The book about real examples of Qt Widgets usage

Preface

I guess that you, reader, know C++, know what is object-oriented programming and design. In this book, you won't find answers on the basics of C++, but you can find some practices, useful practices when developing with Qt. I guess that you understand the basics of Qt. This book is an explanation of the development processes of the real GUI projects, written on C++/Qt. You won't find explanations of public Qt API, as I guess that Qt API is very well described in Qt help.

Projects, described in this book are not so big and it's a very good start point to look at the working code, because a developer should read the code of another developer, this will improve your Qt skills. These projects are Open Source and you can become a part of these projects, you are welcome to make pull requests on GitHub with improvements.

The goal of this book is to introduce the reader with Qt Widgets, the best UI framework, in my opinion, for developing cross-platform, effective desktop applications on the real examples. You can look at the chapters of this book as on tutorials.

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Chapter 1

I want to show on the real example how to create simple GIF editor with Qt widgets. Why Qt widgets and not QML? The answer is simple - I want to create a desktop application, and in my opinion for desktop applications, it's better to use widgets. Full sources of this example you can find here https://github.com/igormironchik/gif-editor

As backend of image processing, I will use Magick++ from ImageMagick.

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Basics of the main window

Introduction

Each Qt widgets application should have one or more top-level widgets. For GIF editor we need one top-level window where we will display frames, current frame, toolbar with actions for editing, a menu bar with different actions. Qt has ready to use class `QMainWindow` which we can derive from and implement needed for us functionality.

Inheritance

Let's inherit from `QMainWindow` to have the ability to implement our functionality. We will start from basics, in the mainwindow.hpp we have:

```
#ifndef GIF_EDITOR_MAINWINDOW_HPP_INCLUDED
#define GIF_EDITOR_MAINWINDOW_HPP_INCLUDED

// Qt include.
#include <QMainWindow>
#include <QScopedPointer>


//
// MainWindow
//

class MainWindowPrivate;

//! Main window.
class MainWindow final
    :    public QMainWindow
{
    Q_OBJECT

public:
    MainWindow();
    ~MainWindow() noexcept override;

private:
    Q_DISABLE_COPY( MainWindow )

    QScopedPointer< MainWindowPrivate > d;
}; // class MainWindow

#endif // GIF_EDITOR_MAINWINDOW_HPP_INCLUDED
```

I publicly inherited from `QMainWindow` and in private section you can see usage of `Q_OBJECT` macros. This macro is needed by Qt's moc to generate auxiliary code for signals and slots. At this time we don't have any signals or slots, but it's a good practice to use `Q_OBJECT` macros in every class derived from `QObject`.

I use in my Qt applications private implementation idiom, for this I declared class `MainWindowPrivate` and in `MainWindow` I declared member - smart pointer to `MainWindowPrivate`. The private implementation is good for reducing compile time, it hides details of implementation from interface.

Implementation at this point is very simple (mainwindow.cpp):

```
// GIF editor include.
#include "mainwindow.hpp"


//
// MainWindowPrivate
//

class MainWindowPrivate {
public:
    MainWindowPrivate( MainWindow * parent )
        :    q( parent )
    {
    }

    //! Parent.
    MainWindow * q;
}; // class MainWindowPrivate


//
// MainWindow
//

MainWindow::MainWindow()
    :    d( new MainWindowPrivate( this ) )
{
}
```

For the future, I defined member to the parent object of `MainWindow` in `MainWindowPrivate` class. It can help us in the future to access `MainWindow` methods from data class (`MainWindowPrivate`).

Menu

Ok. We have the skeleton of our main window. Let's add "File" menu with open, save, save as and quit actions. We want to implement GIF editor and without such basic functions our application will cost nothing. First of all, let's define slots in `MainWindow` class for these actions.

```
private slots:
    //! Open GIF.
    void openGif();
    //! Save GIF.
    void saveGif();
    //! Save GIF as.
    void saveGifAs();
    //! Quit.
    void quit();
```

`QMainWindow` has a menu bar, status bar, central widget, etc. For such actions it's a good place in the "File" menu, as in almost all desktop applications. In the constructor of `MainWindow` we will add code to create the "File" menu and fill it with actions. Let's see:

```
MainWindow::MainWindow()
    :    d( new MainWindowPrivate( this ) )
{
    setWindowTitle( tr( "GIF Editor" ) );

    auto file = menuBar()->addMenu( tr( "&File" ) );
    file->addAction( QIcon( ":/img/document-open.png" ), tr( "Open" ),
        this, &MainWindow::openGif, tr( "Ctrl+O" ) );
    file->addSeparator();
    file->addAction( QIcon( ":/img/document-save.png" ), tr( "Save" ),
        this, &MainWindow::saveGif, tr( "Ctrl+S" ) );
    file->addAction( QIcon( ":/img/document-save-as.png" ), tr( "Save As" ),
        this, &MainWindow::saveGifAs );
    file->addSeparator();
    file->addAction( QIcon( ":/img/application-exit.png" ), tr( "Quit" ),
        this, &MainWindow::quit, tr( "Ctrl+Q" ) );
}
```

I set title of the main window and created "File" menu with actions and separators.

Quit from the application

The first slot that we will implement is quit from the editor and empty implementations of other slots.

```
void
MainWindow::openGif()
{

}

void
MainWindow::saveGif()
{

}

void
MainWindow::saveGifAs()
{

}

void
MainWindow::quit()
{
    if( isWindowModified() )
    {
        auto btn = QMessageBox::question( this, tr( "GIF was changed..." ),
            tr( "GIF was changed. Do you want to save changes?" ) );

        if( btn == QMessageBox::Yes )
            saveGif();
    }

    QApplication::quit();
}
```

`QWidget`, the parent of `QMainWindow`, has a mechanism to read/set a flag if something was changed in. Why not? In our editor we will set this flag on user's changes and clear it on saving. For the future I added in data class member `m_currentGif` of `QString` type, where I will store the full path to the current GIF image.

```
    //! Current file name.
    QString m_currentGif;
    //! Parent.
    MainWindow * q;
}; // class MainWindowPrivate
```

Great. But application can be closed with the close button in the window's header. And it's a good idea to invoke `MainWindow::quit()` slot in handler of this event. For this case we will override `closeEvent()`, so in `MainWindow` :

```
protected:
    void closeEvent( QCloseEvent * e ) override;
```

And implementation:

```
void
MainWindow::closeEvent( QCloseEvent * e )
{
    quit();

    e->accept();
}
```

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First launch of application

We created basic main window, let's have a look at it. We need a `main()` function to start the application.

```
// Qt include.
#include <QApplication>
#include <QTranslator>
#include <QLocale>

// GIF editor include.
#include "mainwindow.hpp"


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

    QIcon appIcon( ":/img/icon_256x256.png" );
    appIcon.addFile( ":/img/icon_128x128.png" );
    appIcon.addFile( ":/img/icon_64x64.png" );
    appIcon.addFile( ":/img/icon_48x48.png" );
    appIcon.addFile( ":/img/icon_32x32.png" );
    appIcon.addFile( ":/img/icon_22x22.png" );
    appIcon.addFile( ":/img/icon_16x16.png" );
    app.setWindowIcon( appIcon );

    QTranslator appTranslator;
    appTranslator.load( "./tr/gif-editor_" + QLocale::system().name() );
    app.installTranslator( &appTranslator );

    MainWindow w;
    w.resize( 800, 600 );
    w.show();

    return app.exec();
}
```

We created `QApplication` object, an icon of our application, translator, that will load translation according to system's locale, and created `MainWindow` object on the stack. Set default size, and invoked `show()` method. Voila, now we need to start application's event loop, what `app.exec()` do.

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Plans

How do you see UI, the main UI, of the editor? I want to have a horizontal scrollable tape with frames of GIF at the bottom, frames should be checkable with checkbox, so the user will be able to delete some frames from the GIF. And resized to fit available space current frame in the centre of the main window. Frames should be clickable, so the user can select any frame. And for first Alpha version of the application I want to implement crop function. The crop will be accessible from toolbar, and in this mode user should be able to draw a rectangle to crop to, and on pressing "Enter" crop should do the job for all frames.

That's all. Sounds not so complicated, let's do it. And let's start from creating a widget that will represent a frame in the tape of frames.

I wrote the code for the next five sections before continuing writing this book because it's very difficult to keep in mind all possible issues that could be during coding. So I wrote the code, debugged it, checked, and started to write an overview of my adventure. After reading next five sections the editor will open GIF images, the user will see the tape with clickable frames, and on clicking in the centre of the window will be displayed selected frame. Believe me, it looks nice, and I spend only half a day on developing it, that is why I love Qt so much.

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Frame

Class

Frame... This is an unit of GIF image. We need a thumbnail frame on the tape to display a sequence of frames in GIF, and a bigger one to display currently selected frame. The task of the frame is to display image, so why not to have one class for both cases? Hmm, why not? But for the current frame we need the image to be scaled to the size of the available area with keeping aspect ratio, whereas for the frame on the tape we need an image scaled to the height of the tape. The image on the frame should automatically resize on parent resizing, and it should be clickable. I guess that this is enough for our application. Possibly we will need something additional in the future, possibly, but for the first attempt this is all that we need. Let declare a class of our frame.

```
#ifndef GIF_EDITOR_FRAME_HPP_INCLUDED
#define GIF_EDITOR_FRAME_HPP_INCLUDED

// Qt include.
#include <QWidget>
#include <QScopedPointer>


//
// Frame
//

class FramePrivate;

//! This is just an image with frame that fit the given size or height.
class Frame final
    :    public QWidget
{
    Q_OBJECT

signals:
    //! Clicked.
    void clicked();

public:
    //! Resize mode.
    enum class ResizeMode {
        //! Fit to size.
        FitToSize,
        //! Fit to height.
        FitToHeight
    }; // enum class ResizeMode

    Frame( const QImage & img, ResizeMode mode, QWidget * parent = nullptr );
    ~Frame() noexcept override;

    //! \return Image.
    const QImage & image() const;
    //! Set image.
    void setImage( const QImage & img );

    QSize sizeHint() const override;

protected:
    void paintEvent( QPaintEvent * ) override;
    void resizeEvent( QResizeEvent * e ) override;
    void mouseReleaseEvent( QMouseEvent * e ) override;

private:
    Q_DISABLE_COPY( Frame )

    QScopedPointer< FramePrivate > d;
}; // class Frame

#endif // GIF_EDITOR_FRAME_HPP_INCLUDED
```

Implementation

With private data class all is simple, it's better to see one time than hear thousand times.

```
class FramePrivate {
public:
    FramePrivate( const QImage & img, Frame::ResizeMode mode,
        Frame * parent )
        :    m_image( img )
        ,    m_mode( mode )
        ,    q( parent )
    {
    }

    //! Create thumbnail.
    void createThumbnail();
    //! Frame widget was resized.
    void resized();

    //! Image.
    QImage m_image;
    //! Thumbnail.
    QImage m_thumbnail;
    //! Resize mode.
```

```
    Frame::ResizeMode m_mode;
    //! Parent.
    Frame * q;
}; // class FramePrivate
```

I declared two methods to create a thumbnail of needed size and auxiliary method to do some stuff when widget will be resized, as creating a thumbnail, notifying layouts about size change and updating our frame.

The creation of a thumbnail is different for different resize modes of a frame. For fit to size mode we need to scale in both directions keeping the aspect ratio of the image, whereas for the fit to height mode we just need to scale to height keeping aspect ratio too. Let's have a look.

```
void
FramePrivate::createThumbnail()
{
    if( m_image.width() > q->width() || m_image.height() > q->height() )
    {
        switch( m_mode )
        {
            case Frame::ResizeMode::FitToSize :
                m_thumbnail = m_image.scaled( q->width(), q->height(),
                    Qt::KeepAspectRatio, Qt::SmoothTransformation );
            break;

            case Frame::ResizeMode::FitToHeight :
                m_thumbnail = m_image.scaledToHeight( q->height(),
                    Qt::SmoothTransformation );
            break;
        }
    }
    else
        m_thumbnail = m_image;
}

void
FramePrivate::resized()
{
    createThumbnail();

    q->updateGeometry();

    q->update();
}
```

Some methods' implementations of `Frame` class are quite simple and don't need an explanation.

```
Frame::Frame( const QImage & img, ResizeMode mode, QWidget * parent )
    :    QWidget( parent )
    ,    d( new FramePrivate( img, mode, this ) )
{
    switch( mode )
    {
        case ResizeMode::FitToSize :
            setSizePolicy( QSizePolicy::Expanding, QSizePolicy::Expanding );
        break;

        case ResizeMode::FitToHeight :
            setSizePolicy( QSizePolicy::Fixed, QSizePolicy::Expanding );
        break;
    }
}

Frame::~Frame() noexcept
{
}

const QImage &
Frame::image() const
{
    return d->m_image;
}

void
Frame::setImage( const QImage & img )
{
    d->m_image = img;

    d->resized();
}

QSize
Frame::sizeHint() const
{
    return d->m_thumbnail.size();
}
```

Events

Painting needs just to draw a thumbnail in the center of the widget.

```
void
Frame::paintEvent( QPaintEvent * )
{
    const int x = ( width() - d->m_thumbnail.width() ) / 2;
    const int y = ( height() - d->m_thumbnail.height() ) / 2;
```

```
    QPainter p( this );
    QRect r = d->m_thumbnail.rect();
    r.moveTopLeft( QPoint( x, y ) );
    p.drawImage( r, d->m_thumbnail, d->m_thumbnail.rect() );
}
```

We want an image to be resized automatically on resizing of widget. That is why I overrided `resizeEvent()`.

```
void
Frame::resizeEvent( QResizeEvent * e )
{
    if( d->m_mode == ResizeMode::FitToSize ||
        ( d->m_mode == ResizeMode::FitToHeight && e->size().height() != d->m_thumbnail.height() ) )
            d->resized();

    e->accept();
}
```

In this resize event handler I have possible issue. Think on this method. Explanations you can find in Chapter 4.

And `mouseReleaseEvent()` to notify about clicking on the frame.

```
void
Frame::mouseReleaseEvent( QMouseEvent * e )
{
    if( e->button() == Qt::LeftButton )
    {
        emit clicked();

        e->accept();
    }
    else
        e->ignore();
}
```

Great, a few hundred lines of code (with blank ones and comments) and we have a class that will display image of the frame, have different behaviour for different cases. Qt rocks!

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Frame on tape

Well, we have a frame widget that will display a thumbnail image. But this is not enough for a frame on the tape. The frame on the tape should have a border, that should signal that this frame is current or not, the frame on the tape should have a checkbox to have the ability to remove some frames from the GIF, just deselect some frames, save file, and voila. And frame on the tape should have a counter, indicating the position of the frame on the tape.

