinks are a must read: QObject, QString, QByteArray, QFile, QDir, QFileInfo, QIODevice, QTextStream, QDataStream, QDebug, QLoggingCategory, QTcpServer, QTcpSocket, QNetworkRequest, QNetworkReply, QAbstractItemModel, QRegExp, QList, QHash, QThread, QProcess, QJsonDocument, QJSValue.

That should be enough for the beginning.

17.5 Models in C++

Models in QML serve the purpose of providing data to `ListViews`, `PathViews` and other views which take a model and create an instance of a delegate for each entry in the model. The view is smart enough to only create these instances which are visible or in the cache range. This makes it possible to have large models with tens of thousands of entries but still have a very slick user interface. The delegate acts like a template to be rendered with the model entries data. So in summary: a view renders entries from the model using a delegate as a template. The model is a data provider for views.

When you do not want to use C++ you can also define models in pure QML. You have several ways to provide a model for the view. For handling of data coming from C++ or a large amount of data, the C++ model is more suitable than this pure QML approach. But often you only need a few entries then these QML models are well suited.

```
ListView {
    // using a integer as model
    model: 5
    delegate: Text { text: 'index: ' + index }
}

ListView {
    // using a JS array as model
    model: ['A', 'B', 'C', 'D', 'E']
    delegate: Text { 'Char['+ index +']: ' + modelData }
}

ListView {
    // using a dynamic QML ListModel as model
    model: ListModel {
        ListElement { char: 'A' }
        ListElement { char: 'B' }
        ListElement { char: 'C' }
        ListElement { char: 'D' }
        ListElement { char: 'E' }
    }
    delegate: Text { 'Char['+ index +']: ' + model.char }
}
```

The QML views know how to handle these different models. For models coming from the C++ world, the view expects a specific protocol to be followed. This protocol is defined in an API (`QAbstractItemModel`) together with documentation for the dynamic behavior. The API was developed for the desktop widget world and is flexible enough to act as a base for trees, or multi-column tables as well as lists. In QML, we use either the list variant of the API (QAbstractListModel) or, for the TableView element, the table variant of the API (QAbstractTableModel). The API contains some mandatory functions to be implemented and some are optional. The optional parts mostly handle the dynamic use case of adding or removing of data.

17.5.1 A simple model

A typical QML C++ model derives from QAbstractListModel and implements at least the data and rowCount function. In this example, we will use a series of SVG color names provided by the QColor class and display them using our model. The data is stored into a QList<QString> data container.

Our DataEntryModel is derived form QAbstractListModel and implements the mandatory functions. We can ignore the parent in rowCount as this is only used in a tree model. The QModelIndex class provides the row and column information for the cell, for which the view wants to retrieve data. The view is pulling information from the model on a row/column and role-based. The QAbstractListModel is defined in QtCore but QColor in QtGui. That is why we have the additional QtGui dependency. For QML applications it is okay to depend on QtGui but it should normally not depend on QtWidgets.

```
#ifndef DATAENTRYMODEL_H
#define DATAENTRYMODEL_H

#include <QtCore>
#include <QtGui>

class DataEntryModel : public QAbstractListModel
{
    Q_OBJECT
public:
    explicit DataEntryModel(QObject *parent = 0);
    ~DataEntryModel();

public: // QAbstractItemModel interface
    virtual int rowCount(const QModelIndex &parent) const;
    virtual QVariant data(const QModelIndex &index, int role) const;
private:
    QList<QString> m_data;
};

#endif // DATAENTRYMODEL_H
```

On the implementation side, the most complex part is the data function. We first need to make a range check. And then we check for the display role. The Qt::DisplayRole is the default text role a view will ask for. There is a small set of default roles defined in Qt which can be used, but normally a model will define its own roles for clarity. All calls which do not contain the display role are ignored at the moment and the default value QVariant() is returned.

```
#include "dataentrymodel.h"

DataEntryModel::DataEntryModel(QObject *parent)
    : QAbstractListModel(parent)
{
    // initialize our data (QList<QString>) with a list of color names
    m_data = QColor::colorNames();
}

DataEntryModel::~DataEntryModel()
{
}

int DataEntryModel::rowCount(const QModelIndex &parent) const
{
```

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```
    Q_UNUSED(parent);
    // return our data count
    return m_data.count();
}

QVariant DataEntryModel::data(const QModelIndex &index, int role) const
{
    // the index returns the requested row and column information.
    // we ignore the column and only use the row information
    int row = index.row();

    // boundary check for the row
    if(row < 0 || row >= m_data.count()) {
        return QVariant();
    }

    // A model can return data for different roles.
    // The default role is the display role.
    // it can be accesses in QML with "model.display"
    switch(role) {
        case Qt::DisplayRole:
            // Return the color name for the particular row
            // Qt automatically converts it to the QVariant type
            return m_data.value(row);
    }

    // The view asked for other data, just return an empty QVariant
    return QVariant();
}
```

The next step would be to register the model with QML using the `qmlRegisterType` call. This is done inside the `main.cpp` before the QML file was loaded.

```
#include <QtGui>
#include <QtQml>

#include "dataentrymodel.h"

int main(int argc, char *argv[])
{
    QGuiApplication app(argc, argv);

    // register the type DataEntryModel
    // under the url "org.example" in version 1.0
    // under the name "DataEntryModel"
    qmlRegisterType<DataEntryModel>("org.example", 1, 0, "DataEntryModel");

    QQmlApplicationEngine engine;
    engine.load(QUrl(QStringLiteral("qrc:/main.qml")));

    return app.exec();
}
```

Now you can access the `DataEntryModel` using the QML import statement `import org.example 1.0` and use it just like other QML item `DataEntryModel {}`.

We use this in this example to display a simple list of color entries.

```
import org.example 1.0

ListView {
```

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```
    id: view
    anchors.fill: parent
    model: DataEntryModel {}
    delegate: ListDelegate {
        // use the defined model role "display"
        text: model.display
    }
    highlight: ListHighlight { }
}
```

The `ListDelegate` is a custom type to display some text. The `ListHighlight` is just a rectangle. The code was extracted to keep the example compact.

The view can now display a list of strings using the C++ model and the display property of the model. It is still very simple, but already usable in QML. Normally the data is provided from outside the model and the model would act as an interface to the view.

Note: To expose a table of data instead of a list, the `QAbstractTableModel` is used. The only difference compared to implementing a `QAbstractListModel` is that you must also provide the `columnCount` method.

17.5.2 More Complex Data

In reality, the model data is often much more complex. So there is a need to define custom roles so that the view can query other data via properties. For example, the model could provide not only the color as a hex string but maybe also the hue, saturation, and brightness from the HSV color model as "model.hue", "model.saturation" and "model.brightness" in QML.

```
#ifndef ROLEENTRYMODEL_H
#define ROLEENTRYMODEL_H

#include <QtCore>
#include <QtGui>

class RoleEntryModel : public QAbstractListModel
{
    Q_OBJECT
public:
    // Define the role names to be used
    enum RoleNames {
        NameRole = Qt::UserRole,
        HueRole = Qt::UserRole+2,
        SaturationRole = Qt::UserRole+3,
        BrightnessRole = Qt::UserRole+4
    };

    explicit RoleEntryModel(QObject *parent = 0);
    ~RoleEntryModel();

    // QAbstractItemModel interface
public:
    virtual int rowCount(const QModelIndex &parent) const override;
    virtual QVariant data(const QModelIndex &index, int role) const override;
protected:
    // return the roles mapping to be used by QML
    virtual QHash<int, QByteArray> roleNames() const override;
private:
    QList<QColor> m_data;
```

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```
    QHash<int, QByteArray> m_roleNames;
};

#endif // ROLEENTRYMODEL_H
```

In the header, we added the role mapping to be used for QML. When QML tries now to access a property from the model (e.g. “model.name”) the listview will lookup the mapping for “name” and ask the model for data using the `NameRole`. User-defined roles should start with `Qt::UserRole` and need to be unique for each model.

```
#include "roleentrymodel.h"

RoleEntryModel::RoleEntryModel(QObject *parent)
    : QAbstractListModel(parent)
{
    // Set names to the role name hash container (QHash<int, QByteArray>)
    // model.name, model.hue, model.saturation, model.brightness
    m_roleNames[NameRole] = "name";
    m_roleNames[HueRole] = "hue";
    m_roleNames[SaturationRole] = "saturation";
    m_roleNames[BrightnessRole] = "brightness";

    // Append the color names as QColor to the data list (QList<QColor>)
    for(const QString& name : QColor::colorNames()) {
        m_data.append(QColor(name));
    }

}

RoleEntryModel::~RoleEntryModel()
{
}

int RoleEntryModel::rowCount(const QModelIndex &parent) const
{
    Q_UNUSED(parent);
    return m_data.count();
}

QVariant RoleEntryModel::data(const QModelIndex &index, int role) const
{
    int row = index.row();
    if(row < 0 || row >= m_data.count()) {
        return QVariant();
    }
    const QColor& color = m_data.at(row);
    qDebug() << row << role << color;
    switch(role) {
    case NameRole:
        // return the color name as hex string (model.name)
        return color.name();
    case HueRole:
        // return the hue of the color (model.hue)
        return color.hueF();
    case SaturationRole:
        // return the saturation of the color (model.saturation)
        return color.saturationF();
    case BrightnessRole:
        // return the brightness of the color (model.brightness)
        return color.lightnessF();
    }
    return QVariant();
```

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```
}

QHash<int, QByteArray> RoleEntryModel::roleNames() const
{
    return m_roleNames;
}
```

The implementation now has changed only in two places. First in the initialization. We now initialize the data list with QColor data types. Additionally, we define our role name map to be accessible for QML. This map is returned later in the `::roleNames` function.

The second change is in the `::data` function. We extend the switch to cover the other roles (e.g hue, saturation, brightness). There is no way to return an SVG name from a color, as a color can take any color and SVG names are limited. So we skip this. Storing the names would require to create a structure `struct { QColor, QString }` to be able to identify the named color.

After registering the type we can use the model and its entries in our user interface.

```
ListView {
    id: view
    anchors.fill: parent
    model: RoleEntryModel {}
    focus: true
    delegate: ListDelegate {
        text: 'hsv(' +
              Number(model.hue).toFixed(2) + ',' +
              Number(model.saturation).toFixed() + ',' +
              Number(model.brightness).toFixed() + ')'
        color: model.name
    }
    highlight: ListHighlight { }
}
```

We convert the returned type to a JS number type to be able to format the number using fixed-point notation. The code would also work without the Number call (e.g. plain `model.saturation.toFixed(2)`). Which format to choose, depends how much you trust the incoming data.

17.5.3 Dynamic Data

Dynamic data covers the aspects of inserting, removing and clearing the data from the model. The `QAbstractListModel` expect a certain behavior when entries are removed or inserted. The behavior is expressed in signals which need to be called before and after the manipulation. For example to insert a row into a model you need first to emit the signal `beginInsertRows`, then manipulate the data and then finally emit `endInsertRows`.

We will add the following functions to our headers. These functions are declared using `Q_INVOKABLE` to be able to call them from QML. Another way would be to declare them as public slots.

```
// inserts a color at the index (0 at begining, count-1 at end)
Q_INVOKABLE void insert(int index, const QString& colorValue);
// uses insert to insert a color at the end
Q_INVOKABLE void append(const QString& colorValue);
// removes a color from the index
Q_INVOKABLE void remove(int index);
// clear the whole model (e.g. reset)
Q_INVOKABLE void clear();
```

Additionally, we define a `count` property to get the size of the model and a `get` method to get a color at the given index. This is useful when you would like to iterate over the model content from QML.

```
// gives the size of the model
Q_PROPERTY(int count READ count NOTIFY countChanged)
// gets a color at the index
Q_INVOKABLE QColor get(int index);
```

The implementation for insert checks first the boundaries and if the given value is valid. Only then do we begin inserting the data.

```
void DynamicEntryModel::insert(int index, const QString &colorValue)
{
    if(index < 0 || index > m_data.count()) {
        return;
    }
    QColor color(colorValue);
    if(!color.isValid()) {
        return;
    }
    // view protocol (begin => manipulate => end]
    emit beginInsertRows(QModelIndex(), index, index);
    m_data.insert(index, color);
    emit endInsertRows();
    // update our count property
    emit countChanged(m_data.count());
}
```

Append is very simple. We reuse the insert function with the size of the model.

```
void DynamicEntryModel::append(const QString &colorValue)
{
    insert(count(), colorValue);
}
```

Remove is similar to insert but it calls according to the remove operation protocol.

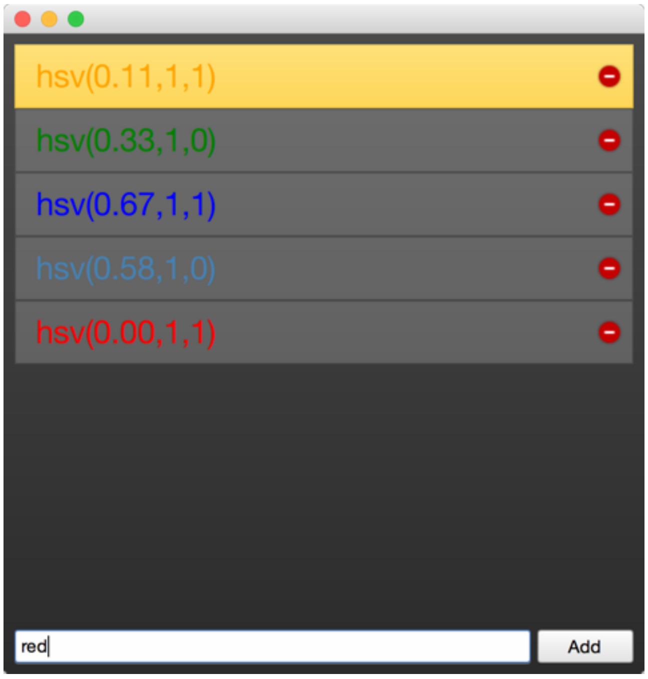
```
void DynamicEntryModel::remove(int index)
{
    if(index < 0 || index >= m_data.count()) {
        return;
    }
    emit beginRemoveRows(QModelIndex(), index, index);
    m_data.removeAt(index);
    emit endRemoveRows();
    // do not forget to update our count property
    emit countChanged(m_data.count());
}
```

The helper function `count` is trivial. It just returns the data count. The `get` function is also quite simple.

```
QColor DynamicEntryModel::get(int index)
{
    if(index < 0 || index >= m_data.count()) {
        return QColor();
    }
    return m_data.at(index);
}
```

You need to be careful that you only return a value which QML understands. If it is not one of the basic QML types or types known to QML you need to register the type first with `qmlRegisterType` or `qmlRegisterUncreatableType`. You use `qmlRegisterUncreatableType` if the user shall not be able to instantiate its own object in QML.

Now you can use the model in QML and insert, append, remove entries from the model. Here is a small example which allows the user to enter a color name or color hex value and the color is then appended onto the model and shown in the list view. The red circle on the delegate allows the user to remove this entry from the model. After the entry is to remove the list view is notified by the model and updates its content.



And here is the QML code. You find the full source code also in the assets for this chapter. The example uses the QtQuick.Controls and QtQuick.Layout module to make the code more compact. These controls module provides a set of desktop related UI elements in QtQuick and the layouts module provides some very useful layout managers.

```
import QtQuick 2.5
import QtQuick.Window 2.2
import QtQuick.Controls 1.5
import QtQuick.Layouts 1.2

// our module
import org.example 1.0

Window {
    visible: true
    width: 480
    height: 480


    Background { // a dark background
        id: background
    }

    // our dyanmic model
    DynamicEntryModel {
        id: dynamic
        onCountChanged: {
            // we print out count and the last entry when count is changing
            print('new count: ' + count);
            print('last entry: ' + get(count-1));
        }
```

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```
    }

    ColumnLayout {
        anchors.fill: parent
        anchors.margins: 8
        ScrollView {
            Layout.fillHeight: true
            Layout.fillWidth: true
            ListView {
                id: view
                // set our dynamic model to the views model property
                model: dynamic
                delegate: ListDelegate {
                    width: ListView.view.width
                    // construct a string based on the models proeprties
                    text: 'hsv(' +
                          Number(model.hue).toFixed(2) + ',' +
                          Number(model.saturation).toFixed() + ',' +
                          Number(model.brightness).toFixed() + ')'
                    // sets the font color of our custom delegates
                    color: model.name

                    onClicked: {
                        // make this delegate the current item
                        view.currentIndex = index
                        view.focus = true
                    }
                    onRemove: {
                        // remove the current entry from the model
                        dynamic.remove(index)
                    }
                }
                highlight: ListHighlight { }
                // some fun with transitions :-)
                add: Transition {
                    // applied when entry is added
                    NumberAnimation {
                        properties: "x"; from: -view.width;
                        duration: 250; easing.type: Easing.InCirc
                    }
                    NumberAnimation { properties: "y"; from: view.height;
                        duration: 250; easing.type: Easing.InCirc
                    }
                }
                remove: Transition {
                    // applied when entry is removed
                    NumberAnimation {
                        properties: "x"; to: view.width;
                        duration: 250; easing.type: Easing.InBounce
                    }
                }
                displaced: Transition {
                    // applied when entry is moved
                    // (e.g because another element was removed)
                    SequentialAnimation {
                        // wait until remove has finished
                        PauseAnimation { duration: 250 }
                        NumberAnimation { properties: "y"; duration: 75
                        }
                    }
                }
```

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```
                }
            }
            TextEntry {
                id: textEntry
                onAppend: {
                    // called when the user presses return on the text field
                    // or clicks the add button
                    dynamic.append(color)
                }

                onUp: {
                    // called when the user presses up while the text field is focused
                    view.decrementCurrentIndex()
                }
                onDown: {
                    // same for down
                    view.incrementCurrentIndex()
                }

            }
        }
}
```

Model view programming is one of the hardest tasks in Qt. It is one of the very few classes where you have to implement an interface as a normal application developer. All other classes you just use normally. The sketching of models should always start on the QML side. You should envision how your users would use your model inside QML. For this, it is often a good idea to create a prototype first using the `ListModel` to see how this best works in QML. This is also true when it comes to defining QML APIs. Making data available from C++ to QML is not only a technology boundary it is also a programming paradigm change from imperative to declarative style programming. So be prepared for some setbacks and aha moments:-).