Sounds like we can do it with standard widgets and layouts. We can create a widget, inherited from `QFrame` to have a border, `QCheckBox` for checkbox, `QLabel` for position indicator, and `QVBoxLayout` and `QHBoxLayout` for layout. Amazing, there is nothing better than reusing of the code, especially if this code written not by us.

The declaration of the new class looks like.

```
#ifndef GIF_EDITOR_FRAMEONTAPE_HPP_INCLUDED
#define GIF_EDITOR_FRAMEONTAPE_HPP_INCLUDED

// Qt include.
#include <QFrame>
#include <QScopedPointer>


//
// FrameOnTape
//

class FrameOnTapePrivate;

//! Frame on tape.
class FrameOnTape final
    :    public QFrame
{
    Q_OBJECT

signals:
    //! Clicked.
    void clicked( int idx );
    //! Checked.
    void checked( bool on );

public:
    FrameOnTape( const QImage & img, int counter, QWidget * parent = nullptr );
    ~FrameOnTape() noexcept override;

    //! \return Image.
    const QImage & image() const;
    //! Set image.
    void setImage( const QImage & img );

    //! \return Is frame checked.
    bool isChecked() const;
    //! Set checked.
    void setChecked( bool on = true );

    //! \return Counter.
    int counter() const;
    //! Set counter.
    void setCounter( int c );

    //! \return Is this frame current?
    bool isCurrent() const;
    //! Set current flag.
    void setCurrent( bool on = true );

private:
    Q_DISABLE_COPY( FrameOnTape )

    QScopedPointer< FrameOnTapePrivate > d;
}; // class FrameOnTape

#endif // GIF_EDITOR_FRAMEONTAPE_HPP_INCLUDED
```

Nothing difficult. We just added some auxiliary API to have access to the underlying full image, counter or position of the frame, ability to set and check if the current frame is current, and ability to check if this frame is checked.

Implementation really very simple. Look at private data class.

```
class FrameOnTapePrivate {
public:
    FrameOnTapePrivate( const QImage & img, int counter, FrameOnTape * parent )
        :    m_counter( counter )
        ,    m_current( false )
        ,    m_frame( new Frame( img, Frame::ResizeMode::FitToHeight, parent ) )
        ,    m_label( new QLabel( parent ) )
        ,    m_checkBox( new QCheckBox( parent ) )
        ,    q( parent )
    {
        m_checkBox->setChecked( true );

        m_label->setAlignment( Qt::AlignVCenter | Qt::AlignRight );
        m_label->setText( FrameOnTape::tr( "#%1" ).arg( m_counter ) );
    }

    //! Set current state.
    void setCurrent( bool on );

    //! Counter.
    int m_counter;
```

```
    //! Is current?
    bool m_current;
    //! Frame.
    Frame * m_frame;
    //! Counter label.
    QLabel * m_label;
    //! Check box.
    QCheckBox * m_checkBox;
    //! Parent.
    FrameOnTape * q;
}; // class FrameOnTapePrivate
```

We declared `setCurrent()` method as we will use this code more than once.

```
void
FrameOnTapePrivate::setCurrent( bool on )
{
    m_current = on;

    if( m_current )
        q->setFrameStyle( QFrame::Panel | QFrame::Sunken );
    else
        q->setFrameStyle( QFrame::Panel | QFrame::Raised );
}
```

We just changing a frame's style to indicate that this frame is currently selected.

And the implementation of the class is so simple that even doesn't need any comments.

```
FrameOnTape::FrameOnTape( const QImage & img, int counter, QWidget * parent )
    :    QFrame( parent )
    ,    d( new FrameOnTapePrivate( img, counter, this ) )
{
    auto vlayout = new QVBoxLayout( this );
    vlayout->setMargin( 0 );
    vlayout->addWidget( d->m_frame );

    auto hlayout = new QHBoxLayout;
    hlayout->setMargin( 0 );
    hlayout->addWidget( d->m_checkBox );
    hlayout->addWidget( d->m_label );

    vlayout->addLayout( hlayout );

    d->setCurrent( false );

    setLineWidth( 2 );

    setSizePolicy( QSizePolicy::Fixed, QSizePolicy::Expanding );

    connect( d->m_checkBox, &QCheckBox::stateChanged,
        [this] ( int state ) { emit this->checked( state != 0 ); } );
    connect( d->m_frame, &Frame::clicked,
        [this] ()
        {
            this->d->setCurrent( true );

            emit this->clicked( this->d->m_counter );
        } );
}

FrameOnTape::~FrameOnTape() noexcept
{
}

const QImage &
FrameOnTape::image() const
{
    return d->m_frame->image();
}

void
FrameOnTape::setImage( const QImage & img )
{
    d->m_frame->setImage( img );
}

bool
FrameOnTape::isChecked() const
{
    return d->m_checkBox->isChecked();
}

void
FrameOnTape::setChecked( bool on )
{
    d->m_checkBox->setChecked( on );
}

int
FrameOnTape::counter() const
{
    return d->m_counter;
}

void
FrameOnTape::setCounter( int c )
{
    d->m_counter = c;

    d->m_label->setText( tr( "#%1" ).arg( c ) );
}
```

```
bool
FrameOnTape::isCurrent() const
{
    return d->m_current;
}

void
FrameOnTape::setCurrent( bool on )
{
    d->setCurrent( on );
}
```

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Tape

Ok, now we have `FrameOnTape` class, but this class can display a single frame. But animated GIF has several frames. And we should display all frames in a sequence - tape. The tape should be a horizontally scrollable widget with all available frames in the GIF. Scrollable? This is simple, in Qt we have `QScrollArea` class, and we just need a widget that should have ability to add, remove frames on it, and should grow in width on adding new frames, as well as it should reduce its width on removing a frame.

Let's reuse as much code as possible. We just need a `QWidget` with `QHBoxLayout` where we will add `FrameOnTape` objects.

So, as usuaul, let's have a look at class declarartion.

```
#ifndef GIF_EDITOR_TAPE_HPP_INCLUDED
#define GIF_EDITOR_TAPE_HPP_INCLUDED

// Qt include.
#include <QWidget>
#include <QScopedPointer>


class FrameOnTape;


//
// Tape
//

class TapePrivate;

//! Tape with frames.
class Tape final
    :    public QWidget
{
    Q_OBJECT

signals:
    //! Frame clicked.
    void clicked( int idx );
    //! Current frame changed.
    void currentFrameChanged( int idx );

public:
    Tape( QWidget * parent = nullptr );
    ~Tape() noexcept override;

    //! \return Count of frames.
    int count() const;
    //! Add frame.
    void addFrame( const QImage & img );
    //! \return Frame.
    FrameOnTape * frame( int idx ) const;
    //! \return Current frame.
    FrameOnTape * currentFrame() const;
    //! Set current frame.
    void setCurrentFrame( int idx );
    //! Remove frame.
    void removeFrame( int idx );
    //! Clear.
    void clear();

private:
    Q_DISABLE_COPY( Tape )

    QScopedPointer< TapePrivate > d;
}; // class Tape

#endif // GIF_EDITOR_TAPE_HPP_INCLUDED
```

API is intuitive, it doesn't need an explanation, so let's look at the implementation.

Private data class looks like.

```
//
// TapePrivate
//

class TapePrivate {
public:
    TapePrivate( Tape * parent )
        :    m_currentFrame( nullptr )
        ,    m_layout( new QHBoxLayout( parent ) )
        ,    q( parent )
    {
        m_layout->setMargin( 5 );
        m_layout->setSpacing( 5 );
    }

    //! Frames.
    QList< FrameOnTape* > m_frames;
    //! Current frame.
    FrameOnTape * m_currentFrame;
    //! Layout.
    QHBoxLayout * m_layout;
    //! Parent.
    Tape * q;
}; // class TapePrivate
```

We need access to all frames, so we have a data member of type `QList< FrameOnTape >`, a auxiliary member that will hold a pointer to the currently selected frame, and our layout.

Trivial methods.

```
Tape::Tape( QWidget * parent )
    :    QWidget( parent )
    ,    d( new TapePrivate( this ) )
{
}

Tape::~Tape() noexcept
{
}

int
Tape::count() const
{
    return d->m_frames.count();
}

FrameOnTape *
Tape::frame( int idx ) const
{
    if( idx >= 1 && idx <= count() )
        return d->m_frames.at( idx - 1 );
    else
        return nullptr;
}

FrameOnTape *
Tape::currentFrame() const
{
    return d->m_currentFrame;
}

void
Tape::clear()
{
    const int c = count();

    for( int i = 1; i <= c; ++i )
        removeFrame( 1 );
}
```

Just will say that indexes in our API start from 1. Let's look at `addFrame()` method.

```
void
Tape::addFrame( const QImage & img )
{
    d->m_frames.append( new FrameOnTape( img, count() + 1, this ) );
    d->m_layout->addWidget( d->m_frames.back() );

    connect( d->m_frames.back(), &FrameOnTape::clicked,
        [this] ( int idx )
        {
            if( this->currentFrame() )
                this->currentFrame()->setCurrent( false );

            this->d->m_currentFrame = this->frame( idx );

            this->d->m_currentFrame->setCurrent( true );

            emit this->currentFrameChanged( idx );

            emit this->clicked( idx );
        } );

    adjustSize();
}
```

We created new `FrameOnTape` object, added it to the list and to the layout. Connected `clicked()` signal to do stuff for the current frame. And resized the entire widget. So, when a new frame will be added the tape will grow in width.

`setCurrentFrame()` is quite simple.

```
void
Tape::setCurrentFrame( int idx )
{
    if( idx >= 1 && idx <= count() )
    {
        if( d->m_currentFrame )
            d->m_currentFrame->setCurrent( false );

        d->m_currentFrame = frame( idx );
        d->m_currentFrame->setCurrent( true );

        emit currentFrameChanged( idx );
    }
    else
        d->m_currentFrame = nullptr;
}
```

And some magic in the `removeFrame()` method. I implemented it so when current frame deletes, a new one will become current, so we always will have selected frame.

```
void
```

```
Tape::removeFrame( int idx )
{
    if( idx <= count() )
    {
        d->m_layout->removeWidget( d->m_frames.at( idx - 1 ) );
        d->m_frames.at( idx - 1 )->deleteLater();

        if( d->m_frames.at( idx - 1 ) == d->m_currentFrame )
        {
            d->m_currentFrame = nullptr;

            if( idx > 1 )
            {
                d->m_currentFrame = d->m_frames.at( idx - 2 );
                d->m_currentFrame->setCurrent( true );

                emit currentFrameChanged( idx - 1 );
            }
            else if( idx < count() )
            {
                d->m_currentFrame = d->m_frames.at( idx );
                d->m_currentFrame->setCurrent( true );

                emit currentFrameChanged( idx + 1 );
            }
            else
                d->m_currentFrame = nullptr;
        }

        d->m_frames.removeAt( idx - 1 );

        adjustSize();
    }
}
```

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View

Now we have everything to display GIF, we just need to combine all together. We have `Frame` class that will display the current frame, we have `Tape` class that will display tape of frames. We need a widget that will combine the current frame with tape, that we will set as a central widget of our main window.

Declaration.

```
#ifndef GIF_EDITOR_VIEW_HPP_INCLUDED
#define GIF_EDITOR_VIEW_HPP_INCLUDED

// Qt include.
#include <QWidget>
#include <QScopedPointer>


class Tape;
class Frame;


//
// View
//

class ViewPrivate;

//! View with current frame and tape with frames.
class View final
    :    public QWidget
{
    Q_OBJECT

public:
    View( QWidget * parent = nullptr );
    ~View() noexcept override;

    //! \return Tape.
    Tape * tape() const;
    //! \return Current frame.
    Frame * currentFrame() const;

private slots:
    //! Frame selected.
    void frameSelected( int idx );

private:
    Q_DISABLE_COPY( View )

    QScopedPointer< ViewPrivate > d;
}; // class View

#endif // GIF_EDITOR_VIEW_HPP_INCLUDED
```

No magic at all, all is simple. Private data class.

```
class ViewPrivate {
public:
    ViewPrivate( View * parent )
        :    m_tape( nullptr )
        ,    m_currentFrame( new Frame( QImage(), Frame::ResizeMode::FitToSize, parent ) )
        ,    q( parent )
    {
    }

    //! Tape.
    Tape * m_tape;
    //! Current frame.
    Frame * m_currentFrame;
    //! Parent.
    View * q;
}; // class ViewPrivate
```

And again all is simple. Current frame will occupy all available space and initialized with an empty image.

You will not believe how implementation is simple. And again Qt rocks. Look.

```
View::View( QWidget * parent )
    :    QWidget( parent )
    ,    d( new ViewPrivate( this ) )
{
    QVBoxLayout * layout = new QVBoxLayout( this );
    layout->setMargin( 0 );
    layout->addWidget( d->m_currentFrame );

    QScrollArea * scroll = new QScrollArea( this );
    scroll->setVerticalScrollBarPolicy( Qt::ScrollBarAlwaysOff );
    scroll->setHorizontalScrollBarPolicy( Qt::ScrollBarAlwaysOn );
    scroll->setMinimumHeight( 150 );
    scroll->setMaximumHeight( 150 );
    scroll->setWidgetResizable( true );

    d->m_tape = new Tape( scroll );
    scroll->setWidget( d->m_tape );

    layout->addWidget( scroll );
```

```
    connect( d->m_tape, &Tape::currentFrameChanged,
        this, &View::frameSelected );
}

View::~View() noexcept
{
}

Tape *
View::tape() const
{
    return d->m_tape;
}

Frame *
View::currentFrame() const
{
    return d->m_currentFrame;
}

void
View::frameSelected( int idx )
{
    d->m_currentFrame->setImage( d->m_tape->frame( idx )->image() );
}
```

This is really simple. Now we just need to create an object of `View` class and set it as a central widget to the main window. UI part is ready to display a GIF image. And in the next section we will open GIF with Magick++ and use API of our UI classes to set the sequence of frames.

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Reading

In the UI we use `QImage`, but Magic++ works with its own `Image` class. We need conversion method from `Magick::Image` to `QImage`. Great place for this is in the main window private data class. We need to create an object of `View` class and set it as a central widget of the main window, and again the place for it is main window private data class. So let's look at it.

```
class MainWindowPrivate {
public:
    MainWindowPrivate( MainWindow * parent )
        :    m_view( new View( parent ) )
        ,    q( parent )
    {
    }

    //! Clear view.
    void clearView();
    //! Convert Magick::Image to QImage.
    QImage convert( const Magick::Image & img );

    //! Current file name.
    QString m_currentGif;
    //! Frames.
    std::vector< Magick::Image > m_frames;
    //! View.
    View * m_view;
    //! Parent.
    MainWindow * q;
}; // class MainWindowPrivate
```

We will work in the future with a sequence of `Magick::Image` objects for editing, so we have a data member for it. When GIf opened and we want to open a new one we should clear the current view, so let's look at the `clearView()` method.

```
void
MainWindowPrivate::clearView()
{
    m_frames.clear();
    m_view->tape()->clear();
    m_view->currentFrame()->setImage( QImage() );
}
```

No comments.

Conversion from `Magick::Image` to `QImage` is simple as well.

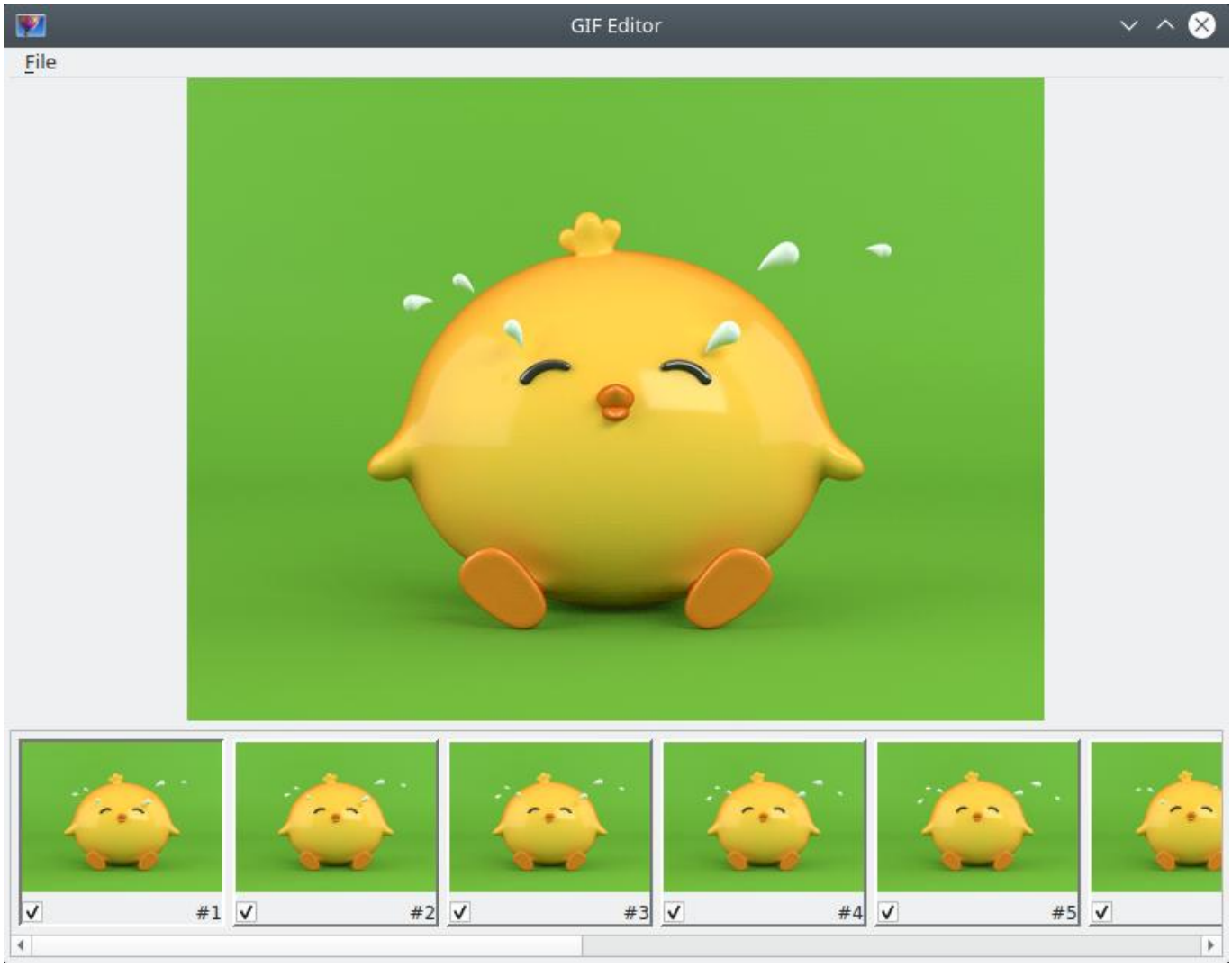
```
QImage
MainWindowPrivate::convert( const Magick::Image & img )
{
    QImage qimg( static_cast< int > ( img.columns() ),
        static_cast< int > ( img.rows() ), QImage::Format_RGB888 );
    const Magick::PixelPacket * pixels;
    Magick::ColorRGB rgb;

    for( int y = 0; y < qimg.height(); ++y)
    {
        pixels = img.getConstPixels( 0, y, static_cast< std::size_t > ( qimg.width() ), 1 );

        for( int x = 0; x < qimg.width(); ++x )
        {
            rgb = ( *( pixels + x ) );

            qimg.setPixel( x, y, QColor( static_cast< int> ( 255 * rgb.red() ),
                static_cast< int > ( 255 * rgb.green() ),
                static_cast< int > ( 255 * rgb.blue() ) ).rgb());
        }
    }

    return qimg;
}
```

Ok. We have empty `openGif()` slot in the `MainWindow` class. And to open GIF we should implement it.

```
void
MainWindow::openGif()
{
    const auto fileName = QFileDialog::getOpenFileName( this,
        tr( "Open GIF..." ), QString(), tr( "GIF (*.gif)" ) );

    if( !fileName.isEmpty() )
    {
        d->clearView();

        try {
            std::vector< Magick::Image > frames;

            Magick::readImages( &frames, fileName.toStdString() );

            Magick::coalesceImages( &d->m_frames, frames.begin(), frames.end() );

            std::for_each( d->m_frames.cbegin(), d->m_frames.cend(),
                [this] ( const Magick::Image & img )
                {
                    this->d->m_view->tape()->addFrame( this->d->convert( img ) );
                } );
```

```
            if( !d->m_frames.empty() )
                d->m_view->tape()->setCurrentFrame( 1 );
        }
        catch( const Magick::Exception & x )
        {
            d->clearView();

            QMessageBox::warning( this, tr( "Failed to open GIF..." ),
                QString::fromLocal8Bit( x.what() ) );
        }
    }
}
```

Simple, isn't it? You can believe, you can not believe, but editor now opens GIF images and displays all frames.



And this is less than 1K lines of code!

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Saving

We can open GIF, we can navigate through the frames, we can uncheck some frames. Let's do saving of GIF with regards to unchecked frames. This is a basic of any GIF editor. First of all we should notify user that file was changed when he checks/unchecks frames. For it we should connect to `Tape` 's `checkStateChanged()` signal. Let's do it in the constructor of MainWindow.

```
connect( d->m_view->tape(), &Tape::checkStateChanged,
        this, &MainWindow::frameChecked );
```

I changed a little `checkStateChanged()` signal, so it looks like.

```
//! Frame checked/unchecked.
void checkStateChanged( int idx, bool checked );
```

`MainWindow` 's `frameChecked()` slot is simple.

```
void
MainWindow::frameChecked( int, bool )
{
    setWindowModified( true );
}
```

We just notifying a user that GIF was changed. Let's have a look at `saveGifAs()` slot

```
void
MainWindow::saveGifAs()
{
    auto fileName = QFileDialog::getSaveFileName( this,
        tr( "Choose file to save to..." ), QString(), tr( "GIF (*.gif)" ) );

    if( !fileName.isEmpty() )
    {
        if( !fileName.endsWith( QLatin1String( ".gif" ), Qt::CaseInsensitive ) )
            fileName.append( QLatin1String( ".gif" ) );

        d->m_currentGif = fileName;

        QFileInfo info( fileName );

        setWindowTitle( tr( "GIF Editor - %1[*]" ).arg( info.fileName() ) );

        saveGif();
    }
}
```

So the main work is done in `saveGif()` slot.

```
void
MainWindow::saveGif()
{
    std::vector< Magick::Image > toSave;

    for( int i = 0; i < d->m_view->tape()->count(); ++i )
    {
        if( d->m_view->tape()->frame( i + 1 )->isChecked() )
            toSave.push_back( d->m_frames.at( static_cast< std::size_t > ( i ) ) );
    }

    if( !toSave.empty() )
    {
        try {
            Magick::writeImages( toSave.begin(), toSave.end(), d->m_currentGif.toStdString() );

            d->m_view->tape()->removeUnchecked();

            d->m_frames = toSave;

            setWindowModified( false );
        }
        catch( const Magick::Exception & x )
        {
            QMessageBox::warning( this, tr( "Failed to save GIF..." ),
                QString::fromLocal8Bit( x.what() ) );
        }
    }
    else
    {
        QMessageBox::information( this, tr( "Can't save GIF..." ),
            tr( "Can't save GIF image with no frames." ) );
    }
}
```

We just iterating through the frames and checking if they checked, saving all checked frames to the GIF, and if all is ok we updating UI. I added a new method to the `Tape` class to simplify this process.

```
void
```

```
Tape::removeUnchecked()
{
    const int c = count();
    int removed = 0;

    for( int i = 1; i <= c; ++i )
    {
        if( !frame( i - removed )->isChecked() )
        {
            removeFrame( i - removed );

            ++removed;
        }
        else
            frame( i - removed )->setCounter( i - removed );
    }
}
```

We just removing unchecked frames and updating counter.

To be more user friendly I changed a little `openGif()` slot.

```
void
MainWindow::openGif()
{
    const auto fileName = QFileDialog::getOpenFileName( this,
        tr( "Open GIF..." ), QString(), tr( "GIF (*.gif)" ) );

    if( !fileName.isEmpty() )
    {
        if( isWindowModified() )
        {
            const auto btn = QMessageBox::question( this,
                tr( "GIF was changed..." ),
                tr( "\"%1\" was changed.\n"
                    "Do you want to save it?" ) );

            if( btn == QMessageBox::Yes )
                saveGif();
        }

        d->clearView();

        setWindowModified( false );

        setWindowTitle( tr( "GIF Editor" ) );

        d->m_view->currentFrame()->setImage( QImage() );

        try {
            std::vector< Magick::Image > frames;

            Magick::readImages( &frames, fileName.toStdString() );

            Magick::coalesceImages( &d->m_frames, frames.begin(), frames.end() );

            QFileInfo info( fileName );

            setWindowTitle( tr( "GIF Editor - %1[*]" ).arg( info.fileName() ) );

            d->m_currentGif = fileName;

            std::for_each( d->m_frames.cbegin(), d->m_frames.cend(),
                [this] ( const Magick::Image & img )
                {
                    this->d->m_view->tape()->addFrame( this->d->convert( img ) );
                } );

            if( !d->m_frames.empty() )
                d->m_view->tape()->setCurrentFrame( 1 );
        }
        catch( const Magick::Exception & x )
        {
            d->clearView();

            QMessageBox::warning( this, tr( "Failed to open GIF..." ),
                QString::fromLocal8Bit( x.what() ) );
        }
    }
}
```

Just added a question, set window's title and a small exception safety.

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What else

As said for the first Alpha version we need a crop function. The user should be able to enable cropping from some action in the tab bar or menu. When the crop is enabled user should be able to draw by dragging mouse cursor a rectangle on the current frame. After releasing the mouse cursor user should be able to adjust drawn rectangle, and on "Enter" key pressing crop function should crop all frames in the GIF. Interesting, isn't it?

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Crop

As said we need to implement a crop function. First of all we need to implement a widget that will draw a rectangle on top of the current frame, that will show the crop region. I spent on this widget not so little time, a day, this is because this widget is very custom and complicated in implementation, not hard but complicated. There are a lot of calculations of regions of handles for adjusting the rectangle, mouse cursor handling, cursor overriding, etc. Let's have a look at this widget.

Widget

Declaration.

```
#ifndef GIF_EDITOR_CROP_HPP_INCLUDED
#define GIF_EDITOR_CROP_HPP_INCLUDED

// Qt include.
#include <QWidget>
#include <QScopedPointer>

class Frame;


//
// CropFrame
//

class CropFramePrivate;

//! Crop frame.
class CropFrame final
    :    public QWidget
{
    Q_OBJECT

public:
    CropFrame( Frame * parent = nullptr );
    ~CropFrame() noexcept override;

    //! \return Crop rectangle.
    QRect cropRect() const;

public slots:
    //! Start.
    void start();
    //! Stop.
    void stop();

private slots:
    //! Frame resized.
    void frameResized();

protected:
    void paintEvent( QPaintEvent * ) override;
    void mousePressEvent( QMouseEvent * e ) override;
    void mouseMoveEvent( QMouseEvent * e ) override;
    void mouseReleaseEvent( QMouseEvent * e ) override;
    void enterEvent( QEvent * e ) override;
    void leaveEvent( QEvent * e ) override;

private:
    Q_DISABLE_COPY( CropFrame )

    QScopedPointer< CropFramePrivate > d;
}; // class CropFrame

#endif // GIF_EDITOR_CROP_HPP_INCLUDED
```

API is simple, but let's look at what is under the hood.