17.5.4 Advanced Techniques

CHAPTER

EIGHTEEN

EXTENDING QML WITH C++

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The source code for this chapter can be found in the assets folder.

Executing QML within the confined space that QML as a language offers can sometimes be limiting. By extending the QML run-time with native functionality written in C++, the application can utilize the full performance and freedom of the base platform.

18.1 Understanding the QML Run-time

When running QML, it is being executed in a run-time environment. The run-time is implemented in C++ in the `QtQml` module. It consists of an engine, responsible for the execution of QML, contexts, holding the properties accessible for each component, and components, the instantiated QML elements.

```
#include <QtGui>
#include <QtQml>

int main(int argc, char **argv)
{
    QGuiApplication app(argc, argv);
    QUrl source(QStringLiteral("qrc:/main.qml"));
    QQmlApplicationEngine engine;
    engine.load(source);
    return app.exec();
}
```

In the example, the `QGuiApplication` encapsulates all that is related to the application instance (e.g. application name, command line arguments and managing the event loop). The `QQmlApplicationEngine` manages the hierarchical order of contexts and components. It requires typical a QML file to be loaded as the starting point of your application. In this case, it is a `main.qml` containing a window and a text type.

Note: Loading a `main.qml` with a simple `Item` as the root type through the `QmlApplicationEngine` will not show anything on your display, as it requires a window to manage a surface for rendering. The engine is capable of loading QML code which does not contain any user interface (e.g plain objects). Because of this, it does not create a window for you by default. The `qmlscene` or the new `qml` runtime will internally first check if the main QML file contains a window as a root item and if not create one for you and set the root item as a child to the newly created window.

```
import QtQuick 2.5
import QtQuick.Window 2.2
```

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```

Window {
    visible: true
    width: 512
    height: 300

    Text {
        anchors.centerIn: parent
        text: "Hello World!"
    }
}
```

In the QML file we declare our dependencies here it is `QtQuick` and `QtQuick.Window`. This declaration will trigger a lookup for these modules in the import paths and on success will load the required plugins by the engine. The newly loaded types will then be made available to the QML file controlled by a `qmldir`.

It is also possible to shortcut the plugin creation by adding our types directly to the engine. Here we assume we have a `CurrentTime` `QObject` based class.

```
QQmlApplicationEngine engine;

qmlRegisterType<CurrentTime>("org.example", 1, 0, "CurrentTime");

engine.load(source);
```

Now we can also use the `CurrentTime` type in our QML file.

```
import org.example 1.0

CurrentTime {
    // access properties, functions, signals
}
```

For the really lazy there is also the very direct way through context properties.

```
QScopedPointer<CurrentTime> current(new CurrentTime());

QQmlApplicationEngine engine;

engine.rootContext().setContextProperty("current", current.value())

engine.load(source);
```

Note: Do not mix up `setContextProperty()` and `setProperty()`. The first one sets a context property on a qml context, and `setProperty()` sets a dynamic property value on a `QObject` and will not help you.

Now you can use the current property everywhere in your application. Thanks to context inheritance.

```
import QtQuick 2.5
import QtQuick.Window 2.0

Window {
    visible: true
    width: 512
    height: 300

    Component.onCompleted: {
        console.log('current: ' + current)
    }
}
```

Here are the different ways you can extend QML in general:

- Context properties - `setContextProperty()`
- Register type with engine - calling `qmlRegisterType` in your main.cpp
- QML extension plugins - To be discussed next

Context properties are easy to use for small applications. They do not require any effort you just expose your system API with kind of global objects. It is helpful to ensure there will be no naming conflicts (e.g by using a special character for this (`$`) for example `$.currentTime`). `$` is a valid character for JS variables.

Registering QML types allows the user to control the lifecycle of a c++ object from QML. This is not possible with the context properties. Also, it does not pollute the global namespace. Still all types need to be registered first and by this, all libraries need to be linked on application start, which in most cases is not really a problem.

The most flexible system is provided by the **QML extension plugins**. They allow you to register types in a plugin which is loaded when the first QML file calls the import identifier. Also by using a QML singleton, there is no need to pollute the global namespace anymore. Plugins allow you to reuse modules across projects, which comes quite handy when you do more than one project with Qt.

For the remainder of this chapter will focus on the QML extension plugins. As they provide the greatest flexibility and reuse.

18.2 Plugin Content

A plugin is a library with a defined interface, which is loaded on demand. This differs from a library as a library is linked and loaded on startup of the application. In the QML case, the interface is called `QQmlExtensionPlugin`. There are two methods interesting for us `initializeEngine()` and `registerTypes()`. When the plugin is loaded first the `initializeEngine()` is called, which allows us to access the engine to expose plugin objects to the root context. In the majority, you will only use the `registerTypes()` method. This allows you to register your custom QML types with the engine on the provided URL.

Let us step back a little bit and think about a potential file IO type which would allow us to read/write small text files from QML. A first iteration could look like this in a mocked QML implementation.

```
// FileIO.qml (good)
QtObject {
    function write(path, text) {};
    function read(path) { return "TEXT"}
}
```

This is a pure QML implementation of a possible C++ based QML API for exploring an API. We see we should have a read and write function. Where the write function takes a path and a text and the read function takes a path and returns a text. As it looks path and text are common parameters and maybe we can extract them as properties.

```
// FileIO.qml (better)
QtObject {
    property url source
    property string text
    function write() { // open file and write text };
    function read() { // read file and assign to text };
}
```

Yes, this looks more like a QML API. We use properties to allow our environment to bind to our properties and react to changes.

To create this API in C++ we would need to create an interface something like this.

```
class FileIO : public QObject {
    ...
    Q_PROPERTY(QUrl source READ source WRITE setSource NOTIFY sourceChanged)
    Q_PROPERTY(QString text READ text WRITE setText NOTIFY textChanged)
    ...
public:
    Q_INVOKABLE void read();
    Q_INVOKABLE void write();
    ...
}
```

This `FileIO` type need to be registered with the QML engine. We want to use it under the “org.example.io” module

```
import org.example.io 1.0

FileIO {
}
```

A plugin could expose several types with the same module. But it can not expose several modules from one plugin. So there is a one to one relationship between modules and plugins. This relationship is expressed by the module identifier.

18.3 Creating the plugin

Qt Creator contains a wizard to create a **QtQuick 2 QML Extension Plugin** we use it to create a plugin called `fileio` with a `FileIO` object to start within the module **“org.example.io”**.

The plugin class is derived from `QQmlExtensionPlugin` and implements the `registerTypes()` function. The `Q_PLUGIN_METADATA` line is mandatory to identify the plugin as a QML extension plugin. Besides this, there is nothing spectacular going on.

```
#ifndef FILEIO_PLUGIN_H
#define FILEIO_PLUGIN_H

#include <QQmlExtensionPlugin>

class FileioPlugin : public QQmlExtensionPlugin
{
    Q_OBJECT
    Q_PLUGIN_METADATA(IID "org.qt-project.Qt.QQmlExtensionInterface")

public:
    void registerTypes(const char *uri);
};

#endif // FILEIO_PLUGIN_H
```

In the implementation of the `registerTypes` we simply register our `FileIO` class using the `qmlRegisterType` function.

```
#include "fileio_plugin.h"
#include "fileio.h"

#include <qqml.h>

void FileioPlugin::registerTypes(const char *uri)
{
    // @uri org.example.io
```

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```
    qmlRegisterType<FileIO>(uri, 1, 0, "FileIO");
}
```

Interestingly we cannot see here the module URI (e.g. **org.example.io**). This seems to be set from the outside.

When you look into your project directory you will find a `qmldir` file. This file specifies the content of your QML plugin or better the QML side of your plugin. It should look like this for you.

```
module org.example.io
plugin fileio
```

The module is the URI under which your plugin is reachable by others and the plugin line must be identical with your plugin file name (under mac this would be *libfileio_debug.dylib* on the file system and *fileio* in the *qmldir*). These files are created by Qt Creator based on the given information. The module URI is also available in the .pro file. There is used to build up the install directory.

When you call `make install` in your build folder the library will be copied into the Qt `qml` folder (for Qt 5.4 on mac this would be *"~/Qt/5.4/clang_64/qml"*. The exact path depends on your Qt installation location and the used compiler on your system). There you will find a library inside the "org/example/io" folder. The content are these two files currently

```
libfileio_debug.dylib
qmldir
```

When importing a module called "org.example.io", the QML engine will look in one of the import paths and tries to locate the "org/example/io" path with a qmldir. The qmldir then will tell the engine which library to load as a QML extension plugin using which module URI. Two modules with the same URI will override each other.

18.4 FileIO Implementation

The `FileIO` implementation is straightforward. Remember the API we want to create should look like this.

```
class FileIO : public QObject {
    ...
    Q_PROPERTY(QUrl source READ source WRITE setSource NOTIFY sourceChanged)
    Q_PROPERTY(QString text READ text WRITE setText NOTIFY textChanged)
    ...
public:
    Q_INVOKABLE void read();
    Q_INVOKABLE void write();
    ...
}
```

We will leave out the properties, as they are simple setters and getters.

The read method opens a file in reading mode and reads the data using a text stream.

```
void FileIO::read()
{
    if(m_source.isEmpty()) {
        return;
    }
    QFile file(m_source.toLocalFile());
    if(!file.exists()) {
        qWarning() << "Does not exits: " << m_source.toLocalFile();
        return;
    }
    if(file.open(QIODevice::ReadOnly)) {
        QTextStream stream(&file);
```

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```
        m_text = stream.readAll();
        emit textChanged(m_text);
    }
}
```

When the text is changed it is necessary to inform others about the change using `emit textChanged(m_text)`. Otherwise, property binding will not work.

The write method does the same but opens the file in write mode and uses the stream to write the contents.

```
void FileIO::write()
{
    if(m_source.isEmpty()) {
        return;
    }
    QFile file(m_source.toLocalFile());
    if(file.open(QIODevice::WriteOnly)) {
        QTextStream stream(&file);
        stream << m_text;
    }
}
```

Do not forget to call `make install` at the end. Otherwise, your plugin files will not be copied over to the qml folder and the qml engine will not be able to locate the module.

As the reading and writing are blocking you should only use this `FileIO` for small texts, otherwise, you will block the UI thread of Qt. Be warned!

18.5 Using FileIO

Now we can use our newly created file to access some nice data. For this example, we want to read some city data in a JSON format and display it in a table. We will use two projects, one the extension plugin (called `fileio`) which provides us a way to read and write text from a file and the other one, which displays the data in a table (`CityUI`) by using the file io for reading and writing of files. The data used in this example is in the `cities.json` file.

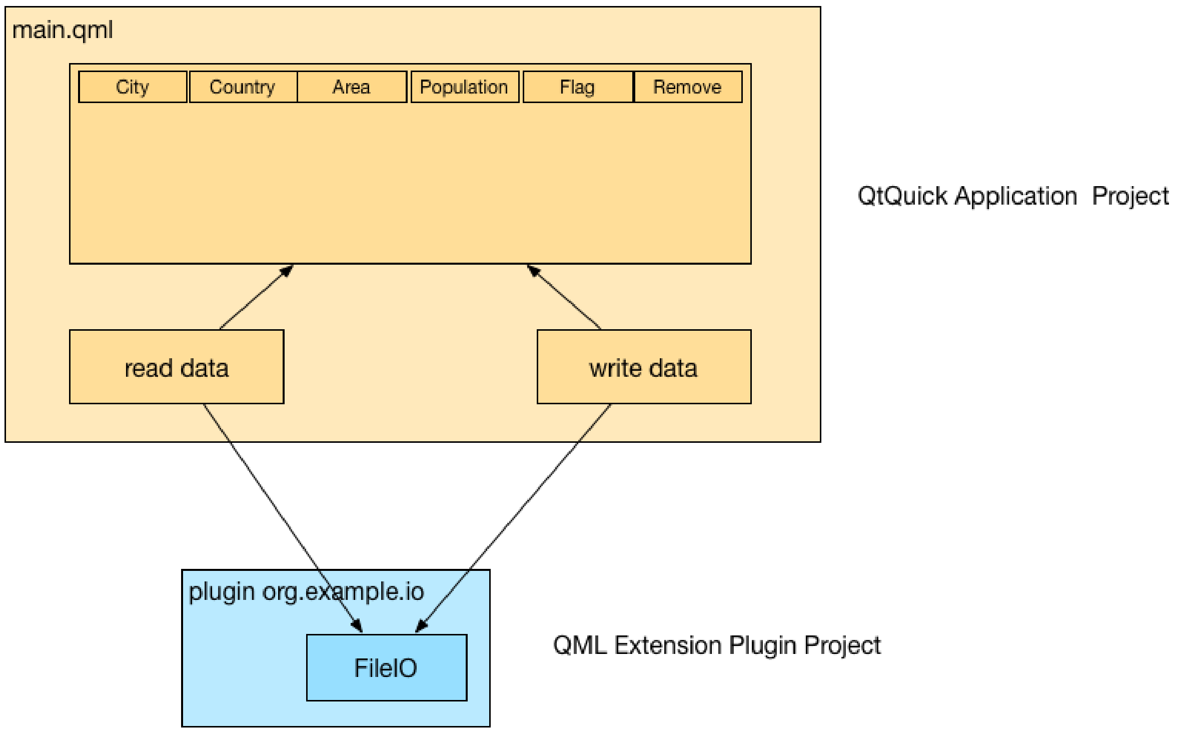
JSON is just text, which is formatted in such a way that it can be converted into a valid JS object/array and back to the text. We use our `FileIO` to read the JSON formatted data and convert it into a JS object using `JSON.parse()`. The data is later used as a model for the table view. This is roughly the content of our read document function. For saving, we convert the data back into a text format and use the write function for saving.

The city JSON data is a formatted text file, with a set of city data entries, where each entry contains interesting data about the city.

```
[
    {
        "area": "1928",
        "city": "Shanghai",
        "country": "China",
        "flag": "22px-Flag_of_the_People's_Republic_of_China.svg.png",
        "population": "13831900"
    },
    ...
]
```

18.5.1 The Application Window

We use the Qt Creator `QtQuick Application` wizard to create a Qt Quick controls based application. We will not use the new QML forms as this is difficult to explain in a book, although the new forms approach with a



ui.qml file is much more usable than previous. So you can remove/delete the forms file for now.

The basic setup is an `ApplicationWindow` which can contain a toolbar, menubar, and status bar. We will only use the menubar to create some standard menu entries for opening and saving the document. The basic setup will just display an empty window.

```
import QtQuick 2.5
import QtQuick.Controls 1.3
import QtQuick.Window 2.2
import QtQuick.Dialogs 1.2

ApplicationWindow {
    id: root
    title: qsTr("City UI")
    width: 640
    height: 480
    visible: true
}
```

18.5.2 Using Actions

To better use/reuse our commands we use the QML `Action` type. This will allow us later to use the same action also for a potential toolbar. The open and save and exit actions are quite standard. The open and save action do not contain any logic yet, this we will come later. The menubar is created with a file menu and these three action entries. Additional we prepare already a file dialog, which will allow us to pick our city document later. A dialog is not visible when declared, you need to use the `open()` method to show it.

```
...
Action {
    id: save
    text: qsTr("&Save")
    shortcut: StandardKey.Save
    onTriggered: { }
```

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```
}

Action {
    id: open
    text: qsTr("&Open")
    shortcut: StandardKey.Open
    onTriggered: {}
}

Action {
    id: exit
    text: qsTr("E&xit")
    onTriggered: Qt.quit();
}

menuBar: MenuBar {
    Menu {
        title: qsTr("&File")
        MenuItem { action: open }
        MenuItem { action: save }
        MenuSeparator { }
        MenuItem { action: exit }
    }
}

...

FileDialog {
    id: openDialog
    onAccepted: { }
}
```

18.5.3 Formatting the Table

The content of the city data shall be displayed in a table. For this, we use the `TableView` control and declare 4 columns: city, country, area, population. Each column is a standard `TableViewColumn`. Later we will add columns for the flag and remove operation which will require a custom column delegate.

```
TableView {
    id: view
    anchors.fill: parent
    TableViewColumn {
        role: 'city'
        title: "City"
        width: 120
    }
    TableViewColumn {
        role: 'country'
        title: "Country"
        width: 120
    }
    TableViewColumn {
        role: 'area'
        title: "Area"
        width: 80
    }
    TableViewColumn {
        role: 'population'
        title: "Population"
```

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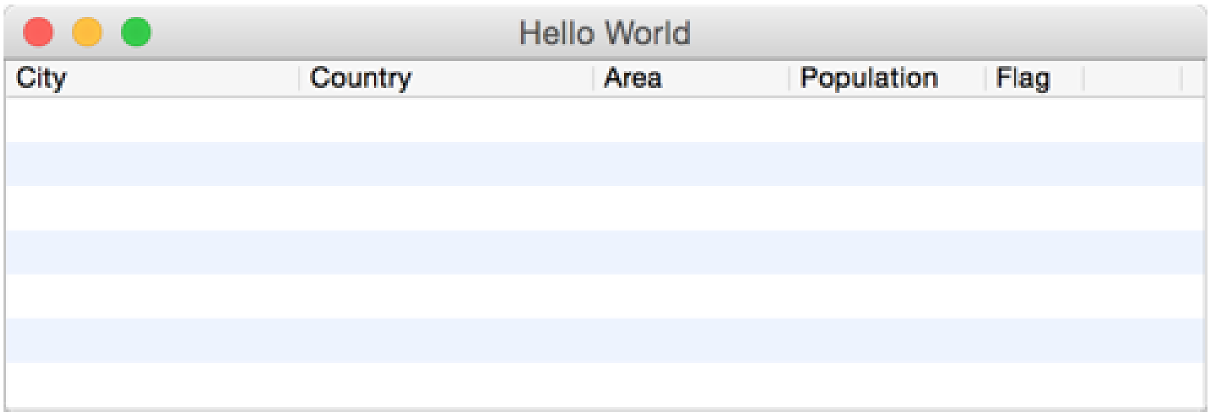
```
        width: 80
    }
}
```

Now the application should show you a menubar with a file menu and an empty table with 4 table headers. The next step will be to populate the table with useful data using our *FileIO* extension.