Crop rectangle will have handles to change the geometry of the rectangle. And in the code I defined a constant to store the size for it.

```
//! Size of the handle to change geometry of selected region.
static const int c_handleSize = 15;
```

Private data class.

```
class CropFramePrivate {
public:
    CropFramePrivate( CropFrame * parent, Frame * toObserve )
        :    m_started( false )
        ,    m_nothing( true )
        ,    m_clicked( false )
        ,    m_hovered( false )
        ,    m_cursorOverriden( false )
        ,    m_handle( Handle::Unknown )
        ,    m_frame( toObserve )
        ,    q( parent )
    {
    }

    enum class Handle {
        Unknown,
```

```
        TopLeft,
        Top,
        TopRight,
        Right,
        BottomRight,
        Bottom,
        BottomLeft,
        Left
    }; // enum class Handle

    //! Bound point to available space.
    QPoint boundToAvailable( const QPoint & p ) const;
    //! Bound left top point to available space.
    QPoint boundLeftTopToAvailable( const QPoint & p ) const;
    //! Check and override cursor if necessary.
    void checkAndOverrideCursor( Qt::CursorShape shape );
    //! Override cursor.
    void overrideCursor( const QPoint & pos );
    //! Resize crop.
    void resize( const QPoint & pos ) ;
    //! \return Cropped rect.
    QRect cropped( const QRect & full ) const;
    //! \return Is handles should be outside selected rect.
    bool isHandleOutside() const
    {
        return ( qAbs( m_selected.width() ) / 3 < c_handleSize + 1 ||
            qAbs( m_selected.height() ) / 3 < c_handleSize + 1 );
    }
    //! \return Top-left handle rect.
    QRect topLeftHandleRect() const
    {
        return ( isHandleOutside() ?
            QRect( m_selected.x() - ( m_selected.width() > 0 ? c_handleSize : 0 ),
                m_selected.y() - ( m_selected.height() > 0 ? c_handleSize : 0 ),
                c_handleSize, c_handleSize ) :
            QRect( m_selected.x() - ( m_selected.width() > 0 ? 0 : c_handleSize ),
                m_selected.y() - ( m_selected.height() > 0 ? 0 : c_handleSize ),
                c_handleSize, c_handleSize ) );
    }
    //! \return Top-right handle rect.
    QRect topRightHandleRect() const
    {
        return ( isHandleOutside() ?
            QRect( m_selected.x() + m_selected.width() - 1 -
                    ( m_selected.width() > 0 ? 0 : c_handleSize ),
                m_selected.y() - ( m_selected.height() > 0 ? c_handleSize : 0 ),
                c_handleSize, c_handleSize ) :
            QRect( m_selected.x() + m_selected.width() -
                    ( m_selected.width() > 0 ? c_handleSize : 0 ) - 1,
                m_selected.y() - ( m_selected.height() > 0 ? 0 : c_handleSize ),
                c_handleSize, c_handleSize ) );
    }
    //! \return Bottom-right handle rect.
    QRect bottomRightHandleRect() const
    {
        return ( isHandleOutside() ?
            QRect( m_selected.x() + m_selected.width() - 1 -
                    ( m_selected.width() > 0 ? 0 : c_handleSize ),
                m_selected.y() + m_selected.height() -
                    ( m_selected.height() > 0 ? 0 : c_handleSize ),
                c_handleSize, c_handleSize ) :
            QRect( m_selected.x() + m_selected.width() -
                    ( m_selected.width() > 0 ? c_handleSize : 0 ) - 1,
                m_selected.y() + m_selected.height() -
                    ( m_selected.height() > 0 ? c_handleSize : 0 )  - 1,
                c_handleSize, c_handleSize ) );
    }
    //! \return Bottom-left handle rect.
    QRect bottomLeftHandleRect() const
    {
        return ( isHandleOutside() ?
            QRect( m_selected.x() - ( m_selected.width() > 0 ? c_handleSize : 0 ),
                m_selected.y() + m_selected.height() - 1 -
                    ( m_selected.height() > 0 ? 0 : c_handleSize),
                c_handleSize, c_handleSize ) :
            QRect( m_selected.x() - ( m_selected.width() > 0 ? 0 : c_handleSize),
                m_selected.y() + m_selected.height() -
                    ( m_selected.height() > 0 ? c_handleSize : 0 ) - 1,
                c_handleSize, c_handleSize ) );
    }
    //! \return Y handle width.
    int yHandleWidth() const
    {
        const int w = m_selected.width() - 1;

        return ( isHandleOutside() ? w :
            w - 2 * c_handleSize - ( w - 2 * c_handleSize ) / 3 );
    }
    //! \return X handle height.
    int xHandleHeight() const
    {
        const int h = m_selected.height() - 1;

        return ( isHandleOutside() ? h :
            h - 2 * c_handleSize - ( h - 2 * c_handleSize ) / 3 );
    }
    //! \return Y handle x position.
    int yHandleXPos() const
    {
        return ( m_selected.x() + ( m_selected.width() - yHandleWidth() ) / 2 );
    }
    //! \return X handle y position.
    int xHandleYPos() const
    {
        return ( m_selected.y() + ( m_selected.height() - xHandleHeight() ) / 2 );
    }
    //! \return Top handle rect.
    QRect topHandleRect() const
    {
        return ( isHandleOutside() ?
            QRect( yHandleXPos(), m_selected.y() - ( m_selected.height() > 0 ? c_handleSize : 0 ),
```

```
                yHandleWidth(), c_handleSize ) :
            QRect( yHandleXPos(), m_selected.y() - ( m_selected.height() > 0 ? 0 : c_handleSize ),
                yHandleWidth(), c_handleSize ) );
    }
    //! \return Bottom handle rect.
    QRect bottomHandleRect() const
    {
        return ( isHandleOutside() ?
            QRect( yHandleXPos(), m_selected.y() + m_selected.height() - 1 -
                    ( m_selected.height() > 0 ? 0 : c_handleSize ),
                yHandleWidth(), c_handleSize ) :
            QRect( yHandleXPos(), m_selected.y() + m_selected.height() - 1 -
                    ( m_selected.height() > 0 ? c_handleSize : 0 ),
                yHandleWidth(), c_handleSize ) );
    }
    //! \return Left handle rect.
    QRect leftHandleRect() const
    {
        return ( isHandleOutside() ?
            QRect( m_selected.x() - ( m_selected.width() > 0 ? c_handleSize : 0 ),
                xHandleYPos(), c_handleSize, xHandleHeight() ) :
            QRect( m_selected.x() - ( m_selected.width() > 0 ? 0 : c_handleSize ),
                xHandleYPos(), c_handleSize, xHandleHeight() ) );
    }
    //! \return Right handle rect.
    QRect rightHandleRect() const
    {
        return ( isHandleOutside() ?
            QRect( m_selected.x() + m_selected.width() - 1 -
                    ( m_selected.width() > 0 ? 0 : c_handleSize ),
                xHandleYPos(), c_handleSize, xHandleHeight() ) :
            QRect( m_selected.x() + m_selected.width() - 1 -
                    ( m_selected.width() > 0 ? c_handleSize : 0 ),
                xHandleYPos(), c_handleSize, xHandleHeight() ) );
    }

    //! Selected rectangle.
    QRect m_selected;
    //! Available rectangle.
    QRect m_available;
    //! Mouse pos.
    QPoint m_mousePos;
    //! Selecting started.
    bool m_started;
    //! Nothing selected yet.
    bool m_nothing;
    //! Clicked.
    bool m_clicked;
    //! Hover entered.
    bool m_hovered;
    //! Cursor overriden.
    bool m_cursorOverriden;
    //! Current handle.
    Handle m_handle;
    //! Frame to observe resize event.
    Frame * m_frame;
    //! Parent.
    CropFrame * q;
}; // class CropFramePrivate
```

Uhh, so many methods... I defined some methods in the class, these methods just returns rectangles of the handles, you could understand it from their names.

We will resize, move selection rectangle, and we don't want this rectangle to go out of frame boundary. And for this task we have two auxiliary methods.

```
QPoint
CropFramePrivate::boundToAvailable( const QPoint & p ) const
{
    QPoint ret = p;

    if( p.x() < m_available.x() )
        ret.setX( m_available.x() );
    else if( p.x() > m_available.x() + m_available.width() - 1 )
        ret.setX( m_available.x() + m_available.width() - 1 );

    if( p.y() < m_available.y() )
        ret.setY( m_available.y() );
    else if( p.y() > m_available.y() + m_available.height() - 1 )
        ret.setY( m_available.y() + m_available.height() - 1 );

    return ret;
}

QPoint
CropFramePrivate::boundLeftTopToAvailable( const QPoint & p ) const
{
    QPoint ret = p;

    if( p.x() < m_available.x() )
        ret.setX( m_available.x() );
    else if( p.x() > m_available.x() + m_available.width() - m_selected.width() - 1)
        ret.setX( m_available.x() + m_available.width() - m_selected.width() - 1 );

    if( p.y() < m_available.y() )
        ret.setY( m_available.y() );
    else if( p.y() > m_available.y() + m_available.height() - m_selected.height() - 1 )
        ret.setY( m_available.y() + m_available.height() - m_selected.height() - 1 );

    return ret;
}
```

When the user moves the mouse cursor over the widget, different regions we need to override cursor to help the user

understand what he can do. Auxiliary methods to override cursor.

```
void
CropFramePrivate::checkAndOverrideCursor( Qt::CursorShape shape )
{
    if( QApplication::overrideCursor() )
    {
        if( *QApplication::overrideCursor() != QCursor( shape ) )
        {
            if( m_cursorOverriden )
                QApplication::restoreOverrideCursor();
            else
                m_cursorOverriden = true;

            QApplication::setOverrideCursor( QCursor( shape ) );
        }
    }
    else
    {
        m_cursorOverriden = true;

        QApplication::setOverrideCursor( QCursor( shape ) );
    }
}

void
CropFramePrivate::overrideCursor( const QPoint & pos )
{
    if( topLeftHandleRect().contains( pos ) )
    {
        m_handle = CropFramePrivate::Handle::TopLeft;
        checkAndOverrideCursor( Qt::SizeFDiagCursor );
    }
    else if( bottomRightHandleRect().contains( pos ) )
    {
        m_handle = CropFramePrivate::Handle::BottomRight;
        checkAndOverrideCursor( Qt::SizeFDiagCursor );
    }
    else if( topRightHandleRect().contains( pos ) )
    {
        m_handle = CropFramePrivate::Handle::TopRight;
        checkAndOverrideCursor( Qt::SizeBDiagCursor );
    }
    else if( bottomLeftHandleRect().contains( pos ) )
    {
        m_handle = CropFramePrivate::Handle::BottomLeft;
        checkAndOverrideCursor( Qt::SizeBDiagCursor );
    }
    else if( topHandleRect().contains( pos ) )
    {
        m_handle = CropFramePrivate::Handle::Top;
        checkAndOverrideCursor( Qt::SizeVerCursor );
    }
    else if( bottomHandleRect().contains( pos ) )
    {
        m_handle = CropFramePrivate::Handle::Bottom;
        checkAndOverrideCursor( Qt::SizeVerCursor );
    }
    else if( leftHandleRect().contains( pos ) )
    {
        m_handle = CropFramePrivate::Handle::Left;
        checkAndOverrideCursor( Qt::SizeHorCursor );
    }
    else if( rightHandleRect().contains( pos ) )
    {
        m_handle = CropFramePrivate::Handle::Right;
        checkAndOverrideCursor( Qt::SizeHorCursor );
    }
    else if( m_selected.contains( pos ) )
    {
        m_handle = CropFramePrivate::Handle::Unknown;
        checkAndOverrideCursor( Qt::SizeAllCursor );
    }
    else if( m_cursorOverriden )
    {
        m_cursorOverriden = false;
        m_handle = CropFramePrivate::Handle::Unknown;
        QApplication::restoreOverrideCursor();
    }
}
```

When user presses and moves handle selection rectangle should resize, so the method for it.

```
void
CropFramePrivate::resize( const QPoint & pos )
{
    switch( m_handle )
    {
        case CropFramePrivate::Handle::Unknown :
            m_selected.moveTo( boundLeftTopToAvailable(
                m_selected.topLeft() - m_mousePos + pos ) );
        break;

        case CropFramePrivate::Handle::TopLeft :
            m_selected.setTopLeft( boundToAvailable( m_selected.topLeft() -
                m_mousePos + pos ) );
        break;

        case CropFramePrivate::Handle::TopRight :
            m_selected.setTopRight( boundToAvailable( m_selected.topRight() -
                m_mousePos + pos ) );
        break;

        case CropFramePrivate::Handle::BottomRight :
            m_selected.setBottomRight( boundToAvailable( m_selected.bottomRight() -
                m_mousePos + pos ) );
        break;
```

```
        case CropFramePrivate::Handle::BottomLeft :
            m_selected.setBottomLeft( boundToAvailable( m_selected.bottomLeft() -
                m_mousePos + pos ) );
        break;

        case CropFramePrivate::Handle::Top :
            m_selected.setTop( boundToAvailable( QPoint( m_selected.left(), m_selected.top() ) -
                m_mousePos + pos ).y() );
        break;

        case CropFramePrivate::Handle::Bottom :
            m_selected.setBottom( boundToAvailable( QPoint( m_selected.left(),
                m_selected.bottom() ) - m_mousePos + pos ).y() );
        break;

        case CropFramePrivate::Handle::Left :
            m_selected.setLeft( boundToAvailable( QPoint( m_selected.left(),
                m_selected.top() ) - m_mousePos + pos ).x() );
        break;

        case CropFramePrivate::Handle::Right :
            m_selected.setRight( boundToAvailable( QPoint( m_selected.right(),
                m_selected.top() ) - m_mousePos + pos ).x() );
        break;
    }

    m_mousePos = pos;
}
```

We can draw a crop rectangle on the scaled frame, but for cropping we need to know rectangle to crop in the original frame's coordinates.

```
QRect
CropFramePrivate::cropped( const QRect & full ) const
{
    const auto oldR = m_available;

    const qreal xRatio = static_cast< qreal > ( full.width() ) /
        static_cast< qreal > ( oldR.width() );
    const qreal yRatio = static_cast< qreal > ( full.height() ) /
        static_cast< qreal > ( oldR.height() );

    QRect r;

    if( !m_nothing )
    {
        const auto x = static_cast< int >( ( m_selected.x() - oldR.x() ) * xRatio ) +
            full.x();
        const auto y = static_cast< int >( ( m_selected.y() - oldR.y() ) * yRatio ) +
            full.y();
        const auto dx = full.bottomRight().x() - static_cast< int >(
            ( oldR.bottomRight().x() - m_selected.bottomRight().x() ) * xRatio );
        const auto dy = full.bottomRight().y() - static_cast< int >(
            ( oldR.bottomRight().y() - m_selected.bottomRight().y() ) * yRatio );

        r.setTopLeft( QPoint( x, y ) );
        r.setBottomRight( QPoint( dx, dy ) );
    }

    return r;
}
```

You can ask how it's possible to write all these methods first and only then implement methods of the widget? I guess that this is impossible. I wrote a skeleton of widget and step by step wrote code, so these private data methods were born from time to time when they were needed. Developing is an iterative process. With some experience you will come to it, but I believe that you are an experienced C++ developer and just want to quickly look at working methods to develop on Qt's widgets. Let's go.