The `cities.json` document is an array of city entries. Here is an example.

```
[
    {
        "area": "1928",
        "city": "Shanghai",
        "country": "China",
        "flag": "22px-Flag_of_the_People's_Republic_of_China.svg.png",
        "population": "13831900"
    },
    ...
]
```

Our job is it to allow the user to select the file, read it, convert it and set it onto the table view.

18.5.4 Reading Data

For this we let the open action open the file dialog. When the user has selected a file the `onAccepted` method is called on the file dialog. There we call the `readDocument()` function. The `readDocument()` function sets the URL from the file dialog to our `FileIO` object and calls the `read()` method. The loaded text from `FileIO` is then parsed using the `JSON.parse()` method and the resulting object is directly set onto the table view as a model. How convenient is that?

```
Action {
    id: open
    ...
    onTriggered: {
        openDialog.open()
    }
}

...

FileDialog {
    id: openDialog
    onAccepted: {
        root.readDocument()
```

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```
    }
}

function readDocument() {
    io.source = openDialog.fileUrl
    io.read()
    view.model = JSON.parse(io.text)
}


FileIO {
    id: io
}
```

18.5.5 Writing Data

For saving the document, we hook up the "save" action to the `saveDocument()` function. The save document function takes the model from the view, which is a JS object and converts it into a string using the `JSON.stringify()` function. The resulting string is set to the text property of our `FileIO` object and we call `write()` to save the data to disk. The "null" and "4" parameters on the `stringify` function will format the resulting JSON data using indentation with 4 spaces. This is just for better reading of the saved document.

```
Action {
    id: save
    ...
    onTriggered: {
        saveDocument()
    }
}

function saveDocument() {
    var data = view.model
    io.text = JSON.stringify(data, null, 4)
    io.write()
}

FileIO {
    id: io
}
```

This is basically the application with reading, writing and displaying a JSON document. Think about all the time spend by writing XML readers and writers. With JSON all you need is a way to read and write a text file or send receive a text buffer.

18.5.6 Finishing Touch

The application is not fully ready yet. We still want to show the flags and allow the user to modify the document by removing cities from the model.

The flags are stored for this example relative to the `main.qml` document in a *flags* folder. To be able to show them the table column needs to define a custom delegate for rendering the flag image.

```
TableViewColumn {
    delegate: Item {
        Image {
            anchors.centerIn: parent
            source: 'flags/' + styleData.value
        }
```

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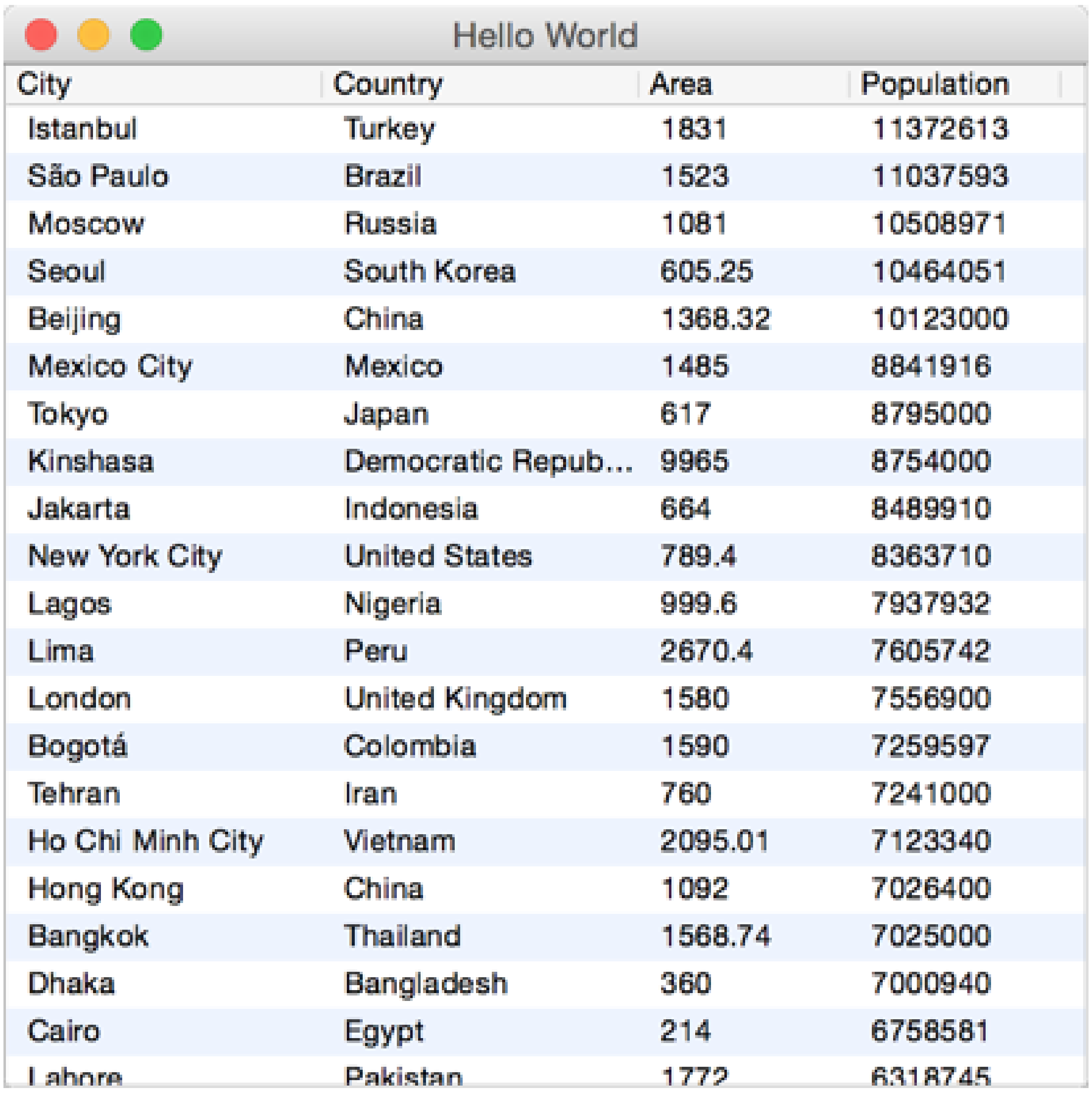

City	Country	Area	Population
Istanbul	Turkey	1831	11372613
São Paulo	Brazil	1523	11037593
Moscow	Russia	1081	10508971
Seoul	South Korea	605.25	10464051
Beijing	China	1368.32	10123000
Mexico City	Mexico	1485	8841916
Tokyo	Japan	617	8795000
Kinshasa	Democratic Repub...	9965	8754000
Jakarta	Indonesia	664	8489910
New York City	United States	789.4	8363710
Lagos	Nigeria	999.6	7937932
Lima	Peru	2670.4	7605742
London	United Kingdom	1580	7556900
Bogotá	Colombia	1590	7259597
Tehran	Iran	760	7241000
Ho Chi Minh City	Vietnam	2095.01	7123340
Hong Kong	China	1092	7026400
Bangkok	Thailand	1568.74	7025000
Dhaka	Bangladesh	360	7000940
Cairo	Egypt	214	6758581
Lahore	Pakistan	1772	6318745

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```
    }
    role: 'flag'
    title: "Flag"
    width: 40
}
```

That is all. It exposes the flag property from the JS model as `styleData.value` to the delegate. The delegate then adjusts the image path to pre-pend `'flags/'` and displays it.

For removing we use a similar technique to display a remove button.

```
TableViewColumn {
    delegate: Button {
        iconSource: "remove.png"
        onClicked: {
            var data = view.model
            data.splice(styleData.row, 1)
            view.model = data
        }
    }
    width: 40
}
```

For the data removal operation, we get a hold on the view model and then remove one entry using the JS `splice` function. This method is available to us as the model is from the type JS array. The splice method changes the content of an array by removing existing elements and/or adding new elements.

A JS array is unfortunately not so smart as a Qt model like the `QAbstractItemModel`, which will notify the view about row changes or data changes. The view will not show any updated data by now as it is never notified of any changes. Only when we set the data back to the view, the view recognizes there is new data and refreshes the view content. Setting the model again using `view.model = data` is a way to let the view know there was a data change.

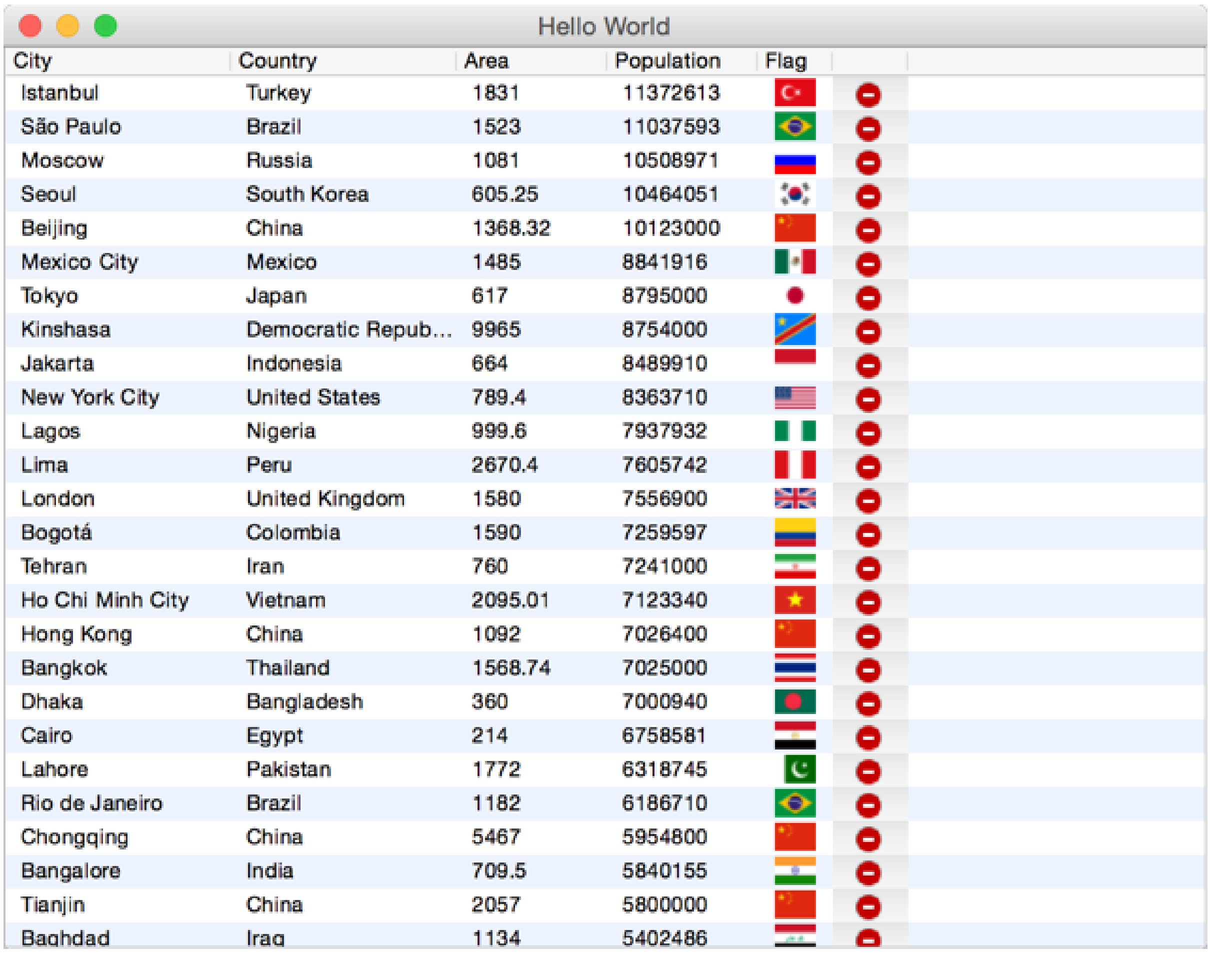
18.6 Summary

The plugin created is a very simple plugin but it can be re-used now and extended by other types for different applications. Using plugins creates a very flexible solution. For example, you can now start the UI by just using the `qmlscene`. Open the folder where your `CityUI` project is a start the UI with `qmlscene main.qml`. I really encourage you to write your applications in a way so that they work with a `qmlscene`. This has a tremendous increase in turnaround time for the UI developer and it is also a good habit to keep a clear separation.

Using plugins has one drawback the deployment gets more difficult for simple applications. You need now to deploy your plugin with your application. If this is a problem for you-you can still use the same `FileIO` object to register it directly in your `main.cpp` using `qmlRegisterType`. The QML code would stay the same.

Often in larger projects, you do not use an application as such. You have a simple qml runtime similar to `qmlscene` and require all native functionality to come as plugins. And your projects are simple pure qml projects using these qml extension plugins. This provides a great flexibility and removes the compilation step for UI changes. After editing a QML file you just need to run the UI. This allows the user interface writers to stay flexible and agile to make all these little changes to push pixels.

Plugins provide a nice and clean separation between C++ backend development and QML frontend development. When developing QML plugins always have the QML side in mind and do not hesitate to start with a QML only mockup first to validate your API before you implement it in C++. If an API is written in C++ people often hesitate to change it or not to speak of to rewrite it. Mocking an API in QML provides much more flexibility and less initial investment. When using plugins the switch between a mocked API and the real API is just changing the import path for the qml runtime.



City	Country	Area	Population	Flag	
Istanbul	Turkey	1831	11372613	🇹🇷	⊖
São Paulo	Brazil	1523	11037593	🇧🇷	⊖
Moscow	Russia	1081	10508971	🇷🇺	⊖
Seoul	South Korea	605.25	10464051	🇰🇷	⊖
Beijing	China	1368.32	10123000	🇨🇳	⊖
Mexico City	Mexico	1485	8841916	🇲🇽	⊖
Tokyo	Japan	617	8795000	🇯🇵	⊖
Kinshasa	Democratic Repub…	9965	8754000	🇨🇩	⊖
Jakarta	Indonesia	664	8489910	🇮🇩	⊖
New York City	United States	789.4	8363710	🇺🇸	⊖
Lagos	Nigeria	999.6	7937932	🇳🇬	⊖
Lima	Peru	2670.4	7605742	🇵🇪	⊖
London	United Kingdom	1580	7556900	🇬🇧	⊖
Bogotá	Colombia	1590	7259597	🇨🇴	⊖
Tehran	Iran	760	7241000	🇮🇷	⊖
Ho Chi Minh City	Vietnam	2095.01	7123340	🇻🇳	⊖
Hong Kong	China	1092	7026400	🇨🇳	⊖
Bangkok	Thailand	1568.74	7025000	🇹🇭	⊖
Dhaka	Bangladesh	360	7000940	🇧🇩	⊖
Cairo	Egypt	214	6758581	🇪🇬	⊖
Lahore	Pakistan	1772	6318745	🇵🇰	⊖
Rio de Janeiro	Brazil	1182	6186710	🇧🇷	⊖
Chongqing	China	5467	5954800	🇨🇳	⊖
Bangalore	India	709.5	5840155	🇮🇳	⊖
Tianjin	China	2057	5800000	🇨🇳	⊖
Baghdad	Iraq	1134	5402486	🇮🇶	⊖

CHAPTER

NINETEEN

FELGO PLUGINS AND QML HOT RELOADING

Section author: e8johan

Note: Last Build: December 07, 2020 at 10:50 CET

The source code for this chapter can be found in the assets folder.

We've already discussed how Felgo enhances Qt and simplifies the creation of applications. In this chapter, we will look a bit deeper at the tooling and the mobile plugins that Felgo provides.

19.1 Tooling

Felgo comes with two main tools that simplify your life as a Qt developer. The Felgo Live that lets you apply your code changes in real-time, and Cloud Builds, that lets you automate the building and deployment of your apps for all platforms.

19.1.1 Felgo Live

The Hot Reload and Felgo Live Clients lets you modify your code and see the changes live. All QML, JavaScript, and assets are updated on every connected device as soon as you save your files.

Hot Reload is smart enough to only modify what you changed, preserving the state of your application. For instance, if you are updating a page containing a toggled switch, it will still be toggled after a reload.

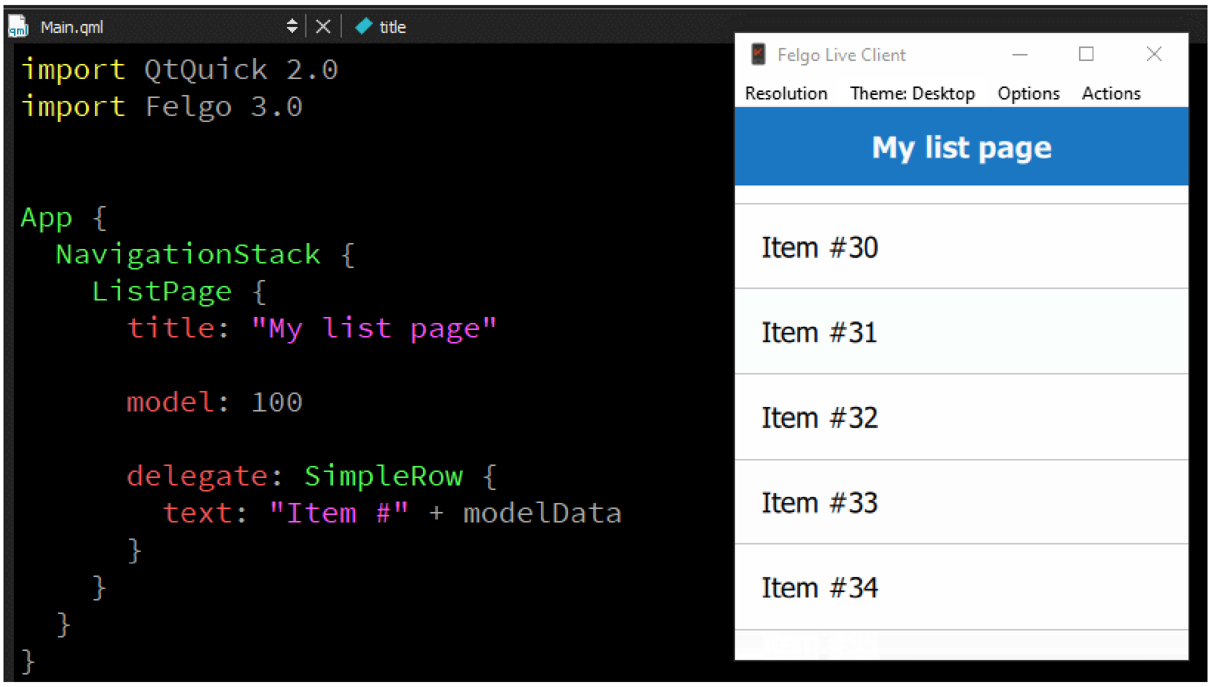
This shortens the roundtrip times dramatically when developing, as you no longer have to go through the complete save, compile, deploy, restart cycle.

The Felgo Live tool is a standalone tool that comes with the Felgo SDK and can be used with any Qt/QML project. You do not have to develop your app with the Felgo SDK to enable QML Hot Reload for your project.

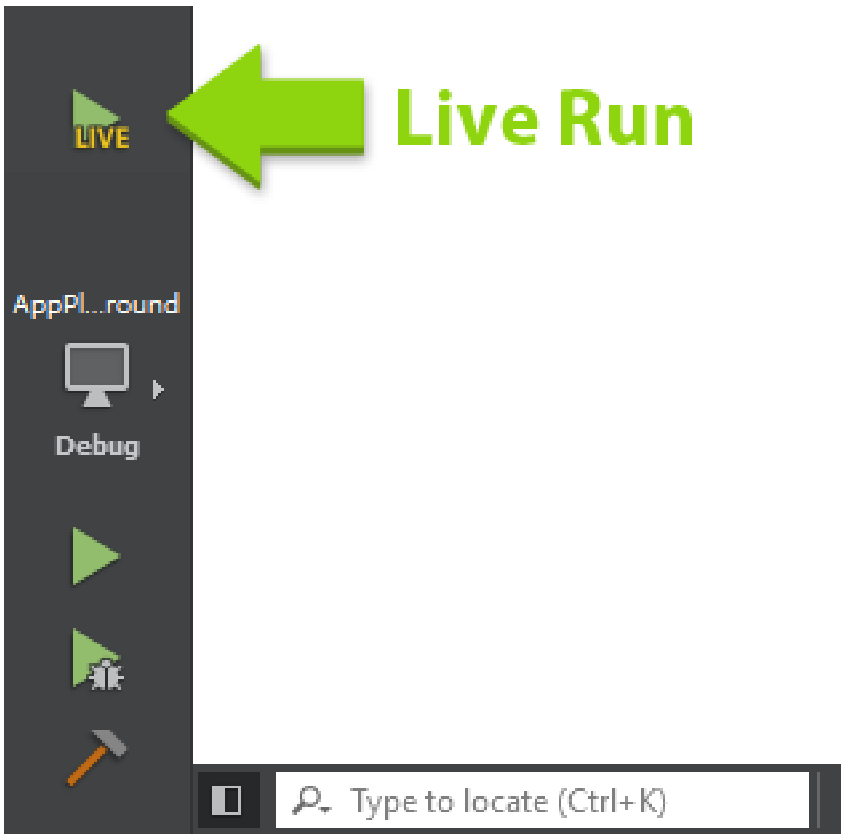
In the Felgo SDK, you launch Felgo Live from the Live Play button in the Qt Creator sidebar, as shown below.

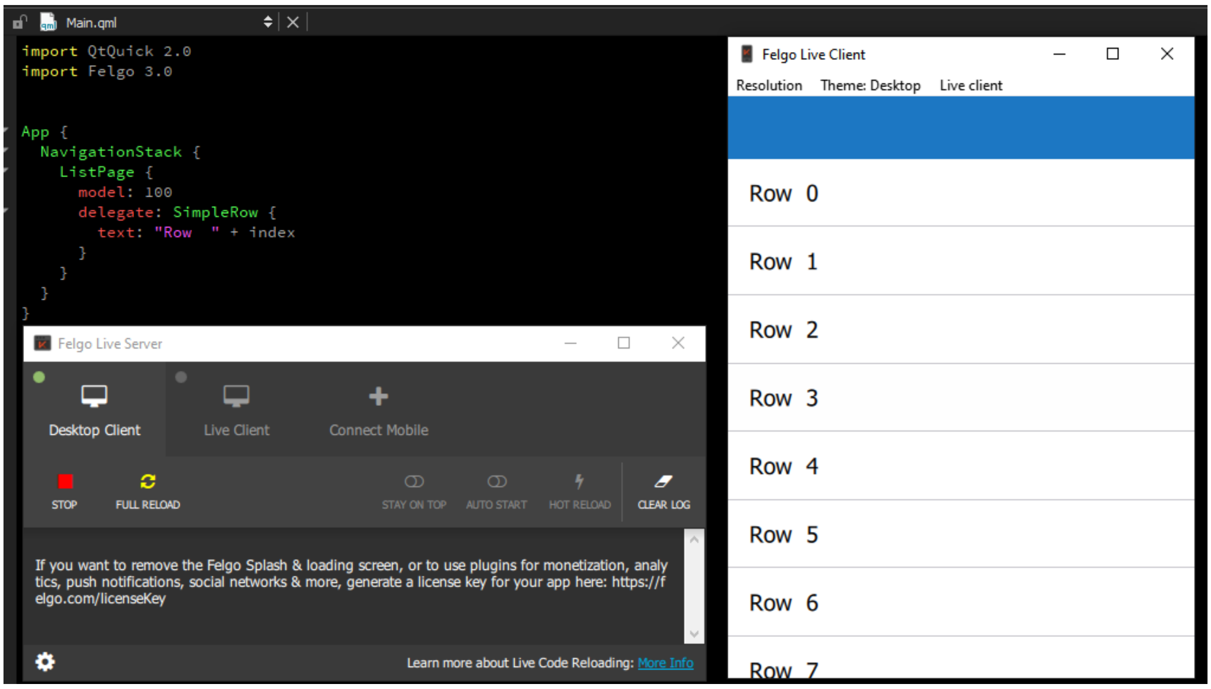
Once started, the Felgo Live Server is running together with your application. Every time you save your source files, the changes are immediately shown in the running application. You can also see logs from all connected devices. It is also possible to start the live server from command line, passing your root QML file as an argument.

Felgo Hot Reload can be used on every target platform - be it desktop or mobile. It even works for WebAssembly and Embedded systems. Felgo has more information on the topic at the product page.



```
import QtQuick 2.0
import Felgo 3.0


App {
  NavigationStack {
    ListPage {
      title: "My list page"

      model: 100

      delegate: SimpleRow {
        text: "Item #" + modelData
      }
    }
  }
}
```





```
import QtQuick 2.0
import Felgo 3.0


App {
  NavigationStack {
    ListPage {
      model: 100
      delegate: SimpleRow {
        text: "Row  " + index
      }
    }
  }
}
```

```
If you want to remove the Felgo Splash & loading screen, or to use plugins for monetization, analy
tics, push notifications, social networks & more, generate a license key for your app here: https://f
elgo.com/licenseKey
```

Learn more about Live Code Reloading: More Info

Felgo Live Client

When used locally on your computer, the Felgo Live Server talks to an instance of the Felgo Live Client. It is possible to connect more clients to each server. For instance, the Felgo Dev App integrates a Live client for Android and iOS devices. You can download it from Google Play and Apple AppStore respectively. This application also provides a showcase of Felgo components and sample applications to give you an overview of what's offered.

After you install the application, make sure your device is on the same network as your PC and click on "Connect Desktop". Your mobile device will show you the live view of your app right away. When you start changing your code you will see both the Desktop and Mobile versions updated instantaneously.

When connecting multiple devices through live clients, you can test many different configurations of screen sizes, DPIs and styles at the same time. You can even deploy your application on an iOS device without having access to an Apple computer.

How does it Actually Work?

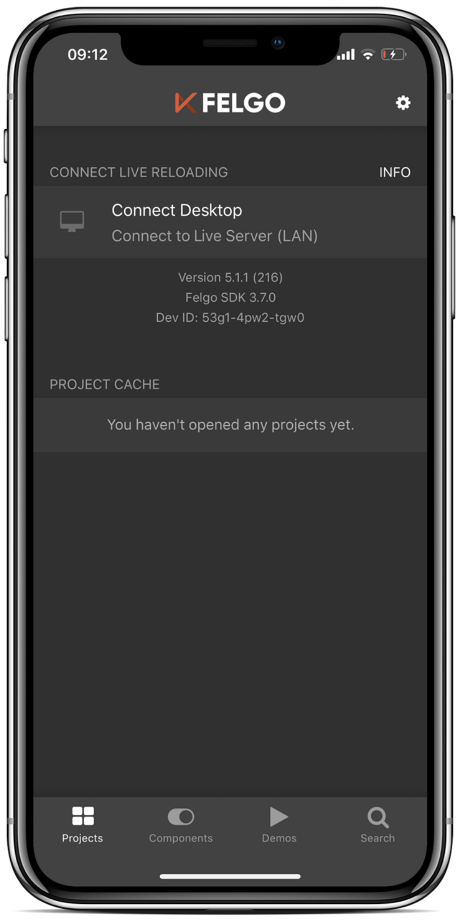
Most QML applications are layered. They have a QML and Javascript layer running in the QML engine, sitting on top of the Qt/C++ layer. The Felgo SDK adds the Felgo Live Module component and the Felgo Live Server, interacting with the module.

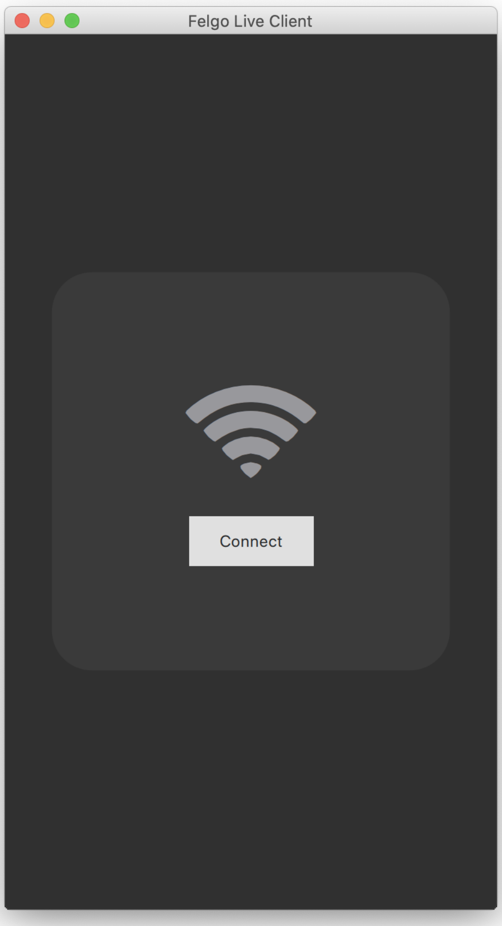
The Live Server monitors your QML, JS and assets files. When they change, it sends the updated tree to the Felgo Live Module. The module takes care of comparing the current tree of QML components with the new one and updates the subtrees which have changed, preserving the state of every other property.

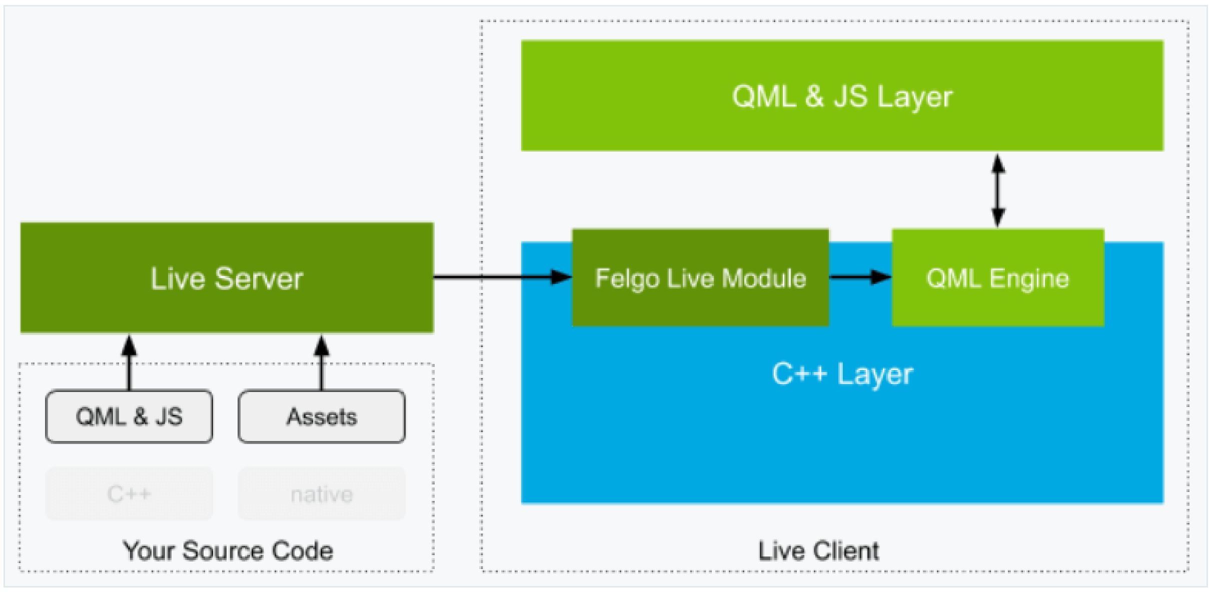
Custom Clients

The Felgo Live Server operates by transmitting changed QML, JS and asset files to the Live Client. However, C++ code always requires compilation which is why the Live Client cannot support custom C++ out of the box. All your native C++ classes need to be built into the application.

The way to solve this with the Felgo SDK is to integrate the Felgo Live Module into your own project. This essentially turns your own app into a custom Live Client that supports QML Hot Reload. The code needed for this is trivial.


09:12
FELGO
CONNECT LIVE RELOADING
INFO
Connect Desktop
Connect to Live Server (LAN)
Version 5.1.1 (216)
Felgo SDK 3.7.0
Dev ID: 53g1-4pw2-tgw0
PROJECT CACHE
You haven't opened any projects yet.
Projects
Components
Demos
Search


Felgo Live Client
Connect


QML & JS Layer
Live Server
Felgo Live Module
QML Engine
C++ Layer
QML & JS
Assets
C++
native
Your Source Code
Live Client

First, you need to add the `felgo-live` module to your Qt `CONFIG` in your project:

```
CONFIG += felgo-live
```

The include `FelgoLiveClient` in your `main.cpp`:

```
#include <FelgoLiveClient>
```

And finally, instead of loading your QML root file, use the live client to configure the `QQmlEngine` instance by replacing:

```
felgo.setMainQmlFileName(QStringLiteral("qml/Main.qml"));
engine.load(QUrl(felgo.mainQmlFileName()));
```

With:

```
FelgoLiveClient liveClient(&engine);
```

The line above creates a `FelgoLiveClient` instance, which handles loading the QML, but also updating of the QML inside the running engine when the code changes.

Now build and run the application for any Qt platform and you have a custom Felgo Live Client that you can connect to your Felgo Live Server. The application includes all your C++ code while allowing you to use Hot Reload for the QML code.

When you are ready for release just revert the `main.cpp` file back the way and remove the Live Client Module. You can do this using a define that you use when calling `qmake`. That way you can use an `ifdef` to avoid having two different versions of `main.cpp`, but instead configure the build environment in Qt Creator to include or exclude the live client functionality.

19.1.2 Cloud Builds

A large task, once your application has been developed, is building it for a variety of target platforms. You might want to build different versions such as, beta releases, production releases and even customer specific versions. You might also want to push builds to various app stores for publishing.

This is a major undertaking. You need to set up and maintain a build environment for each platform. Application packages need to be signed for deployment to the app stores. As an application grows, you will end up building a lot of major or minor builds for testing or new releases. This is where DevOps or CI/CD comes into the picture.

Felgo Cloud Builds is a CI/CD solution for automatic building and deploying of Qt apps. You set up your project and build configuration once and then use this to build apps. You can target iOS, Android, Desktop, or Embedded. Each new version only takes a few minutes to build.

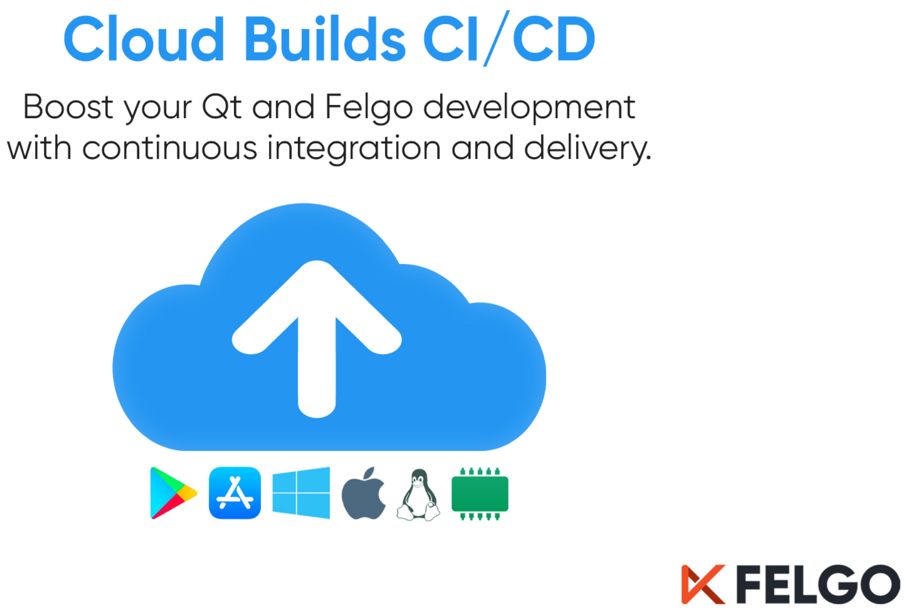
The Felgo Cloud Build is a centralized and stable build environment for every Qt target platform. This means that you, as a developer, do not need the toolchains for every platform on your machine. For example, you can create iOS apps from Windows, even though you cannot install the required tools for compiling iOS apps on your machine. This also removes potential problems that may arise from building the app with different systems and tooling environments. Every release is built with the same system configuration, Qt version and dependencies.