The widget is very simple with all these auxiliary methods, have a look.

```
CropFrame::CropFrame( Frame * parent )
    :    QWidget( parent )
    ,    d( new CropFramePrivate( this, parent ) )
{
    setAutoFillBackground( false );
    setAttribute( Qt::WA_TranslucentBackground, true );
    setMouseTracking( true );

    d->m_available = parent->imageRect();

    connect( d->m_frame, &Frame::resized,
        this, &CropFrame::frameResized );
}

CropFrame::~CropFrame() noexcept
{
    if( d->m_cursorOverriden )
        QApplication::restoreOverrideCursor();

    if( d->m_hovered )
        QApplication::restoreOverrideCursor();
}

QRect
CropFrame::cropRect() const
{
    return d->cropped( d->m_frame->image().rect() );
}

void
CropFrame::start()
{
    d->m_started = true;
```

```
    d->m_nothing = true;

    update();
}

void
CropFrame::stop()
{
    d->m_started = false;

    update();
}
```

I added to `Frame` class `resized()` signal to handle resizing and correctly resize selection region.

```
void
CropFrame::frameResized()
{
    d->m_selected = d->cropped( d->m_frame->imageRect() );

    setGeometry( QRect( 0, 0, d->m_frame->width(), d->m_frame->height() ) );

    d->m_available = d->m_frame->imageRect();

    update();
}
```

Painting of our widget.

```
void
CropFrame::paintEvent( QPaintEvent * )
{
    static const QColor dark( 0, 0, 0, 100 );

    QPainter p( this );
    p.setPen( Qt::black );
    p.setBrush( dark );

    if( d->m_started && !d->m_nothing )
    {
        QPainterPath path;
        path.addRect( QRectF( d->m_available ).adjusted( 0, 0, -1, -1 ) );

        if( d->m_available != d->m_selected )
        {
            QPainterPath spath;
            spath.addRect( QRectF( d->m_selected ).adjusted( 0, 0, -1, -1 ) );
            path = path.subtracted( spath );
        }
        else
            p.setBrush( Qt::transparent );

        p.drawPath( path );
    }

    p.setBrush( Qt::transparent );

    if( d->m_started && !d->m_clicked && !d->m_nothing &&
        d->m_handle == CropFramePrivate::Handle::Unknown )
    {
        p.drawRect( d->topLeftHandleRect() );
        p.drawRect( d->topRightHandleRect() );
        p.drawRect( d->bottomRightHandleRect() );
        p.drawRect( d->bottomLeftHandleRect() );
    }
    else if( d->m_started && !d->m_nothing &&
        d->m_handle != CropFramePrivate::Handle::Unknown )
    {
        switch( d->m_handle )
        {
            case CropFramePrivate::Handle::TopLeft :
                p.drawRect( d->topLeftHandleRect() );
            break;

            case CropFramePrivate::Handle::TopRight :
                p.drawRect( d->topRightHandleRect() );
            break;

            case CropFramePrivate::Handle::BottomRight :
                p.drawRect( d->bottomRightHandleRect() );
            break;

            case CropFramePrivate::Handle::BottomLeft :
                p.drawRect( d->bottomLeftHandleRect() );
            break;

            case CropFramePrivate::Handle::Top :
                p.drawRect( d->topHandleRect() );
            break;

            case CropFramePrivate::Handle::Bottom :
                p.drawRect( d->bottomHandleRect() );
            break;

            case CropFramePrivate::Handle::Left :
                p.drawRect( d->leftHandleRect() );
            break;

            case CropFramePrivate::Handle::Right :
                p.drawRect( d->rightHandleRect() );
            break;

            default:
                break;
```

```
        }
    }
}
```

The behaviour of crop region is like in Gimp. When user has drawn rectangle on mouse release he will see a transparent rectangle with darkening semi-transparent background on a non-selected region and corner handles. To access the top, bottom, left and right handles user should move the mouse cursor in the centres of the edges. And when the mouse cursor is on a handle, only this handle will be drawn and the mouse cursor will be overridden, like in Gimp.

And mouse handling.

```
void
CropFrame::mousePressEvent( QMouseEvent * e )
{
    if( e->button() == Qt::LeftButton )
    {
        d->m_clicked = true;

        if( !d->m_cursorOverriden )
            d->m_selected.setTopLeft( d->boundToAvailable( e->pos() ) );
        else
            d->m_mousePos = e->pos();

        update();

        e->accept();
    }
    else
        e->ignore();
}

void
CropFrame::mouseMoveEvent( QMouseEvent * e )
{
    if( d->m_clicked )
    {
        if ( !d->m_cursorOverriden )
        {
            d->m_selected.setBottomRight( d->boundToAvailable( e->pos() ) );

            d->m_nothing = false;
        }
        else
            d->resize( e->pos() );

        update();

        e->accept();
    }
    else if( !d->m_hovered )
    {
        d->m_hovered = true;

        QApplication::setOverrideCursor( QCursor( Qt::CrossCursor ) );
    }
    else if( d->m_hovered && !d->m_nothing )
    {
        d->overrideCursor( e->pos() );

        update();
    }
    else
        e->ignore();
}

void
CropFrame::mouseReleaseEvent( QMouseEvent * e )
{
    d->m_clicked = false;

    if( e->button() == Qt::LeftButton )
    {
        d->m_selected = d->m_selected.normalized();

        update();

        e->accept();
    }
    else
        e->ignore();
}

void
CropFrame::enterEvent( QEvent * e )
{
    if( d->m_started )
    {
        d->m_hovered = true;

        QApplication::setOverrideCursor( QCursor( Qt::CrossCursor ) );

        e->accept();
    }
    else
        e->ignore();
}

void
CropFrame::leaveEvent( QEvent * e )
{
    if( d->m_started )
    {
        d->m_hovered = false;

        QApplication::restoreOverrideCursor();
```

```
        e->accept();
    }
    else
        e->ignore();
}
```

Integrating crop frame into view

In the `View` private data class I added pointer to `CropFrame` widget.

```
//! Crop.
CropFrame * m_crop;
```

And two slots to start and stop crop operation.

```
void
View::startCrop()
{
    if( !d->m_crop )
    {
        d->m_crop = new CropFrame( d->m_currentFrame );
        d->m_crop->setGeometry( QRect( 0, 0,
            d->m_currentFrame->width(), d->m_currentFrame->height() ) );
        d->m_crop->show();
        d->m_crop->raise();
        d->m_crop->start();
    }
}

void
View::stopCrop()
{
    if( d->m_crop )
    {
        d->m_crop->stop();
        d->m_crop->deleteLater();
        d->m_crop = nullptr;
    }
}
```

So crop frame will be the same size as current frame widget and will be placed on top of it.

To access crop region I added a method.

```
QRect
View::cropRect() const
{
    if( d->m_crop )
        return d->m_crop->cropRect();
    else
        return QRect();
}
```

Nothing more.

Cropping

We need menu and tool bar to start, finish and cancel crop operation, so in `MainWindow` 's constructor we added.

```
d->m_crop = new QAction( QIcon( ":/img/transform-crop.png" ),
    tr( "Crop" ), this );
d->m_crop->setShortcut( tr( "Ctrl+C" ) );
d->m_crop->setShortcutContext( Qt::ApplicationShortcut );
d->m_crop->setCheckable( true );
d->m_crop->setChecked( false );
d->m_crop->setEnabled( false );

d->m_applyEdit = new QAction( this );
d->m_applyEdit->setShortcut( Qt::Key_Return );
d->m_applyEdit->setShortcutContext( Qt::ApplicationShortcut );
d->m_applyEdit->setEnabled( false );

d->m_cancelEdit = new QAction( this );
d->m_cancelEdit->setShortcut( Qt::Key_Escape );
d->m_cancelEdit->setShortcutContext( Qt::ApplicationShortcut );
    d->m_cancelEdit->setEnabled( false );

addAction( d->m_applyEdit );
addAction( d->m_cancelEdit );

connect( d->m_crop, &QAction::triggered, this, &MainWindow::crop );
connect( d->m_applyEdit, &QAction::triggered, this, &MainWindow::applyEdit );
connect( d->m_cancelEdit, &QAction::triggered, this, &MainWindow::cancelEdit );

auto edit = menuBar()->addMenu( tr( "&Edit" ) );
edit->addAction( d->m_crop );

auto editToolBar = new QToolBar( tr( "Edit" ), this );
editToolBar->addAction( d->m_crop );
```

```
addToolBar( Qt::LeftToolBarArea, editToolBar );
```

Reaction on triggering crop action is simple.

```
void
MainWindow::crop( bool on )
{
    if( on )
    {
        d->enableFileActions( false );

        d->m_editMode = MainWindowPrivate::EditMode::Crop;

        d->m_view->startCrop();
    }
    else
    {
        d->m_view->stopCrop();

        d->m_editMode = MainWindowPrivate::EditMode::Unknow;

        d->enableFileActions();
    }
}
```

Where.

```
//! Enable file actions.
void enableFileActions( bool on = true )
{
    m_save->setEnabled( on );
    m_saveAs->setEnabled( on );
    m_open->setEnabled( on );

    m_applyEdit->setEnabled( !on );
    m_cancelEdit->setEnabled( !on );
}
```

Cancelling and applying crop operation.

```
void
MainWindow::cancelEdit()
{
    switch( d->m_editMode )
    {
        case MainWindowPrivate::EditMode::Crop :
        {
            d->m_view->stopCrop();

            d->enableFileActions();

            d->m_crop->setChecked( false );

            d->m_editMode = MainWindowPrivate::EditMode::Unknow;
        }
            break;

        default :
            break;
    }
}

void
MainWindow::applyEdit()
{
    switch( d->m_editMode )
    {
        case MainWindowPrivate::EditMode::Crop :
        {
            const auto rect = d->m_view->cropRect();

            if( !rect.isNull() && rect != d->m_view->currentFrame()->image().rect() )
            {
                QVector< int > unchecked;

                for( int i = 1; i <= d->m_view->tape()->count(); ++i )
                {
                    if( !d->m_view->tape()->frame( i )->isChecked() )
                        unchecked.append( i );
                }

                try {
                    auto tmpFrames = d->m_frames;

                    std::for_each( tmpFrames.begin(), tmpFrames.end(),
                        [&rect] ( auto & frame )
                        {
                            frame.crop( Magick::Geometry( rect.width(), rect.height(),
                                rect.x(), rect.y() ) );
                            frame.repage();
                        } );

                    const auto current = d->m_view->tape()->currentFrame()->counter();
                    d->m_view->tape()->clear();
                    d->m_frames = tmpFrames;

                    d->initTape();

                    d->m_view->tape()->setCurrentFrame( current );
```

```
                    for( const auto & i : qAsConst( unchecked ) )
                        d->m_view->tape()->frame( i )->setChecked( false );

                    setWindowModified( true );

                    cancelEdit();
                }
                catch( const Magick::Exception & x )
                {
                    cancelEdit();

                    QMessageBox::warning( this, tr( "Failed to crop GIF..." ),
                        QString::fromLocal8Bit( x.what() ) );
                }
            }
            else
                cancelEdit();
        }
            break;

        default :
            break;
    }
}
```

That's all. Now our editor can crop GIFs. So first Alpha version almost done.

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About

And the last step. Let's add Help menu with about dialogues.

In the `MainWindow` constructor.

```
auto help = menuBar()->addMenu( tr( "&Help" ) );
help->addAction( QIcon( ":/img/icon_22x22.png" ), tr( "About" ),
    this, &MainWindow::about );
help->addAction( QIcon( ":/img/qt.png" ), tr( "About Qt" ),
    this, &MainWindow::aboutQt );
```

And slots.

```
void
MainWindow::about()
{
    QMessageBox::about( this, tr( "About GIF editor" ),
        tr( "GIF editor.\n\n"
            "Author - Igor Mironchik (igor.mironchik at gmail dot com).\n\n"
            "Copyright (c) 2018 Igor Mironchik.\n\n"
            "Licensed under GNU GPL 3.0." ) );
}

void
MainWindow::aboutQt()
{
    QMessageBox::aboutQt( this );
}
```

Have a good day!

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Chapter 2

In this chapter I will show how to work with `QCamera`, `QAbstractVideoSurface`. How to detect motion with OpenCV, capture with `QCamera` frames and store them in some place on the disk. This chapter is based on the real project SecurityCam that places on GitHub https://github.com/igormironchik/security-cam

In this chapter I will describe only the most interesting parts of the code of SecurityCam, I won't show you how I save configuration file, how I organized configuration of the application. Only a few words, that for reading/saving configuration file I used cfgfile. This is Open Source library for reading and saving configurations. It places on GitHub https://github.com/igormironchik/cfgfile

SecurityCam is an application that connects to USB camera and tries to detect motions in the frame, as soon as motion is detected camera starts to capture images and store them in the configured folder with yyyy/MM/dd hierarchy. SecurityCam can do clean at the configured time and delete folders with images that stored more than N days.

The window of the application displays stream from the camera and on closing minimizes to tray, so the application works in the background and protects the entrusted territory.

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View

In this project we want to detect motion in the frame, so we need to have access to each frame in the camera's stream. So the only solution is `QAbstractVideoSurface`. And we want to display stream from a camera in some case of viewfinder. We need to tie together `QAbstractVideoSurface` and any viewfinder. I see only one solution - is to transmit `QImage` with the current frame from `QAbstractVideoSurface` to custom viewfinder, that will display the current frame.

So let's do such a view finder.

```
#ifndef SECURITYCAM_VIEW_HPP_INCLUDED
#define SECURITYCAM_VIEW_HPP_INCLUDED

// Qt include.
#include <QWidget>
#include <QScopedPointer>


namespace SecurityCam {

//
// View
//

class ViewPrivate;

//! View of the video data from the camera.
class View final
    :    public QWidget
{
    Q_OBJECT

public:
    explicit View( QWidget * parent );
    ~View() noexcept override;

public slots:
    //! Draw image.
    void draw( const QImage & image );

protected:
    void paintEvent( QPaintEvent * ) override;
    void resizeEvent( QResizeEvent * e ) override;

private:
    Q_DISABLE_COPY( View )

    QScopedPointer< ViewPrivate > d;
}; // class View

} /* namespace SecurityCam */

#endif // SECURITYCAM_VIEW_HPP_INCLUDED
```

Private data class.

```
class ViewPrivate {
public:
    explicit ViewPrivate( View * parent )
        :    m_resized( false )
        ,    q( parent )
    {
    }

    //! Image.
    QImage m_image;
    //! Resized?
    bool m_resized;
    //! Parent.
    View * q;
}; // class ViewPrivate
```

In the data class I store the current frame and a flag that current frame was resized. This is the main trick, `draw()` slot will be connected to video surface signal and will receive frames at maximum speed in the background, where we will just copy frame and set resized flag to false, and will trigger an update of the widget. GUI part of the view will draw a new frame when it can do it, so we will not have a long queue of frames to draw, we will quickly process this queue. Let's look.

```
View::View( QWidget * parent )
    :    QWidget( parent )
    ,    d( new ViewPrivate( this ) )
{
    d->init();
}

View::~View() noexcept
{
}

void
View::draw( const QImage & image )
{
    d->m_resized = false;

    d->m_image = image;

    update();
```

```
}

void
View::paintEvent( QPaintEvent * )
{
    if( isVisible() )
    {
        QPainter p( this );

        if( !d->m_image.isNull() )
        {
            if( !d->m_resized )
            {
                d->m_image = d->m_image.scaled( size(), Qt::KeepAspectRatio );

                d->m_resized = true;
            }

            const int x = rect().x() + ( size().width() - d->m_image.width() ) / 2;
            const int y = rect().y() + ( size().height() - d->m_image.height() ) / 2;

            p.drawImage( x, y, d->m_image );
        }
    }
}

void
View::resizeEvent( QResizeEvent * e )
{
    e->accept();

    d->m_resized = false;

    update();
}
```

We do actual resize of the frame only in paint event and only if it was not done before. Believe me, in the running application I don't see any flickering. This simple code does what it was designed for. Memory and CPU usage is constant and very low.