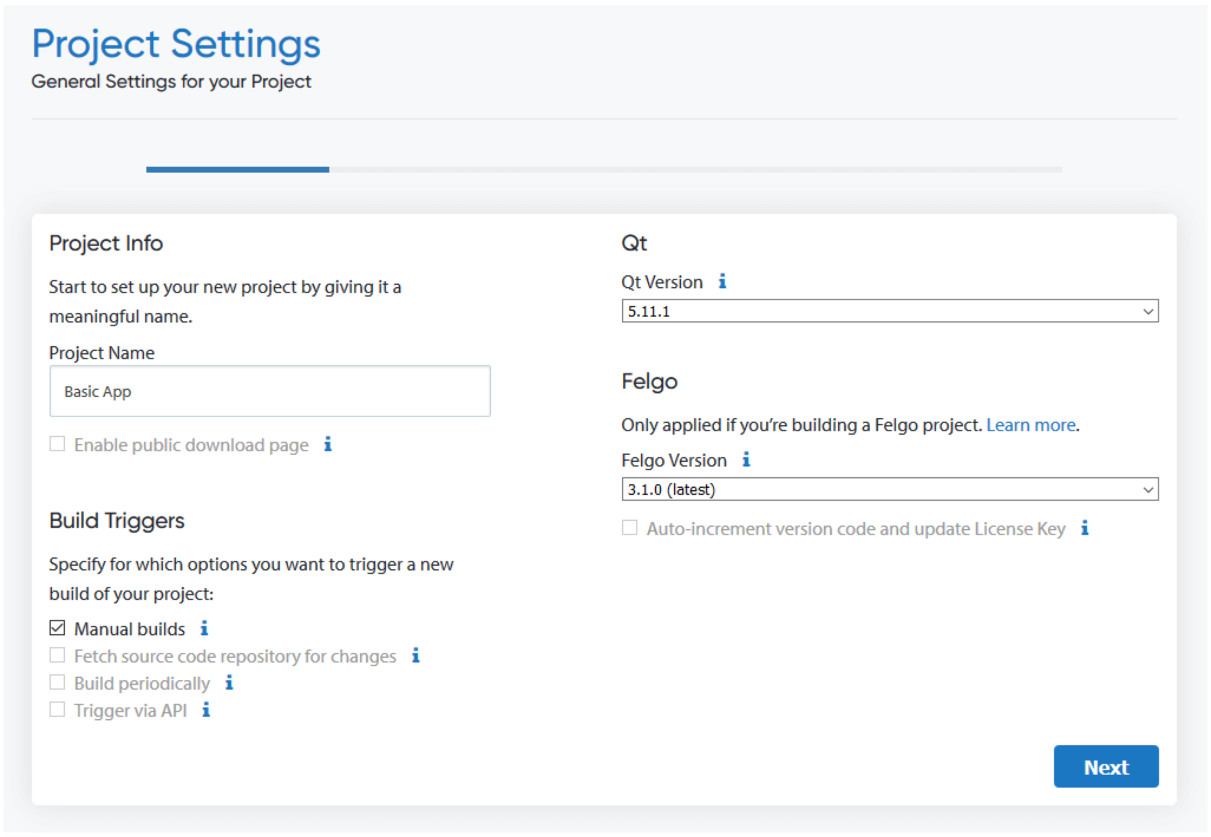
In addition to building apps, you might also want to deploy your apps to Google Play or Apple AppStore. You can use the beta testing mechanisms in the stores to test new versions and then move them to production. This traditionally requires uploading the `apk` bundles or `ipa` packages on the respective store websites.

Felgo Cloud Builds automates this as well. It takes your source code from your repository, builds your project for all platforms in parallel, and then uploads the packages to the stores for testing or publishing, depending on your settings.

To use Felgo Cloud Builds, visit the Cloud Builds page to set up your project.

The web site has step by step guides to create and configure your project. Starting from a Git repository, signing options, and optionally the integration with the stores. If you do not have a Google Play or App Store account yet, or have not setup your application in the app store, it is recommended to first set everything up and have a look at


Cloud Builds CI/CD
Boost your Qt and Felgo development with continuous integration and delivery.
FELGO



Project Settings

General Settings for your Project

Project Info

Start to set up your new project by giving it a meaningful name.

Project Name

Basic App

☐ Enable public download page

Build Triggers

Specify for which options you want to trigger a new build of your project:

☑ Manual builds

☐ Fetch source code repository for changes

☐ Build periodically

☐ Trigger via API

Qt

Qt Version

5.11.1

Felgo

Only applied if you're building a Felgo project. Learn more.

Felgo Version

3.1.0 (latest)

☐ Auto-increment version code and update License Key how to configure the store listing before integrating it into the Cloud Build infrastructure. Your store configuration and testing channels should be ready and working before you configure Cloud Builds for automatic deployment.

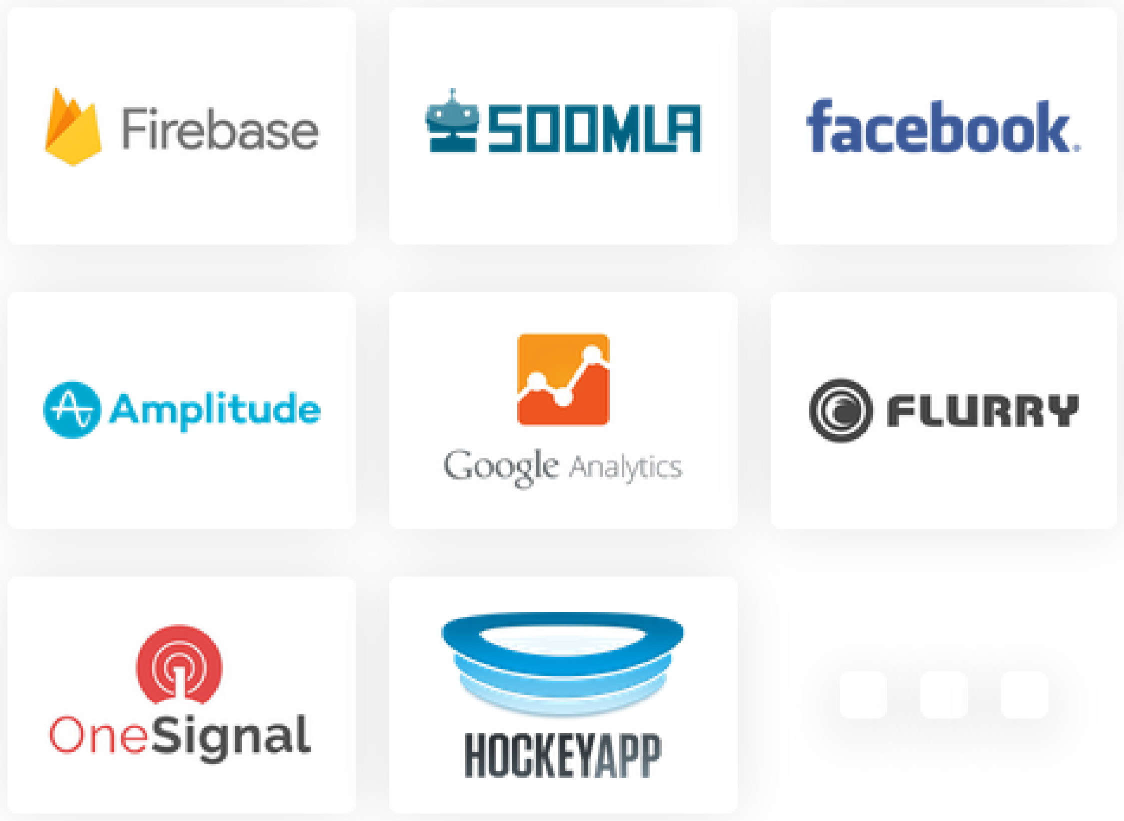
Once everything is set up, you can trigger a build whenever you wish, resulting in a set of application packages. If you enable store deployment for the build, the packages will automatically appear in the respective channels, ready for your testers and users, before you can push the build to production.

Building on-premise

Felgo Cloud Builds is hosted by Felgo, but is also available on-premise. It can be used for any Qt/QML application and custom toolchains or specific Qt versions are possible as well. If you need a specific setup, for example, to target a certain embedded platform, get in touch with Felgo.

19.2 Felgo Plugins

Once you've created a new app, you can look at more advanced topics. Felgo provides extensions to Qt that help you with monetization, push notifications, and analytics, i.e. the study of how the user moves through the app.



These functions usually required platform specific APIs. There are also third party services that provide such services through custom native frameworks. Supporting native SDKs for Android and iOS using Qt/QML is not an easy task. You need to provide a portable abstraction for the APIs, binding to Java/Kotlin for Android or Objective-C/Swift for iOS.

To help with this, Felgo extends Qt with plugins integrating these services directly to QML.

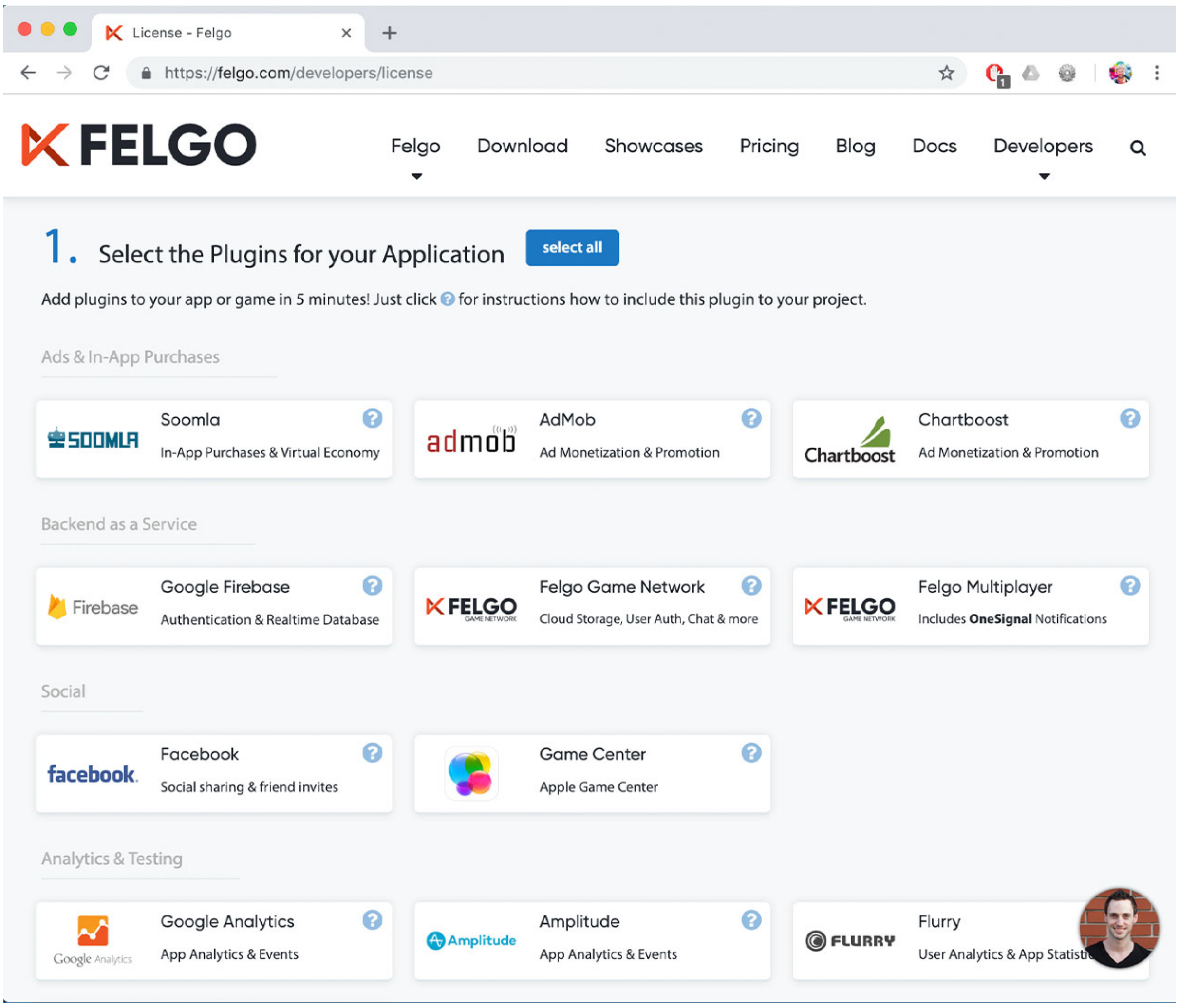
19.2.1 Configuration

The Felgo plugins extend Qt with bindings to external services. This means that you will have register with the third party services. You will also need a Felgo license key. All monetization plugins are available for free, while other plugins require that you purchase an Indie or Enterprise license.

Note: All the examples in this chapter require you to have a custom license key. They are not runnable out of the box.

To get started with the Felgo plugins, start Qt Creator from the Felgo SDK and create a new project. The project wizard presents you with a step that lets you select which plugins to use. Choose the ones that you want to use. This will add the relevant code to your project along with the needed build configurations.

To retrieve a valid Felgo license key for your application, go to https://felgo.com/developers/license and select the plugins that you intend to use.



1. Select the Plugins for your Application

Add plugins to your app or game in 5 minutes! Just click ? for instructions how to include this plugin to your project.

Ads & In-App Purchases

Soomla – In-App Purchases & Virtual Economy
AdMob – Ad Monetization & Promotion
Chartboost – Ad Monetization & Promotion

Backend as a Service

Google Firebase – Authentication & Realtime Database
Felgo Game Network – Cloud Storage, User Auth, Chat & more
Felgo Multiplayer – Includes OneSignal Notifications

Social

Facebook – Social sharing & friend invites
Game Center – Apple Game Center

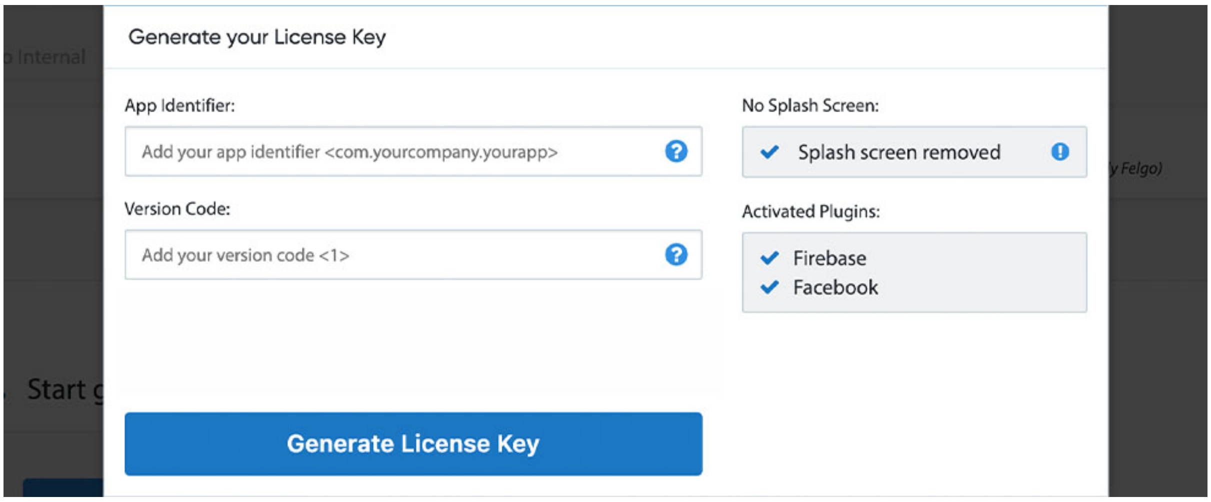
Analytics & Testing

Google Analytics – App Analytics & Events
Amplitude – App Analytics & Events
Flurry – User Analytics & App Statisti

At the bottom of the page, click the *Generate License Key* button. This lets you provide an app identifier and a version code.

This will present you with your generated license key. This key is unique to your license and your app, so make sure to keep it secret.

You can then paste the license key into your application.


Generate your License Key

App Identifier: Add your app identifier <com.yourcompany.yourapp>

Version Code: Add your version code <1>

No Splash Screen: ✓ Splash screen removed

Activated Plugins:
✓ Firebase
✓ Facebook

```
import Felgo 3.0

App {
  licenseKey: "<generate one from https://felgo.com/licenseKey>"
}
```

You can also provide the license key through your project file. This integrates well with the Felgo Cloud Builds platform.

```
# Optionally set a license key that is used instead of the license key from
# main.qml file (App::licenseKey for your app or GameWindow::licenseKey for your␣
↪game)
# Only used for local builds and Felgo Cloud Builds (https://felgo.com/cloud-
↪builds)
# Not used if using Felgo Live
PRODUCT_LICENSE_KEY =
↪"0D923C63118F763ED834BF948AC670952AF36452B936123BC38784F755F8163F07CFD81DC2187BAC8EADE2622BB34B
↪"
```

Once this is in place you can start using the plugins. If you use the paid versions of Felgo, the Felgo splash screen is also removed by specifying the license key.

19.3 Monetization, Ads and In-App Purchases

A common business model in the mobile space is in-app purchases or advertising. Felgo offers APIs to enable both these use-cases powered using multiple alternative backends such as Google AdMob, Soomla, and Chartboost.