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Video surface

As said we need to access each frame in the camera's stream. For such cases in Qt is `QAbstractVideoSurface`. Custom video surface can be set to `QCamera` as viewfider, what we will do. But the video surface doesn't draw anything, it just got access to video frames. Painting of frames will do view that was described in the previous section.

When deriving from `QAbstractVideoSurface` developer should understand that `present()` method will be invoked from the non-GUI thread. And very important to return correct list of supported formats from `supportedPixelFormats()` method. Video frames can come from the device in various formats, but we want to convert `QVideoFrame` to `QImage`, so the format of video frame should be compatible with `QImage` format. Qt can do the trick by pre-converting of video frames format to supported by our video surface format, so we will return just convertible to `QImage` pixel formats.

Our video surface will detect motions and notify the application about it. Surface will emit a signal with new frames with `QImage`, but for performance reasons we will emit every frame only if the motion is detected, otherwise we will emit only keyframes. Surface will have abilities to transform video frame before emitting for painting, such as mirroring and rotating.

Detection of motions is based on comparing keyframe with the current one. Surface will emit a signal about difference value of the current image and keyframe. If this value (L2 relative error) is bigger than a threshold then the motion is detected. Each device has its own parameters of noise in the frames, so the threshold is configurable.

Declaration.

```
#ifndef SECURITYCAM_FRAMES_HPP_INCLUDED
#define SECURITYCAM_FRAMES_HPP_INCLUDED

// Qt include.
#include <QAbstractVideoSurface>
#include <QTransform>
#include <QMutex>
#include <QTimer>

// SecurityCam include.
#include "cfg.hpp"


namespace SecurityCam {

//! Count of processed frames when key farme changes.
static const int c_keyFrameChangesOn = 10;


//
// Frames
//

//! Frames listener.
class Frames final
    :    public QAbstractVideoSurface
{
    Q_OBJECT

signals:
    //! New frame arrived.
    void newFrame( QImage );
    //! Motion detected.
    void motionDetected();
    //! No more motions.
    void noMoreMotions();
    //! Images difference.
    void imgDiff( qreal diff );
    //! No frames.
    void noFrames();
    //! FPS.
    void fps( int v );

public:
    Frames( const Cfg::Cfg & cfg, QObject * parent );

    //! \return Rotation.
    qreal rotation() const;
    //! Set rotation.
    void setRotation( qreal a );

    //! \return Mirrored?
    bool mirrored() const;
    //! Set mirrored.
    void setMirrored( bool on );

    //! \return Threshold.
    qreal threshold() const;
    //! Set threshold.
    void setThreshold( qreal v );

    //! Apply new transformations.
    void applyTransform( bool on = true );

    bool present( const QVideoFrame & frame ) override;

    QList< QVideoFrame::PixelFormat > supportedPixelFormats(
        QAbstractVideoBuffer::HandleType type =
            QAbstractVideoBuffer::NoHandle ) const override;

private:
    //! Detect motion.
    void detectMotion( const QImage & key, const QImage & image );

private slots:
    //! No frames timeout.
    void noFramesTimeout();
```

```
    //! 1 second.
    void second();

private:
    Q_DISABLE_COPY( Frames )

    //! Key frame.
    QImage m_keyFrame;
    //! Frames counter.
    int m_counter;
    //! Motions was detected.
    bool m_motion;
    //! Mutex.
    mutable QMutex m_mutex;
    //! Transformation applied.
    bool m_transformApplied;
    //! Transformation.
    QTransform m_transform;
    //! Threshold.
    qreal m_threshold;
    //! Rotation.
    qreal m_rotation;
    //! Mirrored.
    bool m_mirrored;
    //! Timer.
    QTimer * m_timer;
    //! 1 second timer.
    QTimer * m_secTimer;
    //! FPS.
    int m_fps;
}; // class Frames

} /* namespace SecurityCam */

#endif // SECURITYCAM_FRAMES_HPP_INCLUDED
```

This is a formalization in C++ delcaration of what was said above. Some methods are trivial.

```
static const int c_noFramesTimeout = 3000;

//
// Frames
//

Frames::Frames( const Cfg::Cfg & cfg, QObject * parent )
    :    QAbstractVideoSurface( parent )
    ,    m_counter( 0 )
    ,    m_motion( false )
    ,    m_threshold( cfg.threshold() )
    ,    m_rotation( cfg.rotation() )
    ,    m_mirrored( cfg.mirrored() )
    ,    m_timer( new QTimer( this ) )
    ,    m_secTimer( new QTimer( this ) )
    ,    m_fps( 0 )
{
    if( cfg.applyTransform() )
        applyTransform();

    m_timer->setInterval( c_noFramesTimeout );
    m_secTimer->setInterval( 1000 );

    connect( m_timer, &QTimer::timeout, this, &Frames::noFramesTimeout );
    connect( m_secTimer, &QTimer::timeout, this, &Frames::second );

    m_secTimer->start();
}

qreal
Frames::rotation() const
{
    return m_rotation;
}

void
Frames::setRotation( qreal a )
{
    m_rotation = a;
}

bool
Frames::mirrored() const
{
    return m_mirrored;
}

void
Frames::setMirrored( bool on )
{
    m_mirrored = on;
}

qreal
Frames::threshold() const
{
    QMutexLocker lock( &m_mutex );

    return m_threshold;
}

void
Frames::setThreshold( qreal v )
{
    QMutexLocker lock( &m_mutex );

    m_threshold = v;
}
```

```
void
Frames::applyTransform( bool on )
{
    QMutexLocker lock( &m_mutex );

    if( on )
    {
        m_transform = QTransform();

        m_transform.rotate( m_rotation );

        if( qAbs( m_rotation ) > 0.01 )
            m_transformApplied = true;

        if( m_mirrored )
        {
            m_transform.scale( -1.0, 1.0 );

            m_transformApplied = true;
        }
    }
    else
    {
        m_transformApplied = false;

        m_transform = QTransform();
    }
}
```

The main work is done in `present()` method.

```
bool
Frames::present( const QVideoFrame & frame )
{
    if( !isActive() )
        return false;

    QMutexLocker lock( &m_mutex );

    QVideoFrame f = frame;
    f.map( QAbstractVideoBuffer::ReadOnly );

    QImage image( f.bits(), f.width(), f.height(), f.bytesPerLine(),
        QVideoFrame::imageFormatFromPixelFormat( f.pixelFormat() ) );

    f.unmap();

    if( m_counter == c_keyFrameChangesOn )
        m_counter = 0;

    QImage tmp = ( m_transformApplied ? image.transformed( m_transform )
        :    image.copy() );

    if( m_counter == 0 )
    {
        if( !m_keyFrame.isNull() )
            detectMotion( m_keyFrame, tmp );

        m_keyFrame = tmp;

        emit newFrame( m_keyFrame );
    }
    else if( m_motion )
        emit newFrame( tmp );

    ++m_counter;
    ++m_fps;

    m_timer->start();

    return true;
}
```

We are converting `QVideoFrame` to `QImage`, applying transformation if needed, detecting motion on each keyframe, updating counters and emitting frames for drawing. Important to connect to `newFrame()` signal as queued one, as `present()` method invoked in non-GUI thread. And very important to emit a full copy of image because if we will emit temporary image object the data in it will be destroyed as original `QImage` uses data from `QVideoFrame` directly and in the slot we will try to access destroyed memory.

Motion detection is made with help of OpenCV and is quite simple, look.

```
inline cv::Mat QImageToCvMat( const QImage & inImage )
{
    switch ( inImage.format() )
    {
        case QImage::Format_ARGB32:
        case QImage::Format_ARGB32_Premultiplied:
        {
            cv::Mat mat( inImage.height(), inImage.width(),
                CV_8UC4,
                const_cast< uchar* >( inImage.bits() ),
                static_cast< size_t >( inImage.bytesPerLine() ) );

            return mat;
        }

        case QImage::Format_RGB32:
        case QImage::Format_RGB888:
        {
            QImage swapped;

            if( inImage.format() == QImage::Format_RGB32 )
```

```
                swapped = inImage.convertToFormat( QImage::Format_RGB888 );

            swapped = inImage.rgbSwapped();

            return cv::Mat( swapped.height(), swapped.width(),
                CV_8UC3,
                const_cast< uchar* >( swapped.bits() ),
                static_cast< size_t >( swapped.bytesPerLine() ) ).clone();
        }

        default:
            break;
    }

    return cv::Mat();
}

void
Frames::detectMotion( const QImage & key, const QImage & image )
{
    bool detected = false;

    try {
        const cv::Mat A = QImageToCvMat( key );
        const cv::Mat B = QImageToCvMat( image );

        // Calculate the L2 relative error between images.
        const double errorL2 = cv::norm( A, B, CV_L2 );
        // Convert to a reasonable scale, since L2 error is summed across
        // all pixels of the image.
        const double similarity = errorL2 / (double)( A.rows * A.cols );

        detected = similarity > m_threshold;

        emit imgDiff( similarity );
    }
    catch( const cv::Exception & )
    {
    }

    if( m_motion && !detected )
    {
        m_motion = false;

        emit noMoreMotions();
    }
    else if( !m_motion && detected )
    {
        m_motion = true;

        emit motionDetected();
    }
}
```

And auxiliary trivial methods.

```
QList< QVideoFrame::PixelFormat >
Frames::supportedPixelFormats( QAbstractVideoBuffer::HandleType type ) const
{
    Q_UNUSED( type )

    return QList< QVideoFrame::PixelFormat > ()
        << QVideoFrame::Format_ARGB32
        << QVideoFrame::Format_ARGB32_Premultiplied
        << QVideoFrame::Format_RGB32
        << QVideoFrame::Format_RGB24;
}

void
Frames::noFramesTimeout()
{
    QMutexLocker lock( &m_mutex );

    m_timer->stop();

    emit noFrames();
}

void
Frames::second()
{
    QMutexLocker lock( &m_mutex );

    emit fps( m_fps );

    m_fps = 0;
}
```

If to set this video surface to `QCamera` as viewsfinder and connect `newFrame()` signal to `View` 's `draw()` slot then we will see the stream from the camera in `View` widget.

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Camera

We have the video surface that can be used as viewfinder for `QCamera`, we have the view that will display stream from the camera, now we need to initialize the camera.

```
void
MainWindowPrivate::initCamera()
{
    if( !m_cfg.camera().isEmpty() )
    {
        auto infos = QCameraInfo::availableCameras();

        if( !infos.isEmpty() )
        {
            QCameraInfo info;

            foreach( auto & i, infos )
            {
                if( i.deviceName() == m_cfg.camera() )
                {
                    info = i;

                    m_currCamInfo.reset( new QCameraInfo( info ) );

                    break;
                }
            }

            if( !info.isNull() )
            {
                m_cam = new QCamera( info, q );

                QObject::connect( m_cam, &QCamera::statusChanged,
                    q, &MainWindow::camStatusChanged );

                m_cam->setViewfinder( m_frames );

                m_capture = new QCameraImageCapture( m_cam, q );

                m_cam->setCaptureMode( QCamera::CaptureStillImage );

                q->setStatusLabel();

                m_cam->start();
            }
            else
            {
                QTimer::singleShot( c_cameraReinitTimeout,
                    [&] () { q->cameraError(); } );
            }
        }
    }
}
```

`m_cfg.camera()` is saved device name configured in the options dialog, when the application started it reads configuration and initializes camera, we just are looking for saved camera in the system, and if found allocating new `QCamera`, `QCameraImageCapture` objects, set view finder - our video surface (`m_frames`).

We connected to `QCamera::statusChanged` signal to set a resolution of the camera, we need to do it exactly in `QCamera::LoadedStatus` state, as only there we can ask the camera for supported viewfinder settings.

```
void
MainWindow::camStatusChanged( QCamera::Status st )
{
    if( st == QCamera::LoadedStatus )
    {
        const auto settings = d->m_cam->supportedViewfinderSettings();

        QCameraViewfinderSettings toApply;

        for( const auto & s : settings )
        {
            if( s.resolution().width() == d->m_cfg.resolution().width() &&
                s.resolution().height() == d->m_cfg.resolution().height() &&
                qAbs( s.maximumFrameRate() - d->m_cfg.resolution().fps() ) <= 0.001 )
            {
                toApply = s;

                break;
            }
        }

        if( !toApply.isNull() )
        {
            d->m_cam->stop();

            d->m_cam->setViewfinderSettings( toApply );

            setStatusLabel();

            d->m_cam->start();
        }
    }
}
```

On any error in the camera we do.

```
void
MainWindow::cameraError()
{
    d->stopCamera();

    d->m_view->draw( QImage() );

    QTimer::singleShot( c_cameraReinitTimeout, this,
        [&] () { d->initCamera(); } );
}
```

Where `d->m_view` is our view. And.

```
void
MainWindowPrivate::stopCamera()
{
    m_stopTimer->stop();

    if( m_cam )
    {
        m_cam->stop();

        m_capture->deleteLater();

        m_capture = Q_NULLPTR;

        m_cam->deleteLater();

        m_cam = Q_NULLPTR;

        m_currCamInfo.reset();
    }
}
```

This allow us to have always initialized camera (if this is possible) with correct resolution and frame rate.