19.3.1 Ad Monetization

In this example we will look at using AdMob. AdMob is an in-app mobile advertising platform run by Google.

To get started, you need to register an AdMob account on the AdMob Sign-up Page. Then add an AddMobBanner to your app as shown below.

```
import Felgo 3.0

App {
  licenseKey: "<generate one from https://felgo.com/licenseKey>"

  NavigationStack {
```

(continues on next page)

(continued from previous page)

```
    Page {
      title: qsTr("AdMob Banner")

      AdMobBanner {
        id: adMobBanner
        adUnitId: "ca-app-pub-9155324456588158/9913032020"
        banner: AdMobBanner.Standard

        anchors.horizontalCenter: parent.horizontalCenter
        anchors.bottom: parent.bottom
      }
    }
  }
}
```

Notice that you specify your ad unit id from AdMob through the `adUnitId` property.

This code results in a banner such as the one shown below.

Admob Banner
Test Ad
Nice job!
This is a 320x100 test ad.

In addition to banners, you can use interstitial ads. These are full-screen interactive advertisements. From QML, it is just as simple to integrate such an ad using the AdMobInterstitial element.

```
import Felgo 3.0

App {
  licenseKey: "<generate one from https://felgo.com/licenseKey>"

  NavigationStack {
    Page {
      title: qsTr("AdMob Interstitial")

      AppButton {
        text: "Show Interstitial"
        anchors.centerIn: parent
        onClicked: {
          adInerstitial.loadInterstitial()
        }
      }

      AdMobInterstitial {
        id: adInerstitial
        adUnitId: "ca-app-pub-3940256099942544/1033173712" // interstitial test ad␣
↪by AdMob

        onInterstitialReceived: {
```

(continues on next page)

(continued from previous page)

```
          showInterstitialIfLoaded()
        }
      }
    }
  }
}
```

Use the `loadInterstitial` function to start loading the ad in the background. As soon as you want to show the ad, call the `showInterstitialIfLoaded`. In the example above we call this on the `interstitialReceived` signal. It has a sister signal called `interstitialFailedToReceive` that is called if the interstitial cannot be loaded, for instance, due to network errors.

19.3.2 In-App Purchases

Felgo lets you integrate in-app purchases directly into QML. The Soomla plugin lets you use a cross platform API to integrate the Soomla purchasing services into your application.

The API is built around a Store with Good items. These can be things such as LifetimeGood, which is a purchase that lasts forever, or a SingleUseGood which is a one time purchase that is used once and then has to be purchased again.

To StorePurchase defines how the item can be purchased. By calling the `store.buyItem(noadsGood.itemId)` the purchase is made. The `noadsGood.purchased` property can then be used to check if the purchase has been made or not.

```
import Felgo 3.0
import QtQuick 2.0

App {
  licenseKey: "<generate one from https://felgo.com/licenseKey>"
  Store {
    id: store

    version: 1
    secret: "<your-app-secret>"
    androidPublicKey: "<android-public-key>"

    goods: [
      LifetimeGood {
        id: noadsGood
        itemId: "net.felgo.demos.PluginDemo.noads"
        name: "No Ads"
        description: "Buy this item to remove the app banner"
        purchaseType: StorePurchase { id: noAdPurchase; productId: noadsGood.
↪itemId; }
      }
    ]
  }

  NavigationStack {
    Page {
      title: qsTr("In app purchase")

      AppButton {
        anchors.centerIn: parent
        text: "Remove Ad"
        onClicked: {
          store.buyItem(noadsGood.itemId)
        }
      }
```

(continues on next page)

(continued from previous page)

```
      Rectangle {
        id: annoyingAd
        anchors.bottom: parent.bottom
        width: parent.width
        height: dp(50)
        color: "red"

        // Just one line for handling visiblity of the ad banner, you can use␣
↪property binding for this!
        visible: !noadsGood.purchased

        AppText {
          text: "Annoying Ad"
          color: "white"
          anchors.centerIn: parent
        }
      }
    }
  }
}
```

This example shows the most basic use case. The Soomla APIs let you do much more. For instance, the SyncedStore lets you sync purchases across user devices. You can also provide virtual, an in-app currency, sell packs of items, and much more. Check out the Soomal documentation for more information.

19.4 Notifications

It is common that mobile apps use notifications to indicate to the user that an important event has happened or that an announcement is available. Notifications can either be local, for instance a timer is finished, or remote, such as a friend request. With Felgo, you can integrate both types of notification on iOS and Android.

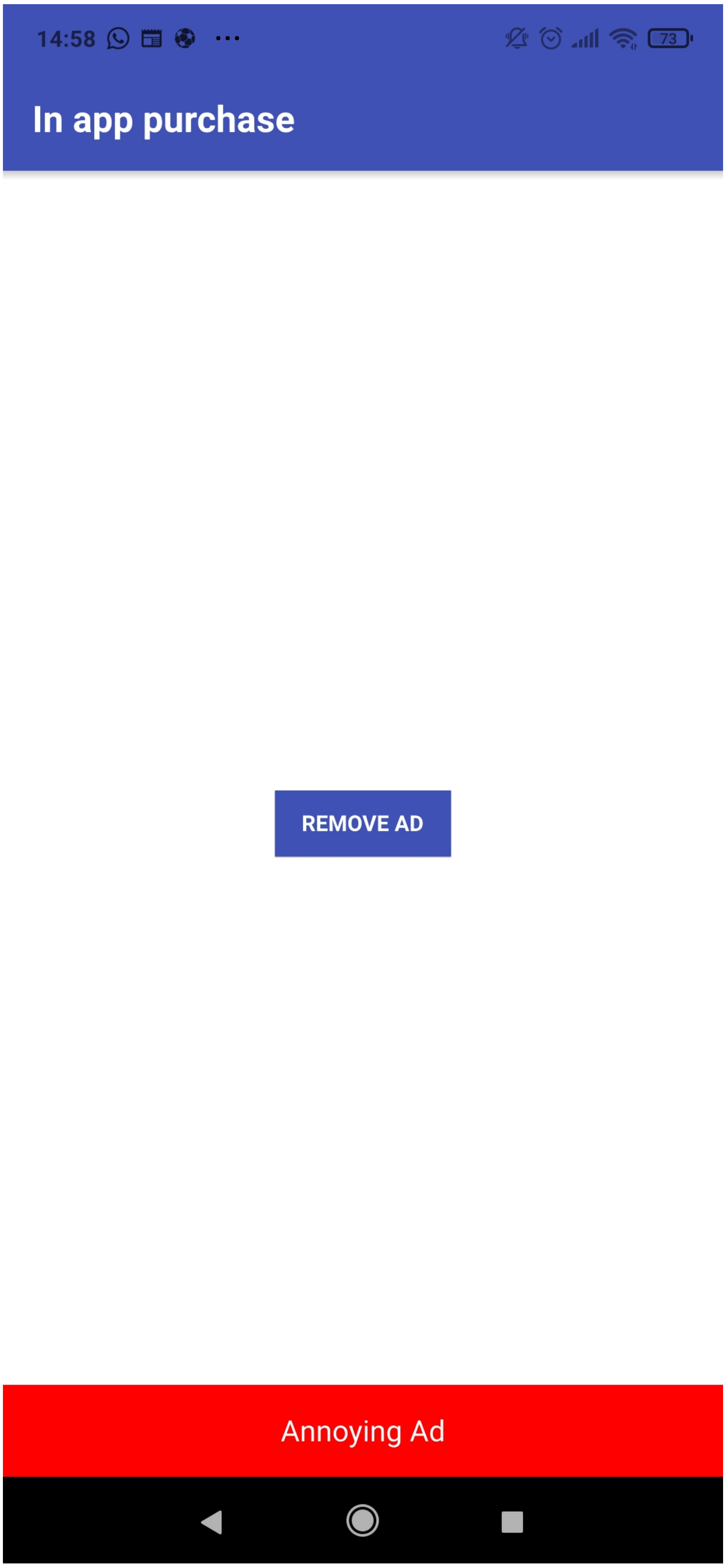
19.4.1 Local Notifications

The NotificationManager is used to schedule local notifications. Notifications can be scheduled either relative to the current time, i.e. in 1 hour, or at a given time, e.g. 3pm on December 24.

In the example below, a Notification is defined declaratively in QML. This is called a *static* notification. Then the `NotificationManager::scheduleNotification` is used to trigger the notification. The `Notification::timeInterval` is used to set a relative time, in this case, 5 seconds. For setting an absolute time, use the `timestamp` property instead.

```
import Felgo 3.0

App {
  licenseKey: "<generate one from https://felgo.com/licenseKey>"

  NotificationManager {
    id: notificationManager

    onNotificationFired: {
      console.debug("Notification with id " + notificationId + " fired")
    }
  }

  Notification {
    id: staticNotification
```

(continues on next page)


14:58
In app purchase
REMOVE AD
Annoying Ad

(continued from previous page)

```
    notificationId: "static_notification"
    message: "I'm statically defined in the app"
    // Time in seconds when the notification should be fired
    timeInterval: 5
  }

  NavigationStack {
    Page {
      id: page
      title: qsTr("Local Notification")

      AppButton {
        text: "Schedule Notification"
        anchors.centerIn: parent
        onClicked: {
          // Trigger notification in 5 seconds
          notificationManager.scheduleNotification(staticNotification)
        }
      }
    }
  }
}
```

The `notificationFired` signal is triggered when a notification is fired. This signal behaves differently if the app is active, or if it is running in the background. When the app is active, the signal is emitted immediately without a banner or sound being played. When the app is in the background, a notification sound is played and the message is shown in a notification banner. The signal is then emitted once the user taps the message to activate the app and bring it into the foreground.

In some scenarios, a statically declared notification is not enough. For that use-case, it is also possible to provide a JavaScript object to the `scheduleNotification` method. This creates the notification dynamically, as shown below.

```
        AppButton {
            text: "Dynamic Notification (timestamp)"
            onClicked: {
              // This time it's dynamically defined inline and with timestamp␣
↪instead of interval
              var unixTimestamp = Math.round((new Date()).getTime() / 1000)
              notificationManager.schedule({ notificationId: "dynamic_notification",
↪ message: "I'm dynamically defined in the app", timestamp: unixTimestamp + 5})
            }
          }
```

19.4.2 Remote Push Notifications

Remote push notifications require a backend server of some sort. Felgo integrates Google Cloud Messaging and OneSignal to provide push notifications to both Android and iOS. Using these services, you can trigger notifications manually or automatically for every user, or targetted at groups of users.

In the examples below, you will use OneSignal to send push notifications to your app. Before you can start with OneSignal, you need to register for an account. This is described in detail on the OneSignal plugin page.

You then create a OneSignal element and configure the `appId`. Each time a notification is received, the `onNotificationReceived` signal is emitted. This signal behaves just as the `notificationFired` signal discussed above, with respect to the app being active or in the background.

```
import QtQuick 2.1
import Felgo 3.0
```

(continues on next page)

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```
 OneSignal {
   id: onesignal

   appId: "<ONESIGNAL-APP-ID>"

   onNotificationReceived: {
      console.debug("Received notification with message:", message)
   }
 }
```

You can use the excellent curl tool to send a notification to all instances of your app.

```
curl --include \
      --request POST \
      --header "Content-Type: application/json" \
      --header "Authorization: Basic <ONESIGNAL-REST-API-KEY>" \
      --data-binary '{
         "app_id": "<ONESIGNAL-APP-ID>",
         "contents": { "en": "Message" }
      }' \
      https://onesignal.com/api/v1/notifications
```

If you want to send the notification to a selected set of users, you need to register a tag on the client side, i.e. in your QML code:

```
onesignal.setTag("my_key", "my_value")
```

This tag can then be referenced when sending the notification.

```
curl --include \
      --request POST \
      --header "Content-Type: application/json" \
      --header "Authorization: Basic <ONESIGNAL-REST-API-KEY>" \
      --data-binary '{
         "app_id": "<ONESIGNAL-APP-ID>",
         "contents": { "en": "Message" },
         "tags": [{"key": "my_key", "relation": "=", "value": "my_value"}]
      }' \
      https://onesignal.com/api/v1/notifications
```

The tags are used to reach groups of users. To reference a specific user, use the OneSignal::userId property instead.

19.5 Analytics and Crash Reporting

Analytics is used to understand how your users work with your app. This will let you understand if all features are used, or if there is a usability problem with the user interface. Felgo provides plugins for Amplitude, Google Analytics and Flurry. In the example below, we demonstrate how to integrate Amplitude.

In order to use Amplitude you need to sign up for an account. You do that at the Amplitude website .

The code is built around the Amplitude element, which provides the `logEvent` method, as shown below.

```
import Felgo 3.0
import QtQuick 2.0

App {
  Amplitude {
     id: amplitude
```

(continues on next page)

(continued from previous page)

```
      // From Amplitude Settings
      apiKey: "<amplitude-api-key>"

      userProperties: ({
        age: 17,
        weight: 110.3,
        name: "Gregor",
        achievements: [1, 2, 4, 8]
      })

      onPluginLoaded: {
        amplitude.logEvent("App started");
      }
  }


  NavigationStack {
    Page {
      title: "Amplitude"

      Column {
        anchors.centerIn: parent

        AppButton {
          text: "Send Event"
          onClicked: amplitude.logEvent("Button clicked")
        }
      }
    }
  }
}
```

Each event should represent an action of the user, for instance, “picture deleted”, “user logged in”, and so on. In addition to the events, Amplitude can log revenues using the `logRevenue` method. This allows you to analyze what user flows leads to revenue streams, e.g. in-app purchases.

To enable further analytics, you can provide a JavaScript object with key-value pairs that you can pass to Amplitude to help analyze the results better. In the example above, we provide an age, a weight, a name and what achievements the user has reached. This way, we can correlate this information with the logs using the Amplitude tools.

The properties can also be things such as free space on the device, or time since the last photo shared, or other relevant data that will make understanding the results easier.

19.6 Firebase: Authentication, Databases, and Storage

The Google Firebase plugin provides three core feature sets: authentication, a database, and generic storage. In this section, we will look at the authentication and database features.

Before you can get started with Firebase you have to register your applications and download the `google-services.json` file from the Firebase console. Notice that using Firebase also requires a Google account.

Using the information from the Firebase console, you can set up your FirebaseConfig item as shown below.

```
import Felgo 3.0
import QtQuick 2.0

App {
```

(continues on next page)

(continued from previous page)

```
  FirebaseConfig {
    id: fbConfig

    projectId: "<your project ID, from project_info | project_number, e.g.,␣
↪82701038584"
    databaseUrl: "<your database URL, from project_info | firebase_url>"

    apiKey: Qt.platform.os === "android"
          ? "<your Android API key, from client | api_key | current_key>"
          : "<your iOS API key>"

    applicationId: Qt.platform.os === "android"
                 ? "<your Android application ID, from client | client_info |␣
↪mobilesdk_app_id>"
                 : "<your iOS application ID>"
  }
}
```

All the required information is found in the `google-services.json` file.

19.6.1 Authentication

In order to use Firebase for authentication, you need to enable the *Email/Password* sign-in method in your Google project. You then use the FirebaseAuth item to interact with the backend.

The example below demonstrates how to sign up a new user using the `registerUser` method. Once the user is registered, the `userRegistered` is emitted, indicating either a success or failure in the registration process.

```
import Felgo 3.0
import QtQuick 2.0

App {

  //...

  FirebaseAuth {
    id: auth
          config: fbConfig
  }

  Page {
    Column {
      spacing: Theme.contentPadding
      anchors.centerIn: parent

      AppTextField {
        id: username
        width: dp(200)
      }

      AppTextField {
        id: password
        inputMode: inputModePassword
        width: dp(200)
      }

      AppButton {
        text: qsTr("Sign-Up")
        anchors.horizontalCenter: parent.horizontalCenter
        onClicked: auth.registerUser(username.text, password.text)
```

(continues on next page)

(continued from previous page)

```
      }
    }
  }
}
```

When a user has been registered, the `loginUser` is used to log in the user. This results in the `loggedIn` signal being emitted. `FirebaseAuth` also provides methods to `loginUserWithGoogle`, `loginUserWithToken`, and `loginUserAnonymously`.

The tokens used when logging in are created by custom authentication servers as described in the Firebase documentation.

When logging in a user anonymously, a local, anonymous, account is created on the current device. If the `registerUser` is called from an anonymously logged in session, the anonymous account is associated with the new user, making it possible to migrate the user data across devices.

19.6.2 Firebase Database

The firebase realtime database can be viewed as a gigantic json file that contains all data for all users. This database is tightly coupled to the Firebase authentication functionality to ensure that all data is protected and secure.

The FirebaseDatabase QML component provides the interface to the database. The API provides functions such as `setUserValue` for storing data. Notice that the function tells you if the value was successfully stored or not - something that is important as the database is located in the Firebase cloud.

```
db.setUserValue("myObject", {
   keyA: 17,
   keyB: "this is my DB object"
 }, function(success, message) {
   if(success) {
     console.log("successfully written user object to DB")
   } else {
     console.log("DB write error:", message)
   }
 })
```

To retrieve a stored value, the `getUserValue` method is used. It is possible to provide *queryParameters* to sort and filter. This is described in detail in the firebase query documentation.

```
db.getUserValue("myvalue", queryParameters, function(success, key, value) {
                   if(success) {
                     console.log("Read user value for key", key, "from DB:", value)
                   }
                 })
```

The `setUserValue` and `getUserValue` works on data for the currently logged in user. The `setValue` and `getValue` methods perform a similar task, but across all users. Use these with care.

Realtime Database

The firebase database offers an interesting function in the shape of real-time updates of data changes.

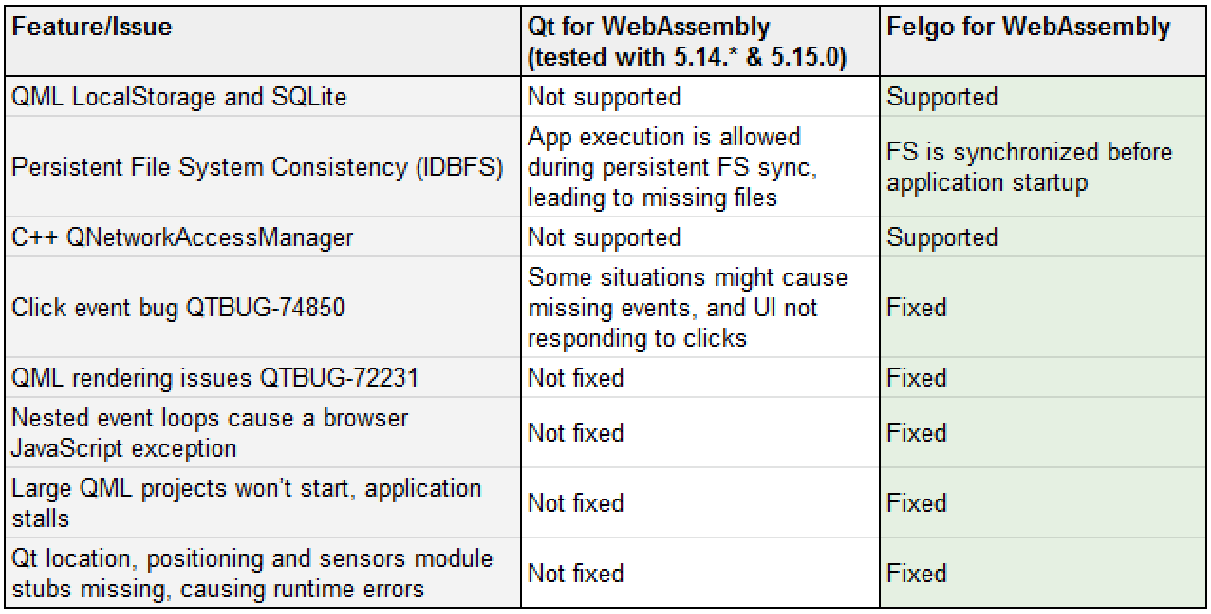
By registering a key in the `realtimeUserValueKeys` property, the realtimeUserValueChanged will signal real-time value changes *across devices*. This function has a user independent sibling in the shape of `realtimeValueChanged`, that acts on global values.

19.7 Cloud Storage, Augmented Reality, and More

The Felgo plugins provide more integration than we've covered here. As an alternative to Firebase, you can use Felgo Cloud. There is also an augmented reality plugin powered by Wikitude, the Felgo Gamification APIs for leaderboards and achievements and Felgo Multiplayer powered by Photon for real-time communication between users.

19.8 Felgo & WebAssembly

In addition to these pure extensions of Qt, Felgo also offers an improved WebAssembly experience, fixing known shortcomings of the current Qt integration, as well as extending the Qt APIs for the WebAssembly environment.



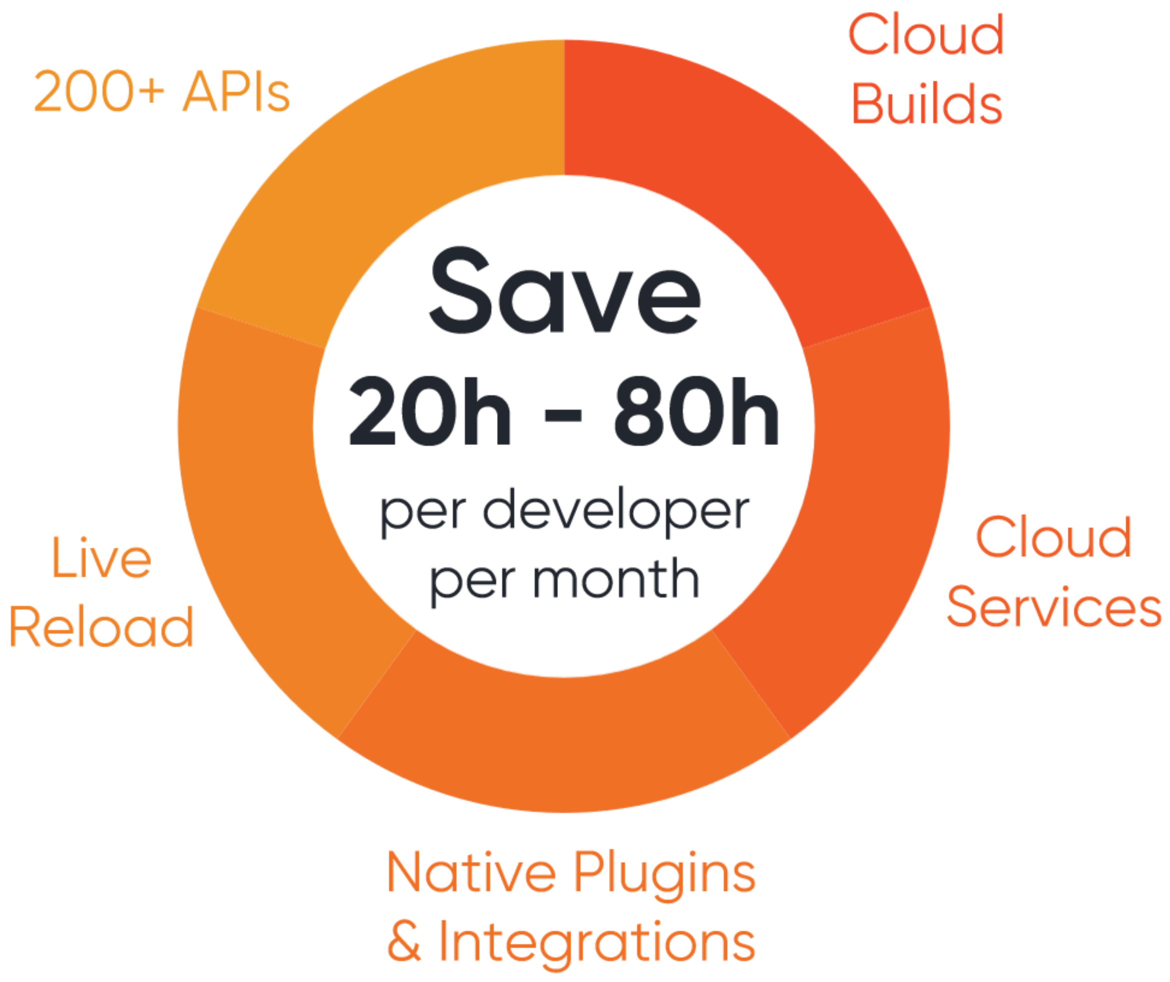
Feature/Issue	Qt for WebAssembly (tested with 5.14.* & 5.15.0)	Felgo for WebAssembly
QML LocalStorage and SQLite	Not supported	Supported
Persistent File System Consistency (IDBFS)	App execution is allowed during persistent FS sync, leading to missing files	FS is synchronized before application startup
C++ QNetworkAccessManager	Not supported	Supported
Click event bug QTBUG-74850	Some situations might cause missing events, and UI not responding to clicks	Fixed
QML rendering issues QTBUG-72231	Not fixed	Fixed
Nested event loops cause a browser JavaScript exception	Not fixed	Fixed
Large QML projects won't start, application stalls	Not fixed	Fixed
Qt location, positioning and sensors module stubs missing, causing runtime errors	Not fixed	Fixed

19.9 Summary

In this chapter, we have looked at some of the ways that Felgo extends Qt. This spans the entire range: tooling, build services, and integration of features. The strength of the Felgo extensions is that they enable access to advanced features directly from QML. This saves the effort needed to first integrate a feature into Qt/C++, and then exposing it to QML.

Many of the integrated functions shown in this chapter require accounts at external services, as well as Felgo account. This means that you will have to modify the example snippets included with your keys, instead of running them straight out of the box. This is why we separated these contents into a distinct chapter.

The functions demonstrated - advertisements, in-app purchases, push notifications, analytics, user accounts, and real-time databases are all integrated by many applications in one shape or form. By providing pre-made QML integrations, Felgo can save a considerable amount of development time. This is on top of the remote building capabilities of Cloud Builds, automating the building and deployment into app stores, and the Hot Reload feature, making it possible to try out changes live across a range of devices. All of this together can lead to great time savings.


200+ APIs
Cloud Builds
Save
20h - 80h
per developer per month
Live Reload
Cloud Services
Native Plugins & Integrations

CHAPTER

TWENTY

QT FOR PYTHON

Section author: e8johan

Note: Last Build: December 07, 2020 at 10:50 CET

The source code for this chapter can be found in the assets folder.

This chapter describes the PySide2 module from the Qt for Python project. You will learn how to install it and how to leverage QML together with Python.

20.1 Introduction

The Qt for Python project provides the tooling to bind C++ and Qt to Python, and a complete Python API to Qt. This means that everything that you can do with Qt and C++, you can also do with Qt and Python. This ranges from headless services to widget based user interfaces. In this chapter, we will focus on how to integrate QML and Python.

Currently, Qt for Python is available for all desktop platforms, but not for mobile. Depending on which platform you use, the setup of Python is slightly different, but as soon as you have a Python and PyPA environment setup, you can install Qt for Python using `pip`. This is discussed in more detail further down.

As the Qt for Python project provides an entirely new language binding for Qt, it also comes with a new set of documentation. The following resources are good to know about when exploring this module.

- Reference documentation: https://doc.qt.io/qtforpython/
- Qt for Python wiki: https://wiki.qt.io/Qt_for_Python
- Caveats: https://wiki.qt.io/Qt_for_Python/Considerations

The Qt for Python bindings are generated using the Shiboken tool. At times, it might be of interest to read about it as well to understand what is going on. The prefered point for finding information about Shiboken is the reference documentation. If you want to mix your own C++ code with Python and QML, Shiboken is the tool that you need.

Note: Through-out this chapter we will use Python 3.6.

20.2 Installing

Qt for Python is available through PyPA using `pip` under the name `pyside2`. In the example below we setup a `venv` environment in which we will install the latest version of Qt for Python:

```
$ mkdir qt-for-python
$ cd qt-for-python
$ python3 -m venv .
$ . bin/activate
(qt-for-python) $ python --version
Python 3.6.6
```

When the environment is setup, we continue to install `pyside2` using `pip`:

```
(qt-for-python) $ pip install pyside2
Collecting pyside2
Downloading [ ... ] (166.4MB)

[ ... ]

Installing collected packages: pyside2
Successfully installed pyside2-5.11.2
```

After the installation, we can test it by running a *Hello World* example from the interactive Python prompt:

```
(qt-for-python) $ python
Python 3.6.6 (default, Jun 27 2018, 14:44:17)
[GCC 8.1.0] on linux
Type "help", "copyright", "credits" or "license" for more information.
>>> from PySide2 import QtWidgets
>>> import sys
>>> app = QtWidgets.QApplication(sys.argv)
>>> widget = QtWidgets.QLabel("Hello World!")
>>> widget.show()
>>> app.exec_()
0
>>>
```

The example results in a window such as the one shown below. To end the program, close the window.

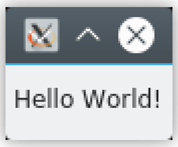


Fig. 1: A Qt Widgets based *Hello World* example using Qt for Python.

20.3 Building an Application

In this chapter we will look at how you can combine Python and QML. The most natural way to combine the two worlds is to do as with C++ and QML, i.e. implement the logic in Python and the presentation in QML.

To do this, we need to understand how to combine QML and Python into a single program, and then how to implement interfaces between the two worlds. In the sub-sections below, we will look at how this is done. We will start simple and progress to an example exposing the capabilities of a Python module to QML through a Qt item model.

20.3.1 Running QML from Python

The very first step is to create a Python program that can host the *Hello World* QML program shown below.

```
import QtQuick 2.0
import QtQuick.Window 2.0

Window {
    width: 640
    height: 480
    visible: true
    title: "Hello Python World!"
}
```

To do this, we need a Qt mainloop provided by `QGuiApplication` from the `QtGui` module. We also need a `QQmlApplicationEngine` from the `QtQml` module. In order to pass the reference to the source file to the QML application engine, we also need the `QUrl` class from the `QtCore` module.

In the code below we emulate the functionality of the boilerplate C++ code generated by Qt Creator for QML projects. It instanciates the application object, and creates a QML application engine. It then loads the QML and then ensures that the QML was loaded by checking if a root object was created. Finally, it exits and returns the value returned by the `exec_` method of the application object.

Note: The `exec_` method ends with an underscore to avoid a name clash with Python. It corresponds to the C++ method named `exec`.

```
import sys
from PySide2.QtGui import QGuiApplication
from PySide2.QtQml import QQmlApplicationEngine
from PySide2.QtCore import QUrl

if __name__ == '__main__':
    app = QGuiApplication(sys.argv)
    engine = QQmlApplicationEngine()
    engine.load(QUrl("main.qml"))

    if not engine.rootObjects():
        sys.exit(-1)

    sys.exit(app.exec_())
```

Executing the example results in a window with the title *Hello Python World*.

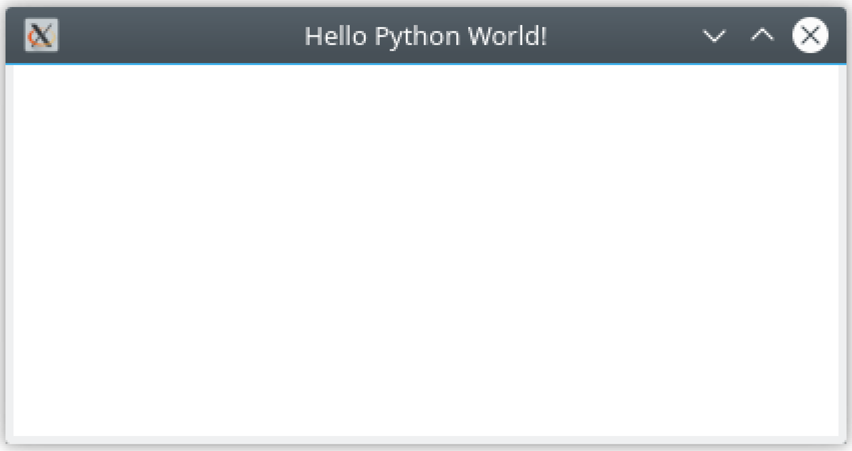


Fig. 2: A QML window created from Python.

Note: The example assumes that it is executed from the directory containing the `main.qml` source file. You can termine the location of the Python file being executed using the `__file__` variable. This can be used to locate the QML files relative to the Python file as shown in this blog post.

20.3.2 Exposing Python Objects to QML

The easiest way to share information between Python and QML is to expose a Python object to QML. This is done by registering a *context property* through the `QQmlApplicationEngine`. Before we can do that, we need to define a class so that we have an object to expose.

Qt classes comes with a number of features that we want to be able to use. These are: signals, slots and properties. In this first example, we will restrict ourselves to a pair of a basic signal and slot. The rest will be covered in the examples further on.

Signals and Slots

We start with the class `NumberGenerator`. It has a constructor, a method called `giveNumber` and a signal called `nextNumber`. The idea is that when you call `giveNumber`, the signal `nextNumber` is emitted with a new random number. You can see the code for the class below, but first we will look at the details.

First of all we make sure to call `QObject.__init__` from our constructor. This is very important, as the example will not work without it.

Then we declare a signal by creating an instance of the `Signal` class from the `PySide2.QtCore` module. In this case, the signal carries an integer value, hence the `int`.

Finally, we *decorate* the `giveNumber` method with the `@Slot()` decorator, thus turning it into a slot. There is not concept of *invokables* in Qt for Python, so all callable methods must be slots.

In the `giveNumber` method we emit the `nextNumber` signal using the `emit` method. This is a bit different than the syntax for doing so from QML or C++ as the signal is represented by an object instead of being a callable function.

```
import random

from PySide2.QtCore import QObject, Signal, Slot

class NumberGenerator(QObject):
    def __init__(self):
        QObject.__init__(self)

    nextNumber = Signal(int)

    @Slot()
    def giveNumber(self):
        self.nextNumber.emit(random.randint(0, 99))
```

Next up is to combine the class we just created with the boilerplate code for combining QML and Python from earlier. This gives us the following entry-point code.

The interesting lines are the one where we first instatiate a `NumberGenerator`. This object is then exposed to QML using the `setContextProperty` method of the `rootContext` of the QML engine. This exposes the object to QML as a global variable under the name `numberGenerator`.

```
if __name__ == '__main__':
    app = QGuiApplication(sys.argv)
    engine = QQmlApplicationEngine()

    number_generator = NumberGenerator()
```

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```
    engine.rootContext().setContextProperty("numberGenerator", number_generator)

    engine.load(QUrl("main.qml"))

    if not engine.rootObjects():
        sys.exit(-1)

    sys.exit(app.exec_())
```

Continuing to the QML code, we can see that we've created a Qt Quick Controls 2 user interface consisting of a `Button` and a `Label`. In the button's `onClicked` handler, the `numberGenerator.giveNumber()` function is called. This is the slot of the object instantiated on the Python side.

To receive a signal from an object that has been instantiated outside of QML we need to use a `Connections` element. This allows us to attach a signal hanlder to an existing target.

Note: At the moment of writing, the name of a signal argument cannot be propagated from Python to QML. To work around this, the Python signal, `numberGenerator.nextNumber`, is connected to a QML defined signal, `reNextNumber`, that has the name `number` for the signal argument. This allows us to capture the value of the signal argument in the signal handler in the `Connections` element.

This is a workaround for issue PYSIDE-634.

```
import QtQuick 2.0
import QtQuick.Window 2.0
import QtQuick.Controls 2.0

Window {
    id: root

    width: 640
    height: 480
    visible: true
    title: "Hello Python World!"

    Flow {
        Button {
            text: "Give me a number!"
            onClicked: numberGenerator.giveNumber();
        }
        Label {
            id: numberLabel
            text: "no number"
        }
    }

    // Signal argument names are not propagated from Python to QML, so we need to␣
↪re-emit the signal
    signal reNextNumber(int number)
    Component.onCompleted: numberGenerator.nextNumber.connect(reNextNumber)

    Connections {
        target: root
        onReNextNumber: numberLabel.text = number
    }
}
```

Properties

Instead of relying soley on signals and slots, the common way to expose state to QML is through properties. A property is a combination of a setter, getter and notification signal. The setter is optional, as we can also have read-only properties.