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Capture images

When video surface detects motion.

```
void
MainWindow::motionDetected()
{
    if( d->m_cam )
    {
        if( !d->m_isRecording )
        {
            d->m_isRecording = true;

            takeImage();

            d->m_timer->start( d->m_takeImageInterval );
        }
        else
            d->m_stopTimer->stop();
    }
}
```

We start to capture images from camera with configured interval.

```
void
MainWindow::takeImage()
{
    if( d->m_capture )
    {
        const QDateTime current = QDateTime::currentDateTime();

        QDir dir( d->m_cfg.folder() );

        const QString path = dir.absolutePath() +
            current.date().toString( QLatin1String( "/yyyy/MM/dd/" ) );

        dir.mkpath( path );

        d->m_cam->searchAndLock();

        d->m_capture->capture( path +
            current.toString( QLatin1String( "hh.mm.ss" ) ) );
    }
}
```

Where `d->m_timer->timeout()` connected to.

```
MainWindow::connect( m_timer, &QTimer::timeout,
        q, &MainWindow::takeImage );
```

And when there is no mo motion in the frame.

```
void
MainWindow::noMoreMotion()
{
    if( d->m_cam )
    {
        if( d->m_isRecording )
            d->m_stopTimer->start( d->m_takeImagesYetInterval );
    }
}

void
MainWindow::stopRecording()
{
    if( d->m_cam )
    {
        d->m_stopTimer->stop();

        d->m_timer->stop();

        d->m_isRecording = false;
    }
}
```

Where `d->m_stopTimer->timeout()` connected to `MainWindow::stopRecording()`.

Thus, we will have pictures of the attackers on the protected area.

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Chapter 3

As you can saw operations like open, save and crop in GIF editor, described in chapter 1, can long very much. And during these processes UI is frozen. This is sad. Why not add some busy animation during these operations? Good! But animations should work in the main thread. Well, we can dilute code of operations with `QApplications::processEvents()`, and move Magick++ operations in a separate thread. Amazing, let's do it.

Want to add that multithreading, especially in GUI, is not a panacea. I saw in my practice that very much amount of threads in the application can only slow down the performance, and very much. But the approach described above sounds very good. Our application will be very responsive.

In Qt there are a lot of mechanisms of multithreading, like `QThread`, `QThreadPool`, `QRunnable`, `QtConcurrent`, queued connections of signals and slots. So let's look at the implementation.

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Implementation

Long Magick++ operations like `readImages()`, `coalesceImages()`, `writeImages()` can longs very much. And during these operations and another UI preparations I'd like to show busy animation. I moved the view of the application to the `QStackedWidget`, that was set as a central widget of `QMainWindow`, and in this stacked widget I added a page with busy animation. During long operations I will show the page with animation, and when all is done I will show the ready result.

With Qt's stuff all is simple, I just dilute the code with `QApplication::processEvents()`, like.

```
//! Initialize tape.
void initTape()
{
    std::for_each( m_frames.cbegin(), m_frames.cend(),
        [this] ( const Magick::Image & img )
        {
            this->m_view->tape()->addFrame( this->convert( img ) );

            QApplication::processEvents();
        } );
}
```

But Magick++ operation should work in separate thread as we can't change the code of Magick++ functions. I decided to run these functions with `QRunnable` on `QThreadPool`. Magick++ can throw exceptions, so I declared the base class for all my runnables.

```
class RunnableWithException
    :    public QRunnable
{
public:
    std::exception_ptr exception() const
    {
        return m_eptr;
    }

    ~RunnableWithException() noexcept override = default;

protected:
    std::exception_ptr m_eptr;
}; // class RunnableWithException
```

And let's look at the implementation of the `readImages()` as runnable object.

```
class ReadGIF final
    :    public RunnableWithException
{
public:
    ReadGIF( std::vector< Magick::Image > * container,
        const std::string & fileName )
        :    m_container( container )
        ,    m_fileName( fileName )
    {
        setAutoDelete( false );
    }

    void run() override
    {
        try {
            Magick::readImages( m_container, m_fileName );
        }
        catch( ... )
        {
            m_eptr = std::current_exception();
        }
    }

private:
    std::vector< Magick::Image > * m_container;
    std::string m_fileName;
}; // class ReadGIF
```

Voila. And when I need to read GIF.

```
std::vector< Magick::Image > frames;

ReadGIF read( &frames, fileName.toStdString() );
QThreadPool::globalInstance()->start( &read );

d->waitThreadPool();

if( read.exception() )
    std::rethrow_exception( read.exception() );
```

Where `d->waitThreadPool()` is.

```
//! Wait for thread pool.
void waitThreadPool()
{
    while( !QThreadPool::globalInstance()->waitForDone( 100 / 6 ) )
        QApplication::processEvents();
```

```
}
```

That's all. Now GIF editor shows busy animation during long operations, UI is responsive.

I decided to disable all actions during such operations, even quit from the application. But what if the user wants to exit from the application during opening? We can allow to do it on the close button in the window's title click.

```
void
MainWindow::closeEvent( QCloseEvent * e )
{
    if ( d->m_busyFlag )
    {
        const auto btn = QMessageBox::question( this, tr( "GIF editor is busy..." ),
            tr( "GIF editor is busy.\nDo you want to terminate the application?" ) );

        if( btn == QMessageBox::Yes )
            exit( -1 );
        else
            e->ignore();
    }
    else
        e->accept();

    quit();
}
```

Where `d->m_busyFlag` is a bool that I set to true when showing busy animation.

Wonderful, UI is always responsive and the user can terminate the application during the long operation at any time.

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Mistakes handling

Who didn't do mistakes? Only that who didn't do anything. I showed this book on Reddit and got some comments. I want to discuss these comments, and fix found problems.

Possible blocking of GUI when resizing application

I created a thumbnail of the central frame's image in the resize event handler. But resize events can come very frequently, and do hard work here is not a good idea. To remind what was done let's have a look at the code.

```
void
Frame::resizeEvent( QResizeEvent * e )
{
    if( d->m_mode == ResizeMode::FitToSize ||
        ( d->m_mode == ResizeMode::FitToHeight && e->size().height() != d->m_thumbnail.height() ) )
            d->resized();

    e->accept();

    emit resized();
}
```

In `d->resized()` I created a thumbnail of the image to fit the new size. I did actual work there. But it's a possible issue.

The solution is quite simple. Instead of actual resizing let's set a special flag to true and in the paint event will check if this flag is set then will do resize before drawing. And I emitted signal `resized()` in resize event. This signal is a subject of interest for crop widget, so I will emit this signal only after real resizing that will be done in paint event.

This approach will offload the application.

An issue with resizing of crop widget corresponding to resize of the window.

In the application exists feature: when you are in crop mode and resize the entire window of the application crop widget resizes corresponding to the new size of the image, that fit window size. I had a bug here. I used `QRect` to store crop area and calculated new crop area with `int`. The casting of `qreal` to `int` brought to the issue. I changed `QRect` to `QRectF` and wrapped calculated values with `qRound()` where were necessary to cast from `qreal` to `int`.

Using of QStringLiteral

I used plain C++ string literals for resources paths, etc... It's good practice to use `QStringLiteral` instead of it. Have a look at the Qt's documentation about `QStringLiteral`.

Private implementation

As you can saw I use PIMPL idiom in the code. I think that this is a holly war - use or no PIMPL in such small applications. I used and my code is clean, look at the header files, they are simple and clear. I hid details of implementation, I reduced recompilation time on changes. Why not? This is a choice of you, use or not use PIMPL in your projects.

Inheritance vs composition

In the comments, I got that I use inheritance where possible to use just a composition. In the `Frame` class, for example. Well, yes it's possible to use composition in this case, it's possible to handle resizes with event filter, yes, it's doable. But how many times I caught myself on the thought that I was lazy, implemented something with composition, all worked, code was just a few lines. But at some point of time, I need to implement something yet, and voila, I understand that with composition it's impossible to do a customer request. And what? I rewrite the code with inheritance, add new class, rewrite functionality with inheritance, add new features. This is time, this is possible issues. And how would be simpler if at the beginning I did it with inheritance?

So, it's my choice to use inheritance even in such simple things. This is very simple to change something, add new features. I was not lazy to implement `Frame` with inheritance, and at any time I can do with `Frame` what I need.

This is the same question of using `*.ui` files with Qt. It's fast, chop-chop and ready form, great. But be very attentive with using `*.ui`. At some time you probably will need to add something, layout the form, and what if your layouts have custom margins, for example, set in the `*.ui` file. Ops, they broken, you forgot about it, and the customer will say to you: "You broke my application!" Nice, really.

This is not a simple question use inheritance or composition. Think twice if you are going to use composition or `*.ui` file. Using inheritance is not a mistake, but can save your time and nerves in the future, and eat time in the beginning. So it's my choice...

Model/View

I was asked why I didn't use Model/View for implementing tape. It was simpler is my answer. I use controls on frames (checkbox). I know it's doable with a view and custom delegate, but it's not a trivial task to have control on the item not in the edit mode. I did such tasks, I know what it is. It's just was simpler.

Yes, I agree, the model for frames on tape can be reused. I know that this is modern to use Model/View approach. But in this case, scroll view with custom widget was simpler.

I wrote a lot of models, custom views with custom delegates. I ate a dog on it.

I don't agree that using Model/View leads to less coding. I guess, that code would be larger than with simple widget. From time to time I practice such simple lists without Model/View. And if I remember all correct it was twice. And tape in GIF editor is the second time. I don't see benefits of using Model/View here, possibly adding/removing frames would be faster with Model/View, but simple code for the custom view of frames on tape with controls outweighed the Model/View.

This question is most controversial for me...

QMovie

Got suggestion to use `QMovie` instead of Magick++, as the GIF editor would be without dependencies and for a novice it would be simpler to start with this example.

But in this case, I would not be able to save edited GIFs, and this example will become usual Qt example, that "can do nothing". I use this application for my own needs from time to time. I need to have a simple GIF editor that can crop and remove unnecessary frames. I need it. And I wanted to show readers "real world" examples.

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Chapter 5

In this small book I wanted to show Qt Widgets usage on the real examples. My idea was to show how it's nice to write GUI applications with Qt, with widgets. But Qt it's not only C++ instrument. I believe that you heard about QML. QML is very good in some cases. If you want the same feel and look on absolutelly all platforms, QML is for you. But it's not the only one reason to use QML. Maybe in your application a lot of animations? QML can help you a lot with it.

Sometimes it's very difficult question what technology to use, QML or widgets. I suggest to use widgets for desktop applications, and QML for mobile platforms. Widgets are very stable in API, they are pure C++, they effective. QML is very dynamically developing, it's not so stable as widgets, from time to time the same QML code on Qt updates can break, yes, you should keep in mind it when using QML. Sometimes you can think that QML is ambiguous, especially in placing elements, but these are working questions. QML is good, as I already said, for mobile platforms, or if you want the same UX for both desktop and mobile.

I'm not an expert in QML, Look at this chapter like on my own opinion and expirience. QML can save a lot of development time. Only bindings of properties in QML can help a lot. Sometimes I write QML code and understand how it's simple to use this technology. Really. But sometimes I'm in struggle with QML. Possibly this is because I don't have a lot of practice with QML, possibly. But I saw that the same QML code worked on previous version of Qt, and something was broken with update, and I was in need to look for a workaround.

But I believe that QML will become more stable and effective instrument in the near future. This is a part of Qt and we need to keep hands on pulse. So let have a look at one small, known to everybody game - chess, written with QML and C++. The source code of this example is placed on GitHub https://github.com/igormironchik/chess

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C++ and QML

QML is good for UI, but it is a good idea to separate business logic from UI and write it on C++ side. What am I talking about? Look. UI for chess is versy simple. This is a square board of 8x8 cells with labels, and 32 figures at the start of the game. Everyone saw the chess. And only this board with some dialogues I suggest to implement with QML. But the chess is something more. We need to handle objects of figures in the memory, make some checks before and after move. And this is the business logic of the game, that I suggest to write in C++.

Both worlds can speak each other with signals/slots. And for placing figures on the board we can use model, usual `QAbstractListModel`.

I will not list tonns of the C++ code of business logic in this chapter, I want to show QML usage only. Just a few words about C++ implementation. I have `Board` class, this is a model of figures on the board. I have hierarchy of chess figures. I have `Game` class to implement game logic, and `Signals` class, that is a bridge of signals between C++ and QML.

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Board

To draw chess board I will use `Grid` QML element with `Repeater` with model from C++. Each place on the board is a `Cell` item. `Cell` is a square that can be white and black colors with image of figure on it, and that can be highlighted with another colors to indicate possible moves, hits and check state. `Cell` item should send `clicked()` signal when it's clicked by user. And in QML is very easy to implement such cell.

```
import QtQuick 2.0

Item {
    id: cell

    property alias cellColor: rectangle.color
    property alias border: rectangle.border
    property alias blueProp: blue.visible
    property alias redProp: red.visible
    property alias checkProp: check.visible
    property int chessX
    property int chessY

    signal clicked( int x, int y )
    signal hovered( int x, int y )

    Rectangle {
        id: rectangle
        anchors.fill: parent
        border.width: 1
    }

    Rectangle {
        id: check
        visible: false
        anchors.fill: parent
        color: "#88FFFF00"
    }

    Rectangle {
        id: red
        visible: false
        anchors.fill: parent
        color: "#88FF0000"
    }

    Rectangle {
        id: blue
        visible: false
        anchors.fill: parent
        color: "#880000FF"
    }

    property alias source: image.source

    Image {
        width: parent.width - 5
        height: parent.height - 5
        id: image
        anchors.centerIn: parent
        fillMode: Image.PreserveAspectFit
        horizontalAlignment: Image.AlignHCenter
        verticalAlignment: Image.AlignVCenter
    }

    MouseArea {
        anchors.fill: parent
        hoverEnabled: true

        onClicked: cell.clicked( chessX, chessY )
    }
}
```

As you can see I use `Rectangle` element to draw the cell and unvisible by default rectangles for highlighting. For drawing chess figure I use `Image` QML element, that a little smaller then cell and centered in it. And for mouse handling I have `MouseArea`. It's very simple, isn't it? Imagine how much code you would write in C++ for such item.