To try this out we will update the `NumberGenerator` from the last example to a property based version. It will have two properties: `number`, a read-only property holding the last random number, and `maxNumber`, a read-write property holding the maximum value that can be returned. It will also have a slot, `updateNumber` that updates the random number.

Before we dive into the details of properties, we create a basic Python class for this. It consists of the relevant getters and setters, but not Qt signalling. As a matter of fact, the only Qt part here is the inheritance from `QObject`. Even the names of the methods are Python style, i.e. using underscores instead of camelCase.

Take notice of the underscores ("__") at the beginning of the `__set_number` method. This implies that it is a private method. So even when the `number` property is read-only, we provide a setter. We just don't make it public. This allows us to take actions when changing the value (e.g. emitting the notification signal).

```
class NumberGenerator(QObject):
    def __init__(self):
        QObject.__init__(self)
        self.__number = 42
        self.__max_number = 99

    def set_max_number(self, val):
        if val < 0:
            val = 0

        if self.__max_number != val:
            self.__max_number = val

        if self.__number > self.__max_number:
            self.__set_number(self.__max_number)

    def get_max_number(self):
        return self.__max_number

    def __set_number(self, val):
        if self.__number != val:
            self.__number = val;

    def get_number(self):
        return self.__number
```

In order to define properties, we need to import the concepts of `Signal`, `Slot`, and `Property` from `PySide2.QtCore`. In the full example, there are more imports, but these are the ones relevant to the properties.

```
from PySide2.QtCore import QObject, Signal, Slot, Property
```

Now we are ready to define the first property, `number`. We start off by declaring the signal `numberChanged`, which we then invoke in the `__set_number` method so that the signal is emitted when the value is changed.

After that, all that is left is to instantiate the `Property` object. The `Property` contructor takes three arguments in this case: the type (`int`), the getter (`get_number`) and the notification signal which is passed as a named argument (`notify=numberChanged`). Notice that the getter has a Python name, i.e. using underscore rather than camelCase, as it is used to read the value from Python. For QML, the property name, `number`, is used.

```
class NumberGenerator(QObject):

    # ...

```

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```
    # number

    numberChanged = Signal(int)

    def __set_number(self, val):
        if self.__number != val:
            self.__number = val;
            self.numberChanged.emit(self.__number)

    def get_number(self):
        return self.__number

    number = Property(int, get_number, notify=numberChanged)
```

This leads us to the next property, `maxNumber`. This is a read-write property, so we need to provide a setter, as well as everything that we did for the `number` property.

First up we declare the `maxNumberChanged` signal. This time, using the `@Signal` decorator instead of instantiating a `Signal` object. We also provide a setter slot, `setMaxNumber` with a Qt name (camelCase) that simply calls the Python method `set_max_number` alongside a getter with a Python name. Again, the setter emits the change signal when the value is updated.

Finally we put the pieces together into a read-write property by instantiating a `Property` object taking the type, getter, setter and notification signal as arguments.

```
class NumberGenerator(QObject):

    # ...

    # maxNumber

    @Signal
    def maxNumberChanged(self):
        pass

    @Slot(int)
    def setMaxNumber(self, val):
        self.set_max_number(val)

    def set_max_number(self, val):
        if val < 0:
            val = 0

        if self.__max_number != val:
            self.__max_number = val
            self.maxNumberChanged.emit()

        if self.__number > self.__max_number:
            self.__set_number(self.__max_number)

    def get_max_number(self):
        return self.__max_number

    maxNumber = Property(int, get_max_number, set_max_number,␣
↪notify=maxNumberChanged)
```

Now we have properties for the current random number, `number`, and the maximum random number, `maxNumber`. All that is left is a slot to produce a new random number. It is called `updateNumber` and simply sets a new random number.

```
class NumberGenerator(QObject):
```

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```
    # ...

    @Slot()
    def updateNumber(self):
        self.__set_number(random.randint(0, self.__max_number))
```

Finally, the number generator is exposed to QML through a root context property.

```
if __name__ == '__main__':
    app = QGuiApplication(sys.argv)
    engine = QQmlApplicationEngine()

    number_generator = NumberGenerator()
    engine.rootContext().setContextProperty("numberGenerator", number_generator)

    engine.load(QUrl("main.qml"))

    if not engine.rootObjects():
        sys.exit(-1)

    sys.exit(app.exec_())
```

In QML, we can bind to the `number` as well as the `maxNumber` properties of the `numberGenerator` object. In the `onClicked` handler of the `Button` we call the `updateNumber` method to generate a new random number and in the `onValueChanged` handler of the `Slider` we set the `maxNumber` property using the `setMaxNumber` method. This is because altering the property directly through Javascript would destroy the bindings to the property. By using the setter method explicitly, this is avoided.

```
import QtQuick 2.0
import QtQuick.Window 2.0
import QtQuick.Controls 2.0

Window {
    id: root

    width: 640
    height: 480
    visible: true
    title: "Hello Python World!"

    Column {
        Flow {
            Button {
                text: "Give me a number!"
                onClicked: numberGenerator.updateNumber();
            }
            Label {
                id: numberLabel
                text: numberGenerator.number
            }
        }
        Flow {
            Slider {
                from: 0
                to: 99
                value: numberGenerator.maxNumber
                onValueChanged: numberGenerator.setMaxNumber(value)
            }
        }
    }
```

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```
}
```

20.3.3 Exposing a Python class to QML

Up until now, we've instantiated an object Python and used the `setContextProperty` method of the `rootContext` to make it available to QML. Being able to instantiate the object from QML allows better control over object life-cycles from QML. To enable this, we need to expose the *class*, instead of the *object*, to QML.

The class that is being exposed to QML is not affected by where it is intantiated. No change is needed to the class definition. However, instead of calling `setContextProperty`, the `qmlRegisterType` function is used. This function comes from the `PySide2.QtQml` module and takes five arguments:

- A reference to the class, `NumberGenerator` in the example below.
- A module name, `'Generators'`.
- A module version consisting of a major and minor number, `1` and `0` meaning `1.0`.
- The QML name of the class, `'NumberGenerator'`

```python
import sys
import random

from PySide2.QtGui import QGuiApplication
from PySide2.QtQml import QQmlApplicationEngine, qmlRegisterType
from PySide2.QtCore import QUrl

from PySide2.QtCore import QObject, Signal, Slot

class NumberGenerator(QObject):
    def __init__(self):
        QObject.__init__(self)

    nextNumber = Signal(int)

    @Slot()
    def giveNumber(self):
        self.nextNumber.emit(random.randint(0, 99))


if __name__ == '__main__':
    app = QGuiApplication(sys.argv)
    engine = QQmlApplicationEngine()

    qmlRegisterType(NumberGenerator, 'Generators', 1, 0, 'NumberGenerator')

    engine.load(QUrl("main.qml"))

    if not engine.rootObjects():
        sys.exit(-1)

    sys.exit(app.exec_())
```

In QML, we need to import the module, e.g. `Generators 1.0` and then instantiate the class as `NumberGenerator { ... }`. The instance now works like any other QML element.

```qml
import QtQuick 2.0
import QtQuick.Window 2.0
import QtQuick.Controls 2.0

import Generators 1.0
```

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```
Window {
    id: root

    width: 640
    height: 480
    visible: true
    title: "Hello Python World!"

    Flow {
        Button {
            text: "Give me a number!"
            onClicked: numberGenerator.giveNumber();
        }
        Label {
            id: numberLabel
            text: "no number"
        }
    }

    NumberGenerator {
        id: numberGenerator

        // Signal argument names are not propagated from Python to QML, so we need␣
↪to re-emit the signal
        signal reNextNumber(int number)
        Component.onCompleted: numberGenerator.nextNumber.connect(reNextNumber)
    }

    Connections {
        target: numberGenerator
        onReNextNumber: numberLabel.text = number
    }
}
```

20.3.4 A Model from Python

One of the more interesting types of objects or classes to expose from Python to QML are item models. These are used with various views or the `Repeater` element to dynamically build a user interface from the model contents.

In this section we will take an existing python utility for monitoring CPU load (and more), `psutil`, and expose it to QML via a custom made item model called `CpuLoadModel`. You can see the program in action below:

Note: The psutil library can be found at https://pypi.org/project/psutil/ .

"psutil (process and system utilities) is a cross-platform library for retrieving information on running processes and system utilization (CPU, memory, disks, network, sensors) in Python."

You can install psutil using `pip install psutil`.

We will use the `psutil.cpu_percent` function (documentation) to sample the CPU load per core every second. To drive the sampling we use a `QTimer`. All of this is exposed through the `CpuLoadModel` which is a `QAbstractListModel`.

Item models are interesting. They allow you to represent a two dimensional data set, or even nested data sets, if using the `QAbstractItemModel`. The `QAbstractListModel` that we use allow us to represent a list of items, so a one dimensional set of data. It is possible to implement a nested set of lists, creating a tree, but we only create one level.

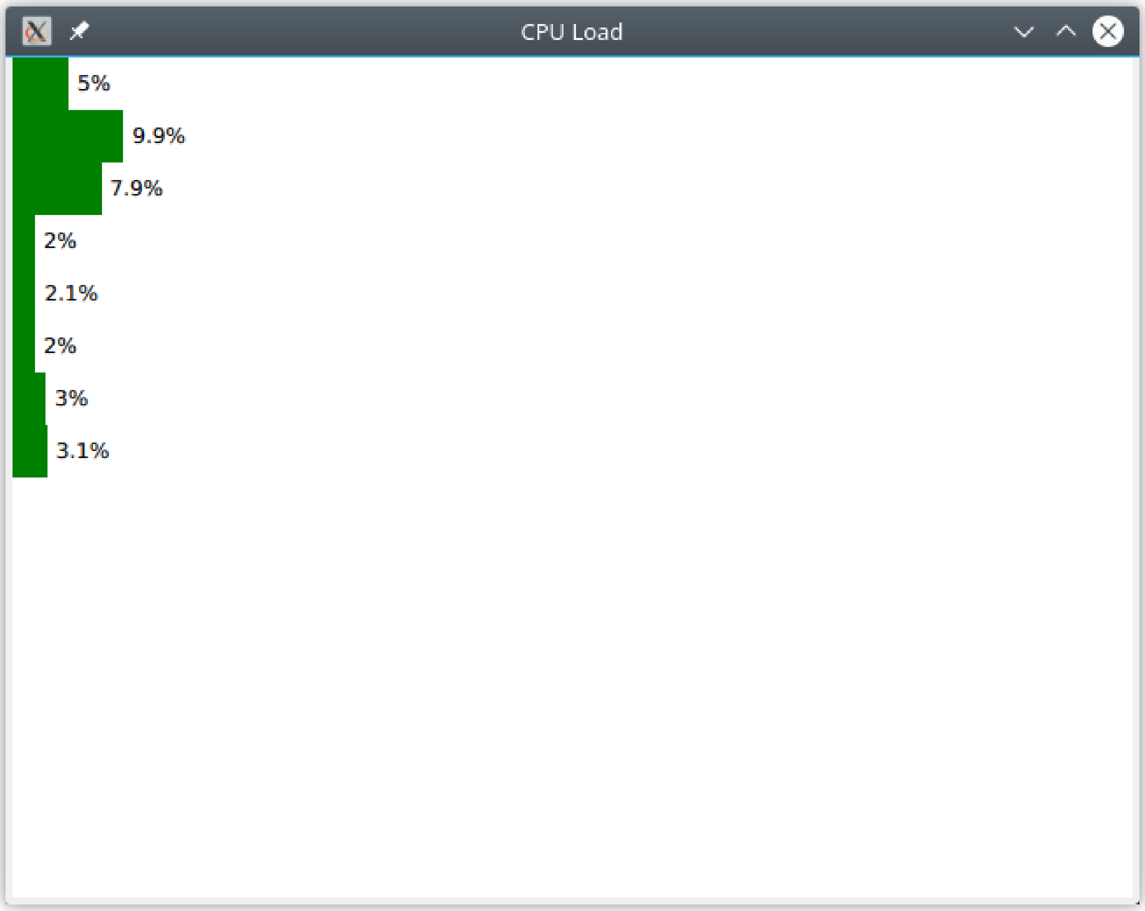

Fig. 3: Showing the CPU load of eight cores through a custom item model using *psutil*.

To implement a `QAbstractListModel` it is necessary to implement the methods `rowCount` and `data`. The `rowCount` returns the number of CPU cores which we get using the `psutil.cpu_count` method. The `data` method returns data for different *roles*. We only support the `Qt.DisplayRole`, which corresponds to what you get when you refer to `display` inside the deletage item from QML.

Looking at the code for the model, you can see that the actual data is stored in the `__cpu_load` list. If a valid request is made to `data`, i.e. the row, column and role is correct, we return the right element from the `__cpu_load` list. Otherwise we return `None` which corresponds to an uninitialized `QVariant` on the Qt side.

Every time the update timer (`__update_timer`) times out, the `__update` method is triggered. Here, the `__cpu_load` list is updated, but we also emit the `dataChanged` signal, indicating that all data was changed. We do not do a `modelReset` as that also implies that the number of items might have changed.

Finally, the `CpuLoadModel` is exposed to QML are a registered type in the `PsUtils` module.

```python
import sys
import psutil

from PySide2.QtGui import QGuiApplication
from PySide2.QtQml import QQmlApplicationEngine, qmlRegisterType
from PySide2.QtCore import QUrl, QTimer, QAbstractListModel

from PySide2.QtCore import QObject, Signal, Slot, Property, Qt

class CpuLoadModel(QAbstractListModel):
    def __init__(self):
        QAbstractListModel.__init__(self)

        self.__cpu_count = psutil.cpu_count()
        self.__cpu_load = [0] * self.__cpu_count

        self.__update_timer = QTimer(self)
        self.__update_timer.setInterval(1000)
        self.__update_timer.timeout.connect(self.__update)
        self.__update_timer.start()

        # The first call returns invalid data
        psutil.cpu_percent(percpu=True)

    def __update(self):
        self.__cpu_load = psutil.cpu_percent(percpu=True)
        self.dataChanged.emit(self.index(0,0), self.index(self.__cpu_count-1, 0))

    def rowCount(self, parent):
        return self.__cpu_count

    def data(self, index, role):
        if (role == Qt.DisplayRole and
            index.row() >= 0 and
            index.row() < len(self.__cpu_load) and
            index.column() == 0):
            return self.__cpu_load[index.row()]
        else:
            return None

if __name__ == '__main__':
    app = QGuiApplication(sys.argv)
    engine = QQmlApplicationEngine()

    qmlRegisterType(CpuLoadModel, 'PsUtils', 1, 0, 'CpuLoadModel')

    engine.load(QUrl("main.qml"))
```

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```
    if not engine.rootObjects():
        sys.exit(-1)

    sys.exit(app.exec_())
```

On the QML side we use a `ListView` to show the CPU load. The model is bound to the `model` property. For each item in the model a `delegate` item will be instantiated. In this case that means a `Rectangle` with a green bar (another `Rectangle`) and a `Text` element displaying the current load.

```
import QtQuick 2.0
import QtQuick.Window 2.0
import QtQuick.Controls 2.0

import PsUtils 1.0

Window {
    id: root

    width: 640
    height: 480
    visible: true
    title: "CPU Load"

    ListView {
        anchors.fill: parent
        model: CpuLoadModel { }
        delegate: Rectangle {
            width: parent.width;
            height: 30;
            color: "white"

            Rectangle {
                id: bar

                width: parent.width * display / 100.0
                height: 30
                color: "green"
            }

            Text {
                anchors.verticalCenter: parent.verticalCenter
                x: Math.min(bar.x + bar.width + 5, parent.width-width)

                text: display + "%"
            }
        }
    }
}
```

20.4 Limitations

At the moment, there are some things that are not easily available. One of them is that you cannot easily create QML plugins using Python. Instead you need to import the Python QML “modules” into your Python program and then use qmlRegisterType to make it possible to import them from QML.

20.5 Summary

In this chapter we have looked at the PySide2 module from the Qt for Python project. After a brief look at installation, we focused on how Qt concepts are used from Python. This included slots, signals and properties. We also looked at a basic list model and how to expose both Python objects and classes from Python to QML.

Assets

The assets contain all files for reading the book offline and also the chapter examples as a downloadable format.

CHAPTER

TWENTYONE

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CHAPTER

TWENTYTWO

SOURCE CODE EXAMPLES

- Chapter 1 examples (ch01-meetqt-assets.tgz)
- Chapter 4 examples (ch04-qmlstart-assets.tgz)
- Chapter 5 examples (ch05-fluid-assets.tgz)
- Chapter 6 examples (ch06-controls-assets.tgz)
- Chapter 7 examples (ch07-modelview-assets.tgz)
- Chapter 8 examples (ch08-felgo-assets.tgz)
- Chapter 9 examples (ch09-canvas-assets.tgz)
- Chapter 10 examples (ch10-particles-assets.tgz)
- Chapter 11 examples (ch11-shaders-assets.tgz)
- Chapter 12 examples (ch12-multimedia-assets.tgz)
- Chapter 13 examples (ch13-networking-assets.tgz)
- Chapter 14 examples (ch14-storage-assets.tgz)
- Chapter 15 examples (ch15-dynamicqml-assets.tgz)
- Chapter 16 examples (ch16-javascript-assets.tgz)
- Chapter 17 examples (ch17-qtcpp-assets.tgz)
- Chapter 18 examples (ch18-extensions-assets.tgz)
- Chapter 19 examples (ch19-felgo-plugins-assets.tgz)
- Chapter 20 examples (ch20-python-assets.tgz)

Chapter Queue

The chapter queue is the chapters we are working on. They might be almost ready or in an infant state. Give it a try if you like.

22.1 Testing

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22.2 Deploying QML Applications

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22.3 Drag and Drop

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INDEX