Ok, we have the `Cell` item and we need to place 8x8 cells on the square board. And we want to show labels of columns and rows.

```
import QtQuick 2.7

Rectangle {
    property int offset: 16
    property int cellWidth: ( width - offset * 2 ) / 8
    property int cellHeight: ( height - offset * 2 ) / 8

    id: board
    transform: rot

    property alias rotation: rot.angle

    Rotation {
        id: rot
        origin.x: board.width / 2
        origin.y: board.height / 2
        angle: 0
    }

    PropertyAnimation {
        id: anim
        duration: 300
```

```
        target: board
        from: ( rot.angle === 0 ? 0 : ( rot.angle === 360 ? 0 : 180 ) )
        to: ( rot.angle === 0 ? 180 : ( rot.angle === 360 ? 180 : 360 ) )
        property: "rotation"
    }

    Connections {
        target: game

        onRotate: {
            if( angle === -1 )
                anim.start()
            else
                rot.angle = 0
        }
    }

    Connections {
        target: anim

        onStarted: {
            rotationStarted()
        }

        onStopped: {
            rotationDone()
        }
    }

    signal clicked( int x, int y )
    signal hovered( int x, int y )
    signal newGame()
    signal transformation( int figure, int color, int x, int y );
    signal undo()
    signal rotationDone()
    signal rotationStarted()

    Row {
        id: top
        height: offset

        // Top letters.
        Item { width: offset; height: offset; }
        Repeater {
            model: [ "A", "B", "C", "D", "E", "F", "G", "H" ]
            delegate: Text {
                width: cellWidth
                height: offset
                text: modelData
                horizontalAlignment: Text.AlignHCenter
                verticalAlignment: Text.AlignVCenter
                font.bold: true
                font.pixelSize: 14
                transform: Rotation {
                    origin.x: width / 2
                    origin.y: height / 2
                    angle: rot.angle
                }
            }
        }
        Item { width: offset; height: offset; }
    }

    Column {
        y: top.y + top.height

        // Left letters.
        Repeater {
            model: 8

            delegate: Text {
                width: offset
                height: cellHeight
                text: 8 - index
                horizontalAlignment: Text.AlignHCenter
                verticalAlignment: Text.AlignVCenter
                font.bold: true
                font.pixelSize: 14
                transform: Rotation {
                    origin.x: width / 2
                    origin.y: height / 2
                    angle: rot.angle
                }
           }
        }
    }

    Grid {
        id: grid
        rows: 8
        columns: 8
        x: offset
        y: top.y + top.height
        objectName: "grid"

        // Chess board.
        Repeater {
            model: chessBoard

            delegate: Cell {
                cellColor: model.CurrentPieceColor
                border.color: model.BorderColor
                chessX: index % 8
                chessY: index / 8
                onClicked: board.clicked( x, y )
                //onHovered: board.hovered( x, y )
                objectName: "c"+ chessX + chessY
                width: cellWidth
                height: cellHeight
                source: model.CellImageSource
                blueProp: model.BluePieceColor
```

```
                redProp: model.RedPieceColor
                checkProp: model.CheckPieceColor
                transform: Rotation {
                    origin.x: width / 2
                    origin.y: height / 2
                    angle: rot.angle
                }
            }
        }
    }

    Column {
        y: grid.y
        x: grid.x + grid.width

        // Right numbers.
        Repeater {
            model: 8

            delegate: Text {
                width: offset
                height: cellHeight
                text: 8 - index
                horizontalAlignment: Text.AlignHCenter
                verticalAlignment: Text.AlignVCenter
                font.bold: true
                font.pixelSize: 14
                transform: Rotation {
                    origin.x: width / 2
                    origin.y: height / 2
                    angle: rot.angle
                }
           }
        }
    }

    Row {
        id: bottom
        height: offset
        y: grid.y + grid.height

        // Bottom letters.
        Item { width: offset; height: offset; }
        Repeater {
            model: [ "A", "B", "C", "D", "E", "F", "G", "H" ]
            delegate: Text {
                width: cellWidth
                height: offset
                text: modelData
                horizontalAlignment: Text.AlignHCenter
                verticalAlignment: Text.AlignVCenter
                font.bold: true
                font.pixelSize: 14
                transform: Rotation {
                    origin.x: width / 2
                    origin.y: height / 2
                    angle: rot.angle
                }
            }
        }
        Item { width: offset; height: offset; }
    }
}
```

The board will rotate after each move. This game is designed for two players, and it's very usefull to rotate the board every time for each player. For this I have `Rotation` and `PropertyAnimation`, and some stuff for synchronization of the rotation animation.

The board starts from the row of letters from A to H, and column of numbers. Cells are placed with `Grid` element, `Repeater` and the model on C++ side. And again the column of numbers, and the row of letters. Voila, this is a board for the chess game written with QML.

It's very easy to write such UI with animation on QML, and bindings of properties help a lot in it. Look at angle property of transformation of labels...

```
transform: Rotation {
    origin.x: width / 2
    origin.y: height / 2
    angle: rot.angle
}
```

I just bind `angle` property to `rot.angle`, where `rot` is a id of our `Rotation` of the board. This is amazing instrument in QML!

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Main window

QML application should have the main window (top widget if it's possible to say so), it is like a `main()` function in C++ code, entry point. Let's do it.

```
import QtQuick.Window 2.2
import QtQuick 2.7
import QtQuick.Controls 2.2
import ChessSignals 1.0

ApplicationWindow {
    id: appWindow
    visible: true

    property int offset: 16
    property int minSize: offset * 2 + 50 * 8

    width: minSize
    height: minSize + offset + 64

    Rectangle {
        id: rect
        anchors.fill: parent

        UndoBtn {
            id: undoBtn
            width: Math.min( Math.min( appWindow.width, appWindow.height ) / 10, 64 )
            height: width
            x: appWindow.width - width - 10
            y: 10
        }

        Board {
            id: board
            width: Math.min( parent.width,
                parent.height - offset - undoBtn.height - 10 - turn.height )
            height: Math.min( parent.width,
                parent.height - offset - undoBtn.height - 10 - turn.height )
            x: Math.abs( rect.width - width ) / 2
            y: Math.abs( rect.height - height - turn.height - undoBtn.height - 10 ) / 2 + undoBtn.height + 10

            objectName: "board"
        }

        Text {
            id: turn
            objectName: "turn"
            height: offset
            anchors.horizontalCenter: rect.horizontalCenter
            y: board.y + board.height
            font.bold: true
            font.pixelSize: 14

            text: qsTr( "White" )
        }
    }

    CheckMateDialog {
        id: checkmate

        appWindowSize: Qt.size( appWindow.width, appWindow.height )
        turnText: turn.text

        onClosed: { board.newGame() }
    }

    DrawGameDialog {
        id: drawgame

        appWindowSize: Qt.size( appWindow.width, appWindow.height )

        onClosed: { board.newGame() }
    }

    TransformDialog {
        id: transform

        appWindowSize: Qt.size( appWindow.width, appWindow.height )

        onClosed: { board.transformation( figure, color, fx, fy ) }
    }

    Connections {
        target: game

        onCheckmate: {
            checkmate.open()
        }

        onDrawgame: {
            drawgame.open()
        }

        onPawnTransformation: {
            transform.color = color
            transform.fx = fx
            transform.fy = fy

            transform.open()
        }

        onNoMoreUndo: {
            undoBtn.disable()
        }
```

```
    }
}
```

Line by line. As you can see I import my own `ChessSignals` type. This is needed to know on QML side about user defined type, in our case about `Signals` bridge. You will understand meaning of this line when will see the `main()` function from C++. But let be step by step.

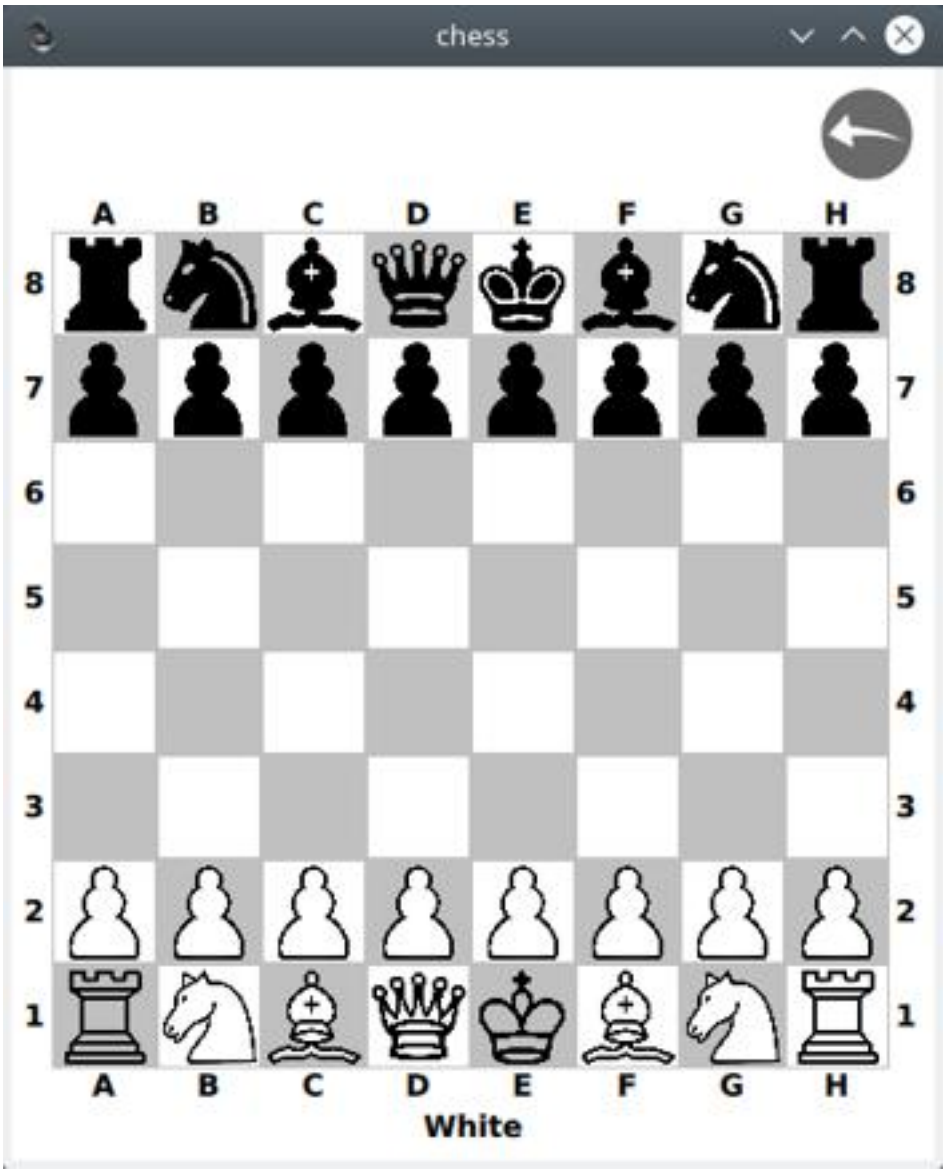
We implement our top window with `ApplicationWindow` element. I placed `Rectangle` in the window, where placed undo button, the board and a label of the color of current move team.

After you can see dialogues definitions and connections.

As you can see the target for the connections is `game` property, this property I set in C++ and this is our `Signals` C++ object. I will show later how to start QML application and set all context properties in the `main()` function in C++.

Just want to add that in QML user defined items names with the name of `*.qml` file. I placed `Board` item into `Board.qml` and simple use `Board` type in the main window.

And this looks like.



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Dialogues

I use some dialogues in the application. And want to show how it's simple to declare custom dialog with QML. I will show on a transformation dialog example that shows on pawn transformation.

```
import QtQuick 2.0
import QtQuick.Controls 2.4
import ChessSignals 1.0

Dialog {
    id: transform

    property size appWindowSize;

    title: qsTr( "Choose figure..." )
    modal: true
    focus: true
    closePolicy: Popup.CloseOnEscape
    x: appWindowSize.width / 2 - width / 2
    y: appWindowSize.height / 2 - height / 2

    property int color: Chess.White
    property int fx: -1
    property int fy: -1
    property int figure: Chess.Queen

    Column {
        anchors.centerIn: parent
        id: column

        ButtonGroup {
            buttons: column.children
        }

        property alias figure: transform.figure

        RadioButton {
            checked: true
            text: qsTr( "Queen" )

            onClicked: {
                column.figure = Chess.Queen
            }
        }

        RadioButton {
            text: qsTr( "Castle" )

            onClicked: {
                column.figure = Chess.Castle
            }
        }

        RadioButton {
            text: qsTr( "Knight" )

            onClicked: {
                column.figure = Chess.Knight
            }
        }

        RadioButton {
            text: qsTr( "Bishop" )

            onClicked: {
                column.figure = Chess.Bishop
            }
        }

        Rectangle {
            height: 25
            width: column.width
        }

        Button {
            text: qsTr( "OK" )
            anchors.right: column.right

            onClicked: {
                close()
            }
        }
    }
}
```

Do you need any explanations? It's quite simple. This dialog set figure property that will be used in the main window's QML code and will be sent to the C++ side. And `Chess` is my `Signals` object named `Chess` imported with `import ChessSignals 1.0`.

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Start of the application.

Just `main()` function from the C++.

```
// Qt include.
#include <QGuiApplication>
#include <QQmlApplicationEngine>
#include <QQmlContext>
#include <QIcon>

// Chess include.
#include "game.hpp"
#include "board.hpp"
#include "signals.hpp"


int main( int argc, char ** argv )
{
    QGuiApplication app( argc, argv );

    QIcon appIcon( ":/img/icon256x256.png" );
    appIcon.addFile( ":/img/icon128x128.png" );
    appIcon.addFile( ":/img/icon64x64.png" );
    appIcon.addFile( ":/img/icon48x48.png" );
    appIcon.addFile( ":/img/icon32x32.png" );
    appIcon.addFile( ":/img/icon22x22.png" );
    appIcon.addFile( ":/img/icon16x16.png" );
    appIcon.addFile( ":/img/icon8x8.png" );
    app.setWindowIcon( appIcon );


    QQmlApplicationEngine engine;
    Chess::Board board;
    Chess::Signals sigs;

    qmlRegisterType< Chess::Signals > ( "ChessSignals", 1, 0, "Chess" );

    engine.rootContext()->setContextProperty( "chessBoard", &board );
    engine.rootContext()->setContextProperty( "game", &sigs );

    engine.load( QUrl( "qrc:/qml/main.qml" ) );

    if( engine.rootObjects().isEmpty() )
        return -1;

    try {
        Chess::Game game( engine.rootObjects().first(), board, sigs );

        engine.rootContext()->setContextProperty( "gameImpl", &game );

        return app.exec();
    }
    catch( const Chess::Error & )
    {
        return -1;
    }
}
```

To start QML application I use `QQmlApplicationEngine`. Set all properties and registered user defined types, defined `Board`, `Signals` and `Game` objects. Loaded main window's QML file with

```
engine.load( QUrl( "qrc:/qml/main.qml" ) );
```

And started Qt's event loop. Voila.

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Links

- Qt - https://www.qt.io/
- ImageMagick - https://www.imagemagick.org/script/index.php
- OpenCV - https://opencv.org/

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If you have Invariant Sections, Front-Cover Texts and Back-Cover Texts, replace the "with … Texts." line with this:

```
    with the Invariant Sections being LIST THEIR TITLES, with the
    Front-Cover Texts being LIST, and with the Back-Cover Texts being LIST.
```

If you have Invariant Sections without Cover Texts, or some other combination of the three, merge those two alternatives to suit the situation.

